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TRAFFIC LAW ENFORCEMENT: A REVIEW OF THE LITERATURE

by

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Abstract:

A study was undertaken to review the recent Australian and international literature relating to traffic law enforcement. The specific areas examined included alcohol, speed, seat belts and signalised intersections. The review documents the types of traffic enforcement methods and the range of options available to policing authorities to increase the overall efficiency (in terms of cost and human resources) and effectiveness of enforcement operations. The review examines many of the issues related to traffic law enforcement including the deterrence mechanism, the effectiveness of legislation and the type of legal sanctions administered to traffic offenders. The need to use enforcement in conjunction with educational and environmental/engineering strategies is also stressed. The use of educational programs and measures targeted at modifying the physical and social environment is also briefly reviewed. The review highlights the importance of developing enforcement strategies designed to maximise deterrence whilst increasing both the perceived and actual probability of apprehension. The use of Random Breath Testing (RBT), automated speed and red light enforcement cameras and selective enforcement programs are highlighted. The need for publicity to support enforcement operations, police training and education programs is also documented. The review concludes with a series of recommendations regarding the most promising options available to authorities to improve the effectiveness of traffic law enforcement operations.

Key Words:
Enforcement, police, alcohol, speed, seat belts, red lights, signalised intersection, driver behaviour, countermeasures, automated enforcement, training legislation, legal sanctions, education, environment

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Contents

EXECUTIVE SUMMARY

Road accidents are a major cause of death in many countries. Estimates indicate that approximately 400,000 people die every year in road accidents around the world. Deaths and injuries caused by road accidents result in significant social and economic costs and it has been estimated that in OECD countries, approximately 1 - 2 per cent of GNP is lost every year due to road traffic accidents.

Research literature dealing with the prevention and reduction of road accidents commonly refers to three approaches, namely environment / engineering solutions, education and enforcement. The most documented of these approaches is that of enforcement which is defined as the area of activity aimed at controlling road user behaviour by preventative, persuasive and punitive measures in order to effect the safe and efficient movement of traffic.

Traffic law enforcement can be an extremely costly activity and many policing authorities have developed methods to increase the efficiency and effectiveness of enforcement operations. With this objective in mind, the Netherlands' Ministry of Transport, Public Works and Water Management commissioned the Institute for Road Safety Research (SWOV) to prepare a 'state of the art' report on road safety enforcement methods.

It was envisaged that the main focus of the report would be on the Dutch enforcement experience, however, it was decided that an international review should also be prepared to highlight new and innovative approaches to traffic law enforcement being undertaken in other countries. The Monash University Accident Research Centre, in Australia, was commissioned by SWOV to prepare such a review. Australia is internationally renowned for its efforts and achievements in the area of road safety enforcement and it was felt that the Australian experiences might prove beneficial in the preparation of the main SWOV report.

THE REVIEW

The project specification called for a review of four specific enforcement areas, namely alcohol, speed, seat belts and intersections. Road safety and enforcement organisations in Australia, Europe and North America were contacted and asked to supply relevant enforcement literature. Major international bibliographic databases were also examined. The literature search identified a large number of enforcement references and, as a result, it was necessary to focus primarily on post 1984 literature.

Approximately 800 references were finally collected and examined. Over 550 references were actually cited in the review. From this extensive literature review, conclusions and recommendations regarding the range of methods available to increase the effectiveness and efficiency of enforcement operations were detailed.

GENERAL CONCLUSIONS ON TRAFFIC LAW ENFORCEMENT

- The success of enforcement is dependent on its ability to create a meaningful deterrent threat to road users. To achieve this, the primary focus should be on increasing surveillance levels to ensure that perceived apprehension risk is high.
    - once this has been achieved, increasing penalty severity and the quick and efficient administration of punishment can further enhance the deterrent effect.

- Significantly increasing the actual level of enforcement activity is the most effective means of increasing the perceived risk of apprehension.

- The use of periodic, short-term intensive enforcement operations (blitzes) is a more cost effective enforcement option, however, the effect on road user behaviour may be reduced.

- The use of selective enforcement strategies, designed to specifically target high risk road user behaviour and traffic accident locations is another cost effective alternative.

- Automated enforcement devices provide the most cost effective means of significantly increasing apprehension risk and should be adopted as a matter of priority.

- The use of publicity to support enforcement operations should be adopted as a means of increasing enforcement effectiveness.

    - it is essential that road users actually observe the publicised increase in the level of enforcement activity otherwise behavioural changes are usually only short-term.

    - publicity as a stand alone measure can increase community awareness of road safety issues, however, it has only a minimal effect on actual road user behaviour.

- If the risk of apprehension is high then the use of legal sanctions, such as licence suspension and revocation procedures, can be an effective deterrent.

- The use of point demerit schemes provides an effective means of linking less serious repeat offences to more severe penalties.

CONCLUSIONS ON ALCOHOL ENFORCEMENT

- The primary focus of alcohol enforcement activities should be on increasing the overall level of surveillance.

- The introduction of per se legislation and provisions which allow police to stop and test any driver, are considered necessary to develop effective alcohol enforcement strategies.

- the use of sustained and highly intensive random breath testing (RBT) operations is one of the most effective means of deterring drink driving behaviour.

    - to maximise the benefits of RBT operations it is essential that a large proportion of drivers are stopped and that ALL are tested for alcohol impairment.

    - RBT operations should be highly visible, accompanied by sustained high levels of publicity, rotated among numerous FIXED locations and undertaken for no longer than a one hour period at each location.

- The strategic deployment of random breath testing operations or enforcement "blitzes" should be considered if a less resource intensive enforcement option is required.

- The use of passive alcohol sensors is one additional means of increasing the efficiency of roadside testing operations.
- Police commitment to RBT is essential to ensure its overall success.
    - police education programs and evaluation studies (to provide feedback) should be an important component of all RBT operations.
- Legal sanctions are an essential element in the process of deterring drink driving behaviour and greater emphasis should be placed on the combined use of fines with licence actions, such as suspension and revocation.
- the use of roadside licence suspensions is an effective countermeasure and provides a means of increasing the immediacy and certainty of punishment.
- The lowering of legal blood alcohol concentration (BAC) limits for more high risk road users can be an effective means of reducing the level of alcohol related accidents.
- The fitment of alcohol ignition interlocks, in the vehicles of recidivist drink drivers is an effective countermeasure which should be considered.
- Publicity campaigns should always be an integral component of enforcement strategies.
- The use of preventative strategies such as the implementation of alcohol control policies and taxation measures, the development of server intervention programs and the increased availability of public and personal breath testing devices can compliment enforcement activities and should be seriously considered.

CONCLUSIONS ON SPEED ENFORCEMENT

- The primary focus of speed enforcement should be on increasing surveillance levels, and hence the actual and the perceived risk of detection.
- Traditional vehicle based enforcement methods should focus on increasing the visibility and unpredictability of traffic policing operations.
    - highly visible stationary enforcement operations have the greatest deterrence potential when using police vehicle deployment methods.
    - these activities should also be supported by the use of both marked (visible) and unmarked (non-visible) mobile speed enforcement operations in order to increase the unpredictability of where, how and when enforcement will be encountered.
- Primary consideration should be given to the implementation of strategies based around the intensive use of automated speed enforcement devices.
    - to maximise the benefits and community acceptance of speed camera operations it is important that enforcement is primarily targeted at accident locations where speed is known to be a causal factor.
- The use of new automated digital imaging systems can increasing the apprehension effectiveness of speed camera operations.

- The use of both fixed (unmanned) and temporary site (manned) speed camera operations can maximise the system wide effectiveness of speed enforcement operations.
- The development of strategies designed to ensure better spatial deployment of available policing resources can increase the efficiency of enforcement operations.
- The use of publicity to support speed enforcement activities is an essential requirement to raise community awareness and improve the effectiveness of enforcement operations.
- Reducing the size of enforcement tolerance levels on speed limits can reducing the level of speeding behaviour and ensuring greater adherence to posted speed limits.
- Behavioural feedback strategies such as the public posting of speed information displays and incentive programs can increase the effectiveness of speed enforcement operations.
- Greater emphasis should be placed on the use licence suspension / revocation procedures.
- The implementation of strategies designed to target and deter repeat offenders, such as point demerit systems, should be given a high priority.
- In order to be effective, speed limits must be perceived by road users as being appropriate for the existing road environment conditions.
    - emphasis should be placed on increasing the credibility of speed zones so as to ensure greater acceptance and adherence, by road users, to the posted speed limits.
    - the use of 'expert' systems for speed zoning classification and the use of variable speed limits are possible methods of increasing speed limit credibility.
- Enforcement should not be relied upon as the sole means of reducing the level of speeding behaviour. Preventative strategies which target the "agents" of speeding, namely the vehicle and roadside environment should be considered as an alternative or supplementary means of reducing the level of speeding behaviour.
    - the use of speed limiting devices and measures designed to physically modify the roadside environment have considerable potential.
    - the use of perceptual speed countermeasures may also offer a low cost means of reducing the level of speeding behaviour.
    - vehicle design characteristics to improve the accident avoidance capability of vehicles, as well as the level of protection provided to vehicle occupants, can potentially reduce the injury consequences of speeding behaviour.

CONCLUSIONS ON SEAT BELT ENFORCEMENT

- Legislation should be based on the policy of 'primary' enforcement in order to support the increased use of more active enforcement operations.

- Consideration should be given to the use of information obtained from automated speed enforcement operations as a means of detecting seat belt offences and significantly increasing the actual and perceived risk of apprehension.
- The simplest and most cost effective enforcement strategy is one which ensures that seat belt checks are adopted as a standard operational procedure when undertaking other forms traffic policing activities requiring roadside stopping of motorists.
- Consideration should be given to the development and implementation of periodic, high intensity enforcement strategies ('blitzes').
- Enforcement activities should be supported by high levels of publicity and program evaluations should be undertaken to provide police and the public with feedback.
- Special consideration should be given to the use of police education programs to promote the safety and cost benefits associated with seat belt enforcement operations.
- Consideration should be given to the more widespread implementation of seat belt incentive programs.
- The use of feedback devices (seat belt warning devices and dashboard stickers) designed specifically to remind occupants to use their seat belts, should be actively promoted.

CONCLUSIONS ON SIGNALISED INTERSECTION ENFORCEMENT

- The primary focus of enforcement activities should be on reducing the level of deliberate red light running behaviour at signalised intersections.
- The use of selective enforcement strategies should be considered as one possible means of improving the effectiveness and efficiency of traditional enforcement activities.
    - highly visible enforcement operations supported by sustained publicity are essential elements.
- Primary consideration should be given to the introduction of automated red light cameras at high accident risk intersections.
- In order to maximise both the deterrence and accident reduction effectiveness of red light cameras consideration should be given to use of:
    - warning signs at intersection approaches;
    - the use of highly visible hardware installations;
    - the rotation of a several cameras through a large number of treated intersections;
    - the use of high levels of supporting publicity; and
    - the visible deployment of the camera flash unit when cameras are not installed at treated sites.

- The use of new digital imaging systems should be considered as they can significantly increase apprehension rates and are able to be used as a portable red light enforcement device.
- Greater consideration should be given to intersection design considerations as a means of reducing intersection conflict situations and as an alternative to enforcement.
    - the use of appropriate intergreen timings, vehicle turning phases (for drivers wishing to turn at a right angle against the opposing flow of traffic) and active intersection warning signs should be considered.
    - the more widespread use of roundabouts (as an alternative to signalised intersections) and the provision of turning lanes at intersections should also be given a greater priority.

1. INTRODUCTION

In 1993 the Netherlands' Ministry of Transport, Public Works and Water Management commissioned the Institute for Road Safety Research (SWOV) to prepare a 'state of the art' report on road safety enforcement methods. The objective of the study was to provide a series of recommendations and deployment options for increasing the effectiveness and efficiency of traffic law enforcement operations in the Netherlands.

While it was envisaged that the main focus of the report would be on the Dutch enforcement experience, it was decided that an international review should also be prepared to highlight new and innovative approaches to traffic law enforcement being undertaken in other countries. The objective of this review was to highlight possible enforcement practices and new countermeasures that may be relevant to the Dutch enforcement situation.

The Monash University Accident Research Centre (MUARC) in Australia was commissioned by SWOV to prepare this review. Australia is internationally renowned for its efforts and achievements in the area of road safety enforcement and it was felt that the Australian experiences, especially those relating to alcohol, speeding, seat belt usage and red light running might prove to be beneficial in the preparation of the main SWOV report.

This review prepared by MUARC describes the current, available Australian and international literature relating to recent developments in traffic law enforcement. This information was obtained through the major transportation bibliographic databases in Australia and the United States of America. Additional information was obtained from road safety organisations and police departments in Australia, Europe and North America.

1.1 BACKGROUND

Road accidents are a major cause of death in many countries. Estimates indicate that approximately 400,000 people die every year in road accidents around the world. Deaths and injuries caused by road accidents result in significant social and economic costs and it has been estimated that in OECD countries, approximately 1-2 per cent of GNP is lost every year due to road traffic accidents. Michon (1990) has stated that if traffic volume and road accidents continue increasing at their present rate there will be a global frequency of one serious accident per second, and one fatality per minute by the year 2020.

The need for increased mobility in today's society has resulted in the development of transportation systems in which the 'human operator' is the central element. However, any system which relies on the individual actions, behaviour and needs of many different operators is invariably bound to result in some form of conflict and the role of human error has been well documented as: one of the main contributing factors in the majority of road accidents. The magnitude of this problem is reflected in the large amount of road safety research which has focused on attitudinal and behavioural approaches to better understand the relationship between the 'human operator' and road accident prevention and causation.

Research literature dealing with the prevention and reduction of road accidents commonly refers to three approaches, namely environment/engineering solutions, education and enforcement. The importance of environmental or engineering approaches as a means of accident prevention and reduction is commonly stressed. Modifying the social environment can change societal attitudes towards road safety which is regarded as a necessary precursor to beneficial behavioural changes (Grasmick et al, 1983). Physical modifications

to the road and/or vehicle cannot only reduce the number of potentially hazardous decisions which a motorist must make, but also the resulting consequences (Searles, 1985).

Road safety education also has the potential to improve road safety by raising community awareness and by influencing road user behaviour and community attitudes. Driver training and school/community based education programs can also promote best road user practice and increase community awareness of road safety issues. The use of mass media information campaigns have also been shown to improve road safety (Elliott, 1993). These campaigns increase awareness of road safety problems, stress the importance of, and need for, road safety countermeasures and can ensure that road users are aware of the risks associated with violating road traffic laws.

The final and most documented approach to the reduction and prevention of road accidents, and the focus of this review, is that of enforcement. The traffic laws and regulations which specify acceptable road user behaviour are an important element in the development of a safe road environment and it is the enforcement of these laws that is commonly regarded as one of the most effective means of moderating and reinforcing compliant road user behaviour. Enforcement is based upon the assumption that not all road users will adhere to the specified traffic rules and regulations, and may need to be encouraged, educated and persuaded to do so.

The impact of traffic law enforcement on road user behaviour is dependent on a range of factors. The type and frequency of enforcement and public perception of enforcement activities are issues commonly referred to in the literature. Traffic law enforcement can also be an extremely costly exercise and economic and resource allocation issues need to be taken into consideration. As a result of these factors and the need to maximise achievable road safety gains there have been increasing moves in many countries to develop more effective and efficient methods of enforcing road traffic laws.

1.2 STUDY OBJECTIVES

The objective of this study is to conduct a review of traffic law enforcement and to describe the current state of knowledge of road safety enforcement methods and the different situations in which they are implemented. The review covers the international English literature relating to this subject area with a particular emphasis on the Australian enforcement situation. The review focuses on, what are regarded as being the four main areas of traffic law enforcement, namely speed, alcohol, red lights and seat belts. The specific objectives of the review are:

- to document the various types of enforcement methods, and combinations thereof, used in different traffic situations;
- to determine the effectiveness of these enforcement methods in influencing different types of road user behaviour;
- to determine the most efficient use of these enforcement methods so as to optimise the use of available resources; and
- to develop a code of best practice for the use of enforcement methods based upon effectiveness and efficiency criteria.

The review also sets out to define traffic law enforcement and provide an overview of current enforcement issues. The review was undertaken in order to provide a greater appreciation of the strategies and techniques which have been documented, relating to international efforts to enforce traffic law. In several sections within the review, the Australian situation is described in more detail, in order to provide a comparative base for determining the implications for traffic law enforcement activities in other countries.

1.3 METHODOLOGY

The first step in the process of preparing this review was to interrogate the major Australian and international road safety bibliographic databases. Databases accessed include: Literature Analysis System on Road Safety (LASORS), Australian Road Research Board Database (ROAD), Transportation Research Information Services (TRIS), National Transportation Information Services (NTIS) and those databases available through Dialog Services in the United States of America.

Keywords were selected to isolate publications and journal articles dealing with the topic areas of enforcement, policing, road safety countermeasures, speed, alcohol, drink/drunk driving, seat belts, traffic signals and red lights. After reviewing the lists of authors and titles, abstracts were requested for those documents which appeared to be most appropriate.

Copies of publications which appeared to warrant more detailed review were obtained directly from various libraries, road safety organisations and police departments around Australia. Other documents, including some of the international literature, were requested through inter-library loan services by the Australian Department of Transport and Communications library. Additional information was also requested, in writing, from a number of international road safety organisations in the United States of America, Canada, New Zealand and many European countries.

Due to the large amount of available literature relating to the area of enforcement it was necessary to restrict the request for information to post 1985 literature. Some critical literature from before that period was examined and included in the review when no other more recent information could be found. The review covers English literature from all over the world and can be broken down in the following manner: Australian (25%), United States of American (35%), European (30%) and other countries (10%).

A large proportion of the literature examined includes reports published in recognised academic journals (50%) or prepared by official road safety organisations (45%). The remaining 5% of literature examined includes in-house publications that have not been formally published or made available to the public. A small proportion of the information also includes personal communication with individuals from various law enforcement and road safety organisations.

In total, over 800 publications were examined but only 550 were included in the review. This was due primarily to a large amount of duplication of research in such situations only the most recent and relevant information was included. In addition, a small number of studies were performed in an ad-hoc manner and appeared to have been undertaken to support political or private agendas, rather than to provide accurate and meaningful research information. This type of information was not included in the review and the information presented represents an unbiased and objective assessment of the present traffic law enforcement situation. The publications that were included in the review were

of a high research standard and the conclusions made were an accurate reflection of the results obtained.

Background information for the review and specific details relating to road traffic law enforcement practice in Australia were obtained through meetings with personnel from Australian State and Territory Police Departments and road safety researchers working in the area of enforcement. These organisations included:

- New South Wales Police Department
- Victorian Police Department
- Victorian - Traffic Camera Office
- Queensland Police Department
- South Australian Police Department
- Australian Federal Police (Australian Capitol Territory)
- Professor Ross Homel (Griffiths University, Queensland)
- Max Cameron (Monash University Accident Research Centre, Victoria)

Additional information was also obtained via discussions and communication with the following police departments, road safety organisations and private organisations:

- Western Australian Police Department
- Tasmanian Police Department
- Roads and Traffic Authority, NSW
- VicRoads
- Queensland Department of Transport
- South Australian Office of Road Safety
- Tasmanian Department of Transport
- New Zealand Department of Transport
- Australian Road Research Board
- Road Accident Research Unit
- Elliott and Shanahan Research Pty
- Locktronics Pty Ltd
- Image Applications Pty Ltd

1.4 OVERVIEW OF THE REVIEW

Section 2 provides an overview of current issues and definitions relating to traffic law enforcement, including:

- Deterrence theory and its applicability to traffic law enforcement;
- Methods to improve the efficiency and effectiveness of traffic law enforcement;
- The use of traditional and automated enforcement methods; and
- Issues relating to traffic law enforcement.

Section 3 details information and research relating to drink driving countermeasures, including:

- An overview of issues relating to alcohol enforcement;
- Drink driving legislation;

- Drink driving countermeasures and methods to improve enforcement efficiency;
- Legislative controls of drink driving; and
- Modifications to the social and physical alcohol environment.
- Conclusions.

Section 4 contains a review of the literature relating to speed enforcement and includes:

- An overview of speed enforcement and speed management issues;
- Speed related legislation;
- Traditional approaches to speed enforcement;
- The use of automated speed detection methods;
- Other means of detecting the speeding motorist;
- Methods to improve the efficiency of speed enforcement;
- Legislative control of speeding behaviour;
- Non-enforcement speed control methods; and
- Conclusions.

Section 5 deals with the literature and issues relating to seat belt enforcement, including:

- An overview of impact of seat belts on road safety;
- Legislation relating to seat belts;
- Seat belt enforcement;
- Improving the efficiency of seat belt enforcement operations;
- Non-enforcement approaches to increasing seat belt usage rates; and
- Conclusions.

Section 6 provides an overview of the strategies and techniques relating to red light enforcement including:

- An overview of road safety issues relating to signalised intersections;
- The problem of red light running. Traditional approaches to red light enforcement;
- Experiences associated with the use of automated red light detection devices;
- New red light detection and intersection enforcement technologies;
- Signal and intersection design considerations; and
- Conclusions.

In Section 7 an overview of the enforcement review and associated findings is provided along with conclusions and recommendations. The information presented includes:

- A summary of the issues relating to traffic law enforcement;
- alcohol enforcement;
- speed enforcement;
- seat belt enforcement; and
- signalised intersection enforcement.

2. TRAFFIC LAW ENFORCEMENT

2.1 INTRODUCTION

Traffic law enforcement has been defined (OECD, 1974) as the area of activity aimed at controlling road user behaviour by preventative, persuasive and punitive measures in order to effect the safe and efficient movement of traffic. The importance of traffic law enforcement, as a means of modifying road user behaviour, has been clearly demonstrated by estimates derived in Norway (Ingebrigtsen, 1988; Assum & Ingebrigtsen, 1990) indicating that the elimination of traffic law violations could result in a 20% to 25% reduction in the number of road injury accidents. Evans (1991) has suggested that the accident reduction potential of traffic law enforcement may even be much higher at a level closer to 40%.

The actual process of traffic: law enforcement has been described by Rothengatter (1990) as consisting of three specific step-wise components. The first is that of legislation which specifies the laws and regulations governing the safe use of the traffic system by road users. The second step is traffic policing to ensure that road users comply with the specified legislation. The final step is that of legal sanctions imposed on the road user when a breach of the legislation has been committed.

All three of these step-wise components play an essential role in determining the impact and effectiveness of a traffic law enforcement system. However, it is the activities associated with the actual policing of traffic laws that are regarded as the central element of an enforcement system. Such activities form the link between the other components of the system, providing the means of regulating compliance with the specified legislation and identifying those road users whose behaviour requires some form of disciplinary action.

The activities associated with traffic policing are also the most visible and interactive aspects of a traffic enforcement system and can often form the basis of public opinion regarding enforcement. The influence that such activities can have on shaping public perception is considered to be an important element in the process of moderating road user behaviour and further highlights the central role of traffic policing within a traffic enforcement system.

2.2 TRAFFIC POLICING

Traffic policing encompasses the area of enforcement activity aimed at moderating road user behaviour by policing the laws and regulations that govern the use of the road network.

The primary aim of traffic policing, as stated by Searles (1985), is to create, promote and maintain a safe road environment by ensuring that road users adhere to the traffic laws.

This definition identifies safety as being the primary objective of traffic policing, however, research undertaken by a number of police organisations (Axup, 1990; Southgate & Mirrlees-Black, 1991) has indicated that traffic policing has two main priorities; those being:

- to reduce the number and severity of road accidents; and

- to improve the efficiency of the road network;

Of these two priorities, safety is still considered by policing authorities to be the main objective (Axup, 1990) but facilitating the free flow of traffic is also viewed as a separate and important objective. The manner in which policing authorities attempt to achieve these objectives is the subject of a large volume of literature and has generated considerable public debate (Solomon, 1987). Southgate and Mirrlees-Black (1991) have indicated that the two most common approaches to traffic policing are:

- the enforcement of traffic laws and regulations; and

- the education of road users as to best practice.

Although both of these approaches are important aspects of traffic policing it is the enforcement of traffic laws and regulations, which has generated the largest amount of research and public interest.

The use of enforcement techniques is a fundamental aspect of traffic policing and this has resulted in numerous studies relating to the development and implementation of strategies designed to improve the effectiveness and efficiency of policing operations. Solomon (1987), specified three ways in which traffic enforcement techniques are used to achieve adherence to traffic laws. Firstly, by deterring unsafe road user behaviour, secondly, by educating the public to adopt safer road user behaviour and lastly, by punishing, when necessary, those road users who breach traffic laws.

Leivesley (1987) stated that the underlying process of traffic enforcement is one of behavioural change, through:

- behaviour modification as a conditional response to cues of police presence;

- attitudinal change so that road safety laws are adhered to as a result of an internalisation of the rules; and

- acceptance within 'social norms' so that road safety laws are reinforced through informal group interactions.

In specifying this process of behavioural change, Leivesley (1987) highlights both the short and long term impacts of traffic enforcement. In the short term, enforcement has an impact on behaviour as a direct result of the road user encountering some form of enforcement activity. In the longer term, enforcement can facilitate a more generalised social process of attitudinal change due to a greater community awareness of the underlying need for, and objectives of traffic law enforcement.

2.3 THE DETERRENCE PROCESS

The mechanism used to achieve behavioural change is that of deterrence which may be simply defined (Gibbs, 1975) as the omission of an act as a response to the perceived risk and fear for contrary behaviour. The underlying principle of deterrence, as a means of social control, and as it relates to traffic law enforcement (Homel, 1988), is that the behaviour of human beings can be modified by making them fearful of the consequences of committing illegal acts.

Ross (1982) developed the concept of 'simple deterrence' to describe the underlying basis of the deterrence process. Simple deterrence refers to the short term mechanism in which people react through fear of threatened punishment. In contrast, the long term component of general deterrence refers to the mechanism in which habit forming and moral education follows from the exposure of the population over time to the short term threat (Ross, 1982).

Simple deterrence is defined as the efficacy of a legal threat when it is a function of the perceived certainty, severity and swiftness of punishment in the event of a violation of the law. The greater the perceived likelihood of apprehension, prosecution, conviction and punishment; the more severe the perceived eventual penalty; and the more swiftly it is perceived to be administered the greater the deterrent effect of the threat.

Deterrence policy, as it relates to traffic law enforcement, is based on the assumption that road users make rational decisions, and exercise free choice as to whether or not to commit a traffic offence (Corbett & Simon, 1992). According to rational choice theory, road users will abide by the law if the expected utility of law-abiding actions is greater than the expected disutility of committing an offence (Palmer, 1977).

Bjørnskau & Elvik, (1990) have questioned the assumptions of the rational choice theory because it only considers road user actions in response to enforcement level and penalty size, and does not simultaneously consider enforcement as a response to road user behaviour.

They highlight the need for the deterrence process to be based on pro-active rather than reactive enforcement measures and stress the use of intensive, long term, high volume detection systems (advocating the use of automated enforcement devices) as a possible means of achieving this objective.

Regardless of the theoretical basis of the deterrence process the underlying aim of deterrence policy, as defined by Corbett & Simon (1992), is to increase the perceived cost of committing an offence whilst decreasing the perceived benefits, so that the former outweigh the latter. In assessing costs and benefits, the would be traffic offender is said to weigh up three factors: the perceived risk of being caught, the fear of being caught and the fear of likely penalty and punishment.

It is generally accepted that traffic law enforcement influences driving behaviour using two processes: general deterrence and specific deterrence. Homel and Wilson (1987) described general deterrence as the impact of the threat of legal punishment on the public at large and specific deterrence as the impact of legal punishment on those who have suffered them. General deterrence results from a belief in the community that traffic laws are being enforced and that a real risk of detection and punishment exists when traffic laws are broken (Armour, 1984). Specific deterrence relates to the influence of enforcement on the road user behaviour of convicted offenders, due to previous detection, prosecution and punishment experiences.

Both general and specific deterrence are commonly thought to operate through on-site effects, memory effects, and general risk of detection effects (Fildes & Lee, 1993). On-site effects refer to a modification in road user behaviour for a finite time and distance after encountering enforcement. Memory effects refer to a behaviour modification at the site where enforcement activities have been previously encountered. General risk of detection

effects refer to behaviour modification as a result of an increased perceived risk of detection.

In many areas of traffic law enforcement detection rates are low and hence the percentage of convicted traffic offenders in the traffic stream is also usually quite low. This implies that specific deterrence only has an influence on the behaviour of a small number of road users and that a large proportion of road users, who have never received a traffic offence notice, are not directly affected by this type of deterrence process.

In contrast, general deterrence results primarily from the high visibility of enforcement activities and has the potential to influence the behaviour of a greater number of road users. As a result of this method for influencing behaviour and the need to obtain the maximum possible enforcement benefits, Armour (1984) has suggested that the primary aim of behaviour modification should be achieved through the process of general deterrence.

However, advocating the use of strategies based upon general deterrence has significant implications for the type and intensity of traffic enforcement required. These implications arise due to the belief (Homel, 1988) that the effectiveness of general deterrence as a means of modifying road user behaviour is dependent on having a level of enforcement that is sufficiently high and/or visible enough to create a perception among road users that there is a real possibility that a traffic offence will be detected.

The type of deterrence approach adopted is dependent on a range of factors including the type of deviant road user behaviour to be targeted, the policing resources available and the existing social, economic and political climate. However, the high cost of enforcement, the need to maximise achievable road safety gains and the increased use of automated enforcement devices has resulted in the common implementation of traffic enforcement strategies designed to maximise general deterrence (Fildes & Lee, 1993).

2.3.1 Risk of Detection

The risk of detection, as perceived by road users, is regarded as being one of the most important factors in determining the overall effectiveness of traffic law enforcement as a means of deterring illegal road user behaviour (Department of Transport / Home Office, 1988). If road users believe that there is a low probability that a traffic offence will be detected and punished then it is highly unlikely that enforcement will pose a significant and meaningful deterrent threat.

It is generally accepted that there are two different risk functions which operate on the road user. The first of these is the perceived (subjective) risk of detection, which results from the road user's perception of the intensity of enforcement related activities. The second risk function is the actual (objective) risk of detection, which reflects the real likelihood of detection due to the actual level of traffic policing activity. There exists a complex relationship between these two risk functions with the perceived risk of detection often being dependent upon, but not necessarily directly related to, the actual risk of detection.

There can often be a great difference between these two risk levels with the perceived risk of detection usually being much lower than the actual risk of detection. However, the optimal situation is one where the perceived risk of detection is the same as or higher than the actual risk of detection. This is due to the fact that it is the road user's perception of the possibility that a breach of the law will be detected which is most likely to influence

driving behaviour (Riley, 1991). As a result, the primary focus of most traffic enforcement activities is on methods designed to maximise the perceived risk of detection.

Designing strategies to maximise the perceived risk of detection has major implications for traffic law enforcement operations. One recognised means of increasing perceived detection risk is to increase the actual level of enforcement activity. However, Aberg (1988) has suggested that enforcement levels may need to be increased several times over in order to result in a significant increase in the perceived risk of detection. This has major financial and human resource implications because intensive police enforcement activities usually come at a high cost.

There are a number of factors, other than increased enforcement levels, which may facilitate the process of increasing perceived detection risk. Harper (1991) stressed the need for enforcement programs to be highly visible both in terms of road side activities and media publicity. A number of researchers (Shinar & McKnight, 1985; Rothengatter, 1990) have also emphasised the importance of increasing apprehension rates and have highlighted the use and potential benefits of automated enforcement devices as an effective means of increasing both the perceived and actual risk of detection.

The use of the media to publicise enforcement activities can also be an effective means of increasing the perceived risk of detection. However, unless publicity levels are maintained over a long period their effect is usually only short term (Elliott, 1993). Road users adapt their behaviour according to their own experiences as well as those of acquaintances, and unless the use of publicity is accompanied by a visible increase in the level of enforcement, drivers soon become aware of the real enforcement situation and modify their behaviour accordingly (Shinar &; McKnight, 1985).

The duration of enforcement programs, aimed at increasing both the actual and perceived risk of detection also has implications for the overall effectiveness of traffic enforcement activities. Studies undertaken by Mäkinen (1988) and Aberg (1988) raise questions as to the long term validity of intensive periodic strategies aimed at increasing the perceived risk of detection. Despite high levels of enforcement and mass publicity these studies were unable to show evidence of any long term impact on deviant road user behaviour. These results highlight the need to develop enforcement strategies which are highly intensive and sustained over a long time period (Harper, 1991).

2.3.2 Severity of Punishment

In recent years the introduction of more severe penalties for traffic offences, as a primary means of reducing the level of illegal road user behaviour, has been questioned. In a review of deterrence based policy, Ross (1990) concluded that if the probability of detection was perceived by the majority of road users as being low then the existence of severe penalties would be negligible. This proposition is supported by Scandinavian research (Aberg, 1986; Assum, 1986) which found that enforcement policies which emphasised the severity of punishment rather than the perceived probability of detection had a less significant impact on road user behaviour.

In a study examining the impact of increases in the severity of speeding fines in Sweden in 1982, Aberg et al (1989) found no change in subsequent driving behaviour even though a significant proportion of drivers knew about the fine increases. In 1987 when the speeding fines were again increased in Sweden, Andersson (1989) still found no evidence of a change in offending road user behaviour. Although these results suggest that penalty

severity has little deterrence impact upon road user behaviour, Bjørnskau & Elvik (1990) have suggested that the results may in fact indicate that the severity of the penalty is less crucial to the deterrent impact on the road user than the actual existence of the penalty itself.

One additional component of the traffic enforcement process which may hinder the deterrence effectiveness of penalty severity is the legal system. Rothengatter (1990) stated that the judicial response to traffic law enforcement was a largely ineffectual deterrent, because in the majority of cases the penalties issued are paltry in comparison to the type of traffic offences committed. One additional aspect of the legal system which may in part explain a reduction in the deterrence effect is that the more severe the penalty the more legal representations usually required (Ross, 1990). This may, in turn, lead to slowness in receiving punishment and even uncertainty about receiving any punishment at all, thus compromising other aspects of the deterrence threat (National Institute of Justice, 1984).

Some support for punishment severity, as it relates to the deterrent effectiveness of jail sentences for more serious traffic offences, has been documented by Zador et al (1988). However, Homel (1988) and Ross et al. (1990), in similar methodological studies, found no evidence that jail sentences had an impact on subsequent levels of recidivism. Ross (1988), in a review of research evidence relating to penalty severity, concluded that unless road users perceive the risk of apprehension and punishment as being sufficiently high then there may be only minimal deterrence benefits to be gained by introducing more severe penalties.

Increasing the deterrence potential of penalty severity does not necessary have to involve the actual introduction of more severe penalties. Road user's perception regarding penalty severity can be an important factor in the deterrence process (Homel, 1988). Many road users have never been subject to offence prosecution and punishment procedures and the use publicity can be an effective means of enhancing road user perception regarding the unpleasant and humiliating nature of such procedures.

2.3.3 Immediacy of Punishment

Immediacy of punishment has been pin-pointed in both laboratory and field experiments as a crucial factor in behavioural change (Rothengatter, 1990). With regard to traffic law enforcement, immediacy of punishment has been shown to be an important variable (Harper, 1991). However, there continues to be considerable debate in the research literature regarding just how immediate punitive measures must be received, in order to provide an effective deterrent effect.

The immediate on-site recognition and punishment of traffic offences associated with traditional enforcement methods, has been shown in road user surveys (Corbett & Simon, 1992) to be an effective means of reducing the level of recidivist road user behaviour. This approach to traffic law enforcement is based primarily on a process of specific deterrence which has been shown to be most effective when deviant road user behaviour is punished at the time and location where it actually occurs (Harper, 1991).

The experience with using automated enforcement devices has also shown (Rogerson et al, 1993) that considerable reductions in both recidivist and deviant road user behaviour can still occur even after a two week delay between the time an offence is detected and the time notification of the offence is received. Bodinnar (1993) indicated that such time delays can still result in behaviour modification due to the process of general deterrence

associated with the intensive use of automated enforcement devices. This is due to road users becoming aware of the way in which such devices work, that the probability of offence detection and subsequent punitive measures is high and that detection could result at any time without being stopped or even seeing the enforcement activity (Portans, 1988).

Regardless of the reported benefits of automated enforcement devices the issue of immediacy of punishment continues to generate considerable debate over whether or not such devices provide an adequate educational component for the offending road user. The difficulty with providing this educational component is that in order to be effective and produce a strong general deterrence effect the use of such devices must be incorporated into a widespread and intensive enforcement program (Southgate & Mirrlees-Black; 1991). However, to achieve this aim and use these devices to their full potential it is presently not feasible to stop motorists and provide immediate on-site recognition and punishment of the traffic offences being targeted.

Rothengatter (1990) suggests that the only way to mitigate this problem is to develop some cost effective means of making the road user immediately aware that an offence has been detected and that notification of punishment will shortly follow. However, Portans (1988) suggests that on-site recognition and punishment is not a crucial factor when the level of enforcement is high because the resulting level of general deterrence provides sufficient behaviour modification cues to the road user.

Ross (1987) provided details of an enforcement strategy where detection and apprehension was immediate but where there was a short time delay before punishment was administered. This enforcement strategy related to the introduction of administrative licence revocation procedures which allowed police to confiscate licences for certain traffic offences. These procedures involved on-site apprehension but allowed driving privileges to be maintained for a short period (usually several weeks) in order to permit administrative appeals of the police action. Evidence to support the potential road safety benefits resulting from such procedures has been documented by Nichols and Ross (1990). They found a reduction in the number of night time fatalities following the adoption of administrative licence revocation procedures in several American States.

2.4 THE EFFICIENCY & EFFECTIVENESS OF TRAFFIC LAW ENFORCEMENT

The large volume of literature relating to the deterrence based approach to traffic law enforcement suggests that, in order to be effective, policing activities need to be structured so as to pose a meaningful and immediate deterrence threat to the would-be traffic offender. One of the fundamental problems hindering this process, which has been consistently identified in the research literature, is the inability of authorities to maintain the necessary high levels of enforcement (Rothengatter, 1990).

One of the main factors contributing to this situation is insufficient policing resources. This particular problem was clearly demonstrated in a recent survey, undertaken by Ostvik et al. (1989), of police in The Netherlands, Spain, Norway and Ireland. This survey found that understaffing was seen by police as one of the most important factors hindering effective traffic law enforcement operations. Rothengatter (1990) has identified a number of factors which contribute to this situation:

- the intensity of motorised traffic has increased rapidly in the last decade, without corresponding increases in policing resources;

- in the assignment of available policing resources traffic law enforcement has to compete with other social issues which also demand the attention of policing authorities, such as the increase in violence, criminality and environmental problems;

- public opinion and politics are generally not in favour of intensive surveillance and enforcement;

- the enforcement strategies and techniques which are presently used are often not particularly efficient and are mostly based on common sense notions rather than empirical evidence; and

- legal requirements and procedures often seriously jeopardise efficient traffic law enforcement.

There are several possible solutions available which would increase the efficiency and effectiveness of traffic law enforcement. The first solution is simply to increase the level of policing resources allocated to the task of traffic policing (Axup, 1990). The main problem with this solution is that it can be extremely expensive and it is usually not a viable option due to fixed budgetary constraints.

Another possible solution which does not require additional policing resources is to initiate some form of selective enforcement strategy. This involves the strategic utilisation and deployment of available resources to target specific locations and areas within the traffic network with an identified accident history. It also allows available resources to be allocated is such a way as to provide enforcement where it is most required and where it has a maximum deterrence potential (Leggett, 1993).

One final solution, which appears to be gaining increasing support, is the introduction of automated enforcement and detection devices. These devices are designed to be used to support speeding and red light enforcement operations. Although the initial cost of these devices can be high, the experience in countries where such devices are used has shown that, once in operation and correctly utilised, they can be a cost effective policing tool able to increase deterrence and conviction rates without significant additional increases in police resources (Cameron, 1992).

2.4.1 Traditional Enforcement Methods

The development of strategies designed to increase the efficiency and effectiveness of traditional traffic law enforcement operations has led to the use of a range of different vehicle deployment options. The aim of such strategies being to increase the potential deterrence effect that the presence of a police vehicle has on the behaviour of road users.

Common deployment options involve the use of marked (visible) or unmarked (non-visible) police vehicles and the use of either moving or stationary vehicles. Each of these options is designed to maximise deterrence, however, the manner in which this is achieved and the effect on road user behaviour has been shown to differ significantly.

Visibility of Enforcement

Armour (1984) stated that the best way of influencing community driving habits and maximising the perceived risk of detection is through the use of highly visible enforcement

strategies. The visible presence of police has been shown in numerous studies to have a significant impact on road user behaviour but it has also raised questions regarding the duration or 'halo' effect of traffic enforcement activities. Axup (1990) has suggested that highly visible enforcement strategies are often compromised by drivers simply adapting their behaviour at the site of enforcement activity.

This proposition has led a number of researchers (Sanderson, 1982; Barnes, 1984; Ostvik & Elvik, 1990) to advocate the use of enforcement which is not visibly evident to the road user. The main advantage of this enforcement approach is that it prevents drivers from modifying their behaviour only at the site of enforcement (Barnes, 1984). In addition, non-visible traffic enforcement not only serves to increase the uncertainty as to the location, time and manner that enforcement might be encountered but also reduces the possibility that offenders will feel confident that vigilance will prevent them from being detected and punished (Fildes & Lee, 1993).

Several studies have, however, questioned the benefits of strategies based upon the deployment of non-visible enforcement. Galizio et al (1979) found that while the presence of a visible police vehicle had a significant impact on road user behaviour, the presence of an unmarked vehicle resulted in no apparent behavioural change. Evans (1991) has further suggested that community attitudes towards the use of non-visible enforcement techniques can have an adverse impact on the overall objectives of traffic policing. Evans (1991) argued that non-visible enforcement which is based on the principle of punishing offending drivers, reduces the perceived fairness of enforcement and does little to encourage road users to adopt more appropriate driving behaviour.

Sanderson (1982) proposed that, under certain circumstances, both visible and non-visible enforcement strategies can be an effective means of deterring drivers from committing traffic offences. In particular he argued that 'fixed offences' (such as drink driving or unlicensed driving) were more suited to visible enforcement techniques as the offender cannot change behaviour quickly to avoid apprehension and punishment. On the other hand, he argued that transient offences such as speeding, non seat belt wearing or red light running, where the driver can alter behaviour to avoid detection, are more suited to non-visible enforcement techniques.

The available evidence indicates that the use of both visible and non-visible enforcement can have a positive impact on road user behaviour. As a result many police organisations have developed enforcement strategies which incorporate both of these elements. The aim of these strategies is to maximise the deterrence potential of both deployment methods by ensuring that enforcement is not only visible but that it results in a level of uncertainty regarding the time, manner and location that it will be encountered.

Enforcement Mobility

The question of whether to use stationary or mobile police vehicles in traffic enforcement operations has also generated a considerable amount of debate. It has been shown in several studies (Council, 1970; Dart & Hunter, 1976; Shinar & Steibel, 1986) that the deployment of a stationary vehicle has a more immediate effect on road user behaviour because it is seen by more drivers. Armour (1984) has argued however, that at anyone time, there is usually only a small number of police vehicles deployed, and that drivers, having seen a stationary vehicle, may revert back to their previous speeding behaviour because they know that enforcement resources are limited and may therefore assume that there is a good chance that no other police vehicles will be encountered.

Southgate & Mirrlees-Black (1991) have proposed a simple solution to the problem of site specific deterrence which involves the deployment of two or more stationary units a short distance apart from each other. They have argued that this type of deployment option increases the deterrence effect in two ways. Firstly, the additional number of police vehicles encountered can create a perception of increased enforcement and secondly, the deployment of additional vehicles can create a pattern of enforcement expectation, and hence increases the uncertainty about the possible deployment of yet another stationary vehicle further down the road.

Studies examining the deployment of mobile police vehicles within the traffic stream have found that their effect on road user behaviour occurs over a longer distance and time period (Shinar & Steibel, 1986). Armour (1984) has suggested that the use of mobile police vehicles in the traffic stream may result in an increased deterrent effect due to the uncertainty of the road user regarding the location and movement of the police vehicles once visual contact has been lost. Fildes and Lee (1993) have further suggested that the deterrent effect of a mobile vehicle may be greater than that of a stationary vehicle because the increased mobility may be perceived by roads users as a greater preparedness to apprehend.

Shinar and Steibel (1986) have argued that the benefits of non-stationary vehicle deployment are often offset by a reduction in the level of visible deterrence. They stated that non-stationary police vehicles may have a greater influence on road user behaviour but that this influence is limited to only a small number of road users. They further stated that the use of stationary police vehicles has a greater potential to influence road user behaviour due to the fact that they are seen by a larger number of road users.

Bailey (1987) examined the deterrent effect of both stationary and mobile police vehicle deployment. He stated that each had the potential to influence road user behaviour in different situations. Stationary vehicle deployment has a high deterrence potential at the site of enforcement and is therefore best suited to fixed-site operations at known accident locations. Moving vehicle deployment has a greater area-wide deterrence potential and should therefore be used on stretches of roads where behaviour modification over longer distances is required. Bailey (1987) concluded that the maximum deterrence potential can be achieved by incorporating both vehicle deployment methods in an integrated enforcement strategy.

Problems with traditional enforcement methods

The main problem with traditional enforcement methods is that their effect on road user behaviour is usually only temporary. Road users usually only modify their behaviour at the enforcement site or where they perceive the risk of apprehension is greatest. Once the road user believes that the enforcement threat is no longer present their behaviour soon reverts back to pre-enforcement levels. The problem is that there are not enough policing resources to cover the entire road network and road users are well aware that the risk of apprehension at anyone time is very low.

One possible solution is to significantly increase the level of policing activity. A number of these studies (Armour, 1984; Shinar & Knight, 1985) have focused on evaluating the effect of traditional enforcement programs involving an increase in resource allocations. The results from these studies indicate that increasing policing resources can lead to a reduction in both the number and severity of road accidents.

However, the main problem with this approach is that the increase in the resource allocation required to obtain any lasting effect is, often difficult to sustain (Aberg, 1988). Indeed, there is strong evidence to suggest that unless the increased level of enforcement activity is sustained indefinitely then the accident reduction benefits soon revert back to pre-enforcement levels (Axup, 1990). One additional problem with an increase in policing resources is the associated increase in cost, and the resultant need to justify the additional expense in terms or tangible road safety gains. This is a particular problem in many countries where an environment of public expenditure restraint exists (Leggett, 1990).

The enforcement or traffic laws by the police has, been shown to be an extremely expensive countermeasure (Armour, 1984). Estimates from a number of Australian police departments have indicated that in 1992 the cost of traffic law enforcement in Australia was in the vicinity of $500 million. Despite this seemingly high level of expenditure the resources available for traffic policing activities are still limited.

Increasing the level of resources available for traffic law enforcement can also result in negative community and political reactions and create a perception that enforcement is primarily a revenue raising exercise. The resulting debate often focuses attention away from the real purpose of traffic enforcement; being to improve and promote road safety. However, the problem that faces many police organisations is not an increase but rather a decrease in the level of resources allocated to traffic law enforcement. This can, in turn, lead to an increase in deviant road user behaviour and have a detrimental impact on road safety. In situations of low enforcement, deviant road user behaviour can be reinforced because road users modify their behaviour due to the reduced likelihood of apprehension and the perceived lack of importance placed on road safety (Deitch et al, 1985).

The problem of insufficient resources has made it necessary to develop and adopt new traffic enforcement strategies and techniques which are aimed at increasing the effectiveness of enforcement operations without significantly increasing the resources required. The use of selective enforcement strategies is one such approach which has been found to achieve both of these objectives by increasing the level of deterrence without the major resource allocation increases.

2.4.2 Selective Traffic Enforcement

The actual manner in which traffic policing resources are deployed has been identified as an important factor in the attempt to increase police efficiency. Armour (1984) suggested that police deployment should be such that drivers have maximum uncertainty as to where police cars will be located, and that a large proportion I:)f drivers see police vehicles as often as possible. Armour (1984) further stated that these requirements suggested the need for some type of random allocation of resources with weightings given to high volume, high accident roads.

A number of early studies (Bankhead & Herms, 1970; Rutherford, 1971) used accident records as a guide to the deployment of traffic policing resources. These studies reported a reduction in both the number of offending drivers and the actual number of traffic accidents. O'Brien (1980) expanded this concept, advocating the introduction of a policy of selective enforcement whereby traffic laws are more heavily enforced at high frequency accident locations and associated policing activities are more highly visible.

The use of selective enforcement techniques requires the examination of traffic and accident data to identify and prioritise accident locations including the time of day of high

risk taking behaviour. The underlying principle of selective enforcement is that available policing resources are systematically allocated to various locations: within the traffic network on the basis of where enforcement is most required to bring about a reduction in the number of accidents and to have the greatest affect on risk taking behaviour. The objective is to obtain the maximum possible gains: in road safety without increasing police resources. This is achieved by allocating more police resources to high priority locations at the expense of low priority locations.

Selective enforcement appears to modify road user behaviour in two ways. Firstly, the presence of police at high risk accident locations at different high risk times reduces the level of deviant behaviour and hence the potential for all accident situation to occur (Roope & Brackett, 1981). Secondly, the random deployment of police, over a long period of time, at particular locations and stretches of road can create a level of expectancy among road users that enforcement may be present (Leggett, 1990). This may lead to an increase in the vigilance and awareness of drivers which can, in turn, result in a reduction in illegal road user behaviour.

The benefits of using selective enforcement techniques are that they allow existing traffic policing resources to be deployed in a more efficient and effective manner resulting in increased deterrence and a greater accident reduction potential (Leggett, 1990). The success of using such techniques is, however, dependent on range of factors. O'Brien (1980) stressed that the identification of accident locations, road users and offences to be targeted is of paramount importance where developing selective enforcement strategies.

Other factors requiring direction from management include the frequency and duration of patrols, the randomisation of sites, time of day of enforcement activities and the number of officers at each location at anyone time. Homel and Wilson (1987) stated that the integration of data collection and data processing into a selective enforcement program is essential, and that when this integration is accomplished it is possible to estimate optimum levels of each of the above mentioned parameters.

Leggett (1990) has described the use of a long term, low intensity, random-deployment police enforcement strategy in Tasmania, Australia. The aim of this type of selective enforcement was to use scheduling methods to enable a low level of police presence to achieve reductions in the number of traffic accidents. This technique involved the visible deployment of a single stationary police vehicle on one of three contiguous stretches of rural highway (between 16 km and 20 km in length), selected on the basis of high accident rates. Each stretch of highway was divided up in to smaller, one kilometre sections, with the nominated police vehicle being randomly allocated to one of these sections for a two hour period during the high accident time of the day (between 3 pm and 11 pm). This technique, involving three site visits per week over a two year period" on each of the three stretches of rural highway, was reported to have resulted in a 58% reduction in traffic accidents (fatal and hospital admission accidents) and to have a benefit-cost ratio of 4:1.

Selective enforcement programs have been implemented in various forms in many different countries. Jernigan (1986) evaluated a number of selective enforcement programs in the United States of America and showed that such programs resulted in accident reduction benefits off between 6% and 27% and had benefit-cost ratios ranging from 3.4:1 to 25:1 Jernigan (1986) also found that the more successful programs were those that were based on a well researched strategy, implemented correctly, highly visible, and maintained over a long time period.

2.4.3 Integrated Traffic Enforcement Operations

The integration of traffic enforcement activities, into one coordinated strategy, is one further means of improving' the efficiency of policing operations. The targeting of a range of illegal road user behaviours, all at the same time, can maximise the use of available policing resources and ensures that all traffic laws are equally enforced. This, in turn, conveys the message to road users that no form of illegal road user behaviour will be tolerated and that the risk of apprehension is the same for all types of traffic offences. Mathijssen (1992) has documented the use of an integrated enforcement strategy undertaken in the Netherlands.

Integrated traffic surveillance in the Netherlands

In 1990, State and Municipal police of the Leyden region, in the Netherlands, conducted a one-year experiment to examine the use of integrated traffic surveillance techniques. The objective was to combine, where possible, surveillance of various major traffic offence categories, in order to improve the overall efficiency of traffic enforcement operations. This experimental surveillance included alcohol consumption by road users, speeding offences, seat belt use by motorists and the use of helmets by moped riders. The police capacity reserved for this experimental surveillance project amounted to about 3,000 man hours (approximately 60 man hours per week). In addition to police surveillance, an information and publicity campaign also formed part of the experiment.

Over the course of the year, a total of 225 speed controls, each averaging about one hour, was carried out at 37 different locations in the region of Leyden. During this time, 6863 speeding offenders were fined, 3348 on the basis of number plate registration. Prior to the experiment, the police and public prosecutor agreed that no more than 40% of speeding offenders would be prosecuted on the basis of their vehicle registration number. However, the figures show that this percentage rose to almost 50%. The 'quota' set by the public prosecutor meant that only a small proportion (roughly one third) of the observed speeding offenders could actually be prosecuted. On 80 km/h roads, no improvement in driving speeds was observed. On 50 km/h roads, the mean travel speed dropped by approximately one kilometre per hour.

In addition to the speed measurements, a telephone survey was carried out about five months after the experiment commenced; 486 motorists who commuted regularly in the region of Leyden were questioned. Of those motorists questioned, only 32% believed that the probability of being caught for a speeding offence had increased. This is a rather low percentage in comparison with the 41% of motorists who believed that the probability of being apprehended for driving under the influence of alcohol had increased. In fact, the objective risk of apprehension for drink driving had actually decreased as compared to the preceding period.

In total, 3430 motorists were tested at random for alcohol consumption during the experimental period. This is equivalent to one test per 58 inhabitants of the sub-region of Leyden. In addition, speeding offenders were also breath tested to a limited degree. The behavioural effects of alcohol surveillance were established on the basis of a preliminary and a follow-up measurement during weekend nights. In the preliminary measurement, 6.0% of motorists were found to have a punishable BAC (greater than 0.05mg/100ml), while during the follow-up measurement, the measured rate was 6.6%. This slight increase was not statistically significant. The fact that no significant improvement was observed was attributed to a more intensive alcohol surveillance campaign held in 1989. During that

campaign, the number of offenders was reduced by 25%. Experience has since shown that intensive police surveillance, coupled with information and publicity campaigns, can realise a rapid drop in driving under the influence up to a certain threshold value (Mathijssen, 1992). However, any further drop apparently demands more stringent deterrents.

Surveillance of seat belt use was mainly carried out in combination with speed and alcohol controls. During these controls, a total of almost 7000 motorists were checked, only 277 of which were fined for not wearing their seat belt. This number represents only a fraction of the approximately 3,000 motorists who were actually found not to be wearing a seat belt most of them got off with a caution. In addition, a limited number of specific seat belt controls was carried out, which did not actually fit into the concept of integrated surveillance. With regard 'to these latter controls, the police acted considerably more repressively: 515 motorists were stopped and fined. An information campaign was carried out through press reports, and through the distribution of information cards to about 6000 motorists who were observed in preliminary and follow-up measurements of seat belt use.

Although the objective risk of apprehension had hardly increased, seat belt use of motorists and front seat passengers rose from 57% to 62%. This development deviated in a favourable sense from the nationwide trend, but the aim of achieving a compliance rate of 90% was not achieved. The results of the telephone survey demonstrated that the public - correctly believed there was only a small chance of being fined for not wearing a seat belt during the experimental surveillance period. Furthermore, only orle of the 486 persons questioned believed that police surveillance should give priority to seat belt use over other aspects of traffic behaviour.

Surveillance of helmet wearing was not combined with surveillance of the three other categories of behaviour in traffic, but was linked to technical moped controls. Surveillance was very limited in scope and was hardly associated with repressive action against improper helmet use. In addition, the information campaigns, intended to improve both the attitude of moped riders with regard to correct helmet use as well as to increase the subjective risk of being apprehended, were limited in scope.

The results of the study, consisting of a preliminary and a follow-up measurement, indicated an improvement in the use of the helmet, in particular with respect to fastening of the chin strap: a 72% compliance rate during the preliminary measurement and a 77% compliance rate during the follow-up measurement was found. This increase is associated with a slight, non-significant improvement in attitude with regard to wearing a helmet. The subjective risk of detection did not increase as a result of surveillance and information campaigns. Fastening of the chin strap, however, was not the only area of concern with respect to helmet wearing. Less than one quarter of all moped riders wore a helmet that was in good condition, fitted correctly and was applied to the head properly.

2.4.4 Automated Enforcement Devices

Automated enforcement devices have the potential to reduce the level of traffic policing resources required whilst providing an efficient and effective means of detecting and deterring traffic offenders. The use of automated enforcement devices is becoming increasingly popular, in many countries, as an alternative to traditional based enforcement methods. Areas where the use of automated traffic enforcement devices have been used include:

- speed limit enforcement;
- red light traffic signal enforcement;
- high occupancy vehicle lane enforcement; and
- heavy vehicle enforcement.

Automated enforcement devices typically consist of detection equipment, a processing unit and a camera and a video or digital image recording device. When a vehicle is detected the processing unit determines whether or not an offence is being committed and if so an image is recorded. The image typically records information about the vehicle, driver and the time and date of the offence. The information is then used to identify the owner and, if required, the driver of the vehicle. A traffic offence notification or warning letter is then mailed to the owner of the vehicle.

Rothengatter (1990) has described several ways in which automated enforcement devices can contribute to the effectiveness of the efforts of police traffic enforcement. Firstly, such devices can increase the probability of detection of traffic violations (in theory the detection probability can be equal to one) without requiring substantial increases in police resources. Secondly, such devices can increase the amount and relevance of information or feedback provided to the road user, and thus, can result in a decrease in the likelihood of an offence being committed. Finally, these devices produce definite evidence that an offence has been committed which can increase the 'fairness' and objectivity of enforcement because it is not necessary to rely on the subjective judgement of the police officer as to whether or not an offence has been committed.

The use of automated enforcement devices has a range of other benefits relating to the simplification of prosecution and notification procedures. The diminished requirement to write out individual traffic infringement notices can improve the efficiency of policing operations and result in a significant increase in detection and prosecution rates (Axup, 1990). Fitzpatrick (1991) stated that the existence of definite evidence that an offence has been committed can also result in efficiency gains because offending road users are more likely to agree with the nominated penalty rather than to try to dispute it. Rothengatter (1990) further indicated that the reluctance of drivers to dispute offences could lead to the simplification of court procedures or even make them superfluous.

The use and effectiveness of automated enforcement detection devices are discussed in greater detail in later chapters of this review. However, it is important to note that the majority of the research literature examined supports the conclusion that automated enforcement devices, with their numerous deployment options, demonstrated productivity, impact on driver behaviour and potential to reduce accidents can be a highly cost effective means of traffic law enforcement even when taking into account resource requirements and relatively high initial deployment costs.

Legal issues associated with automated enforcement devices

The use of automated camera detection devices has raised a number of legal issues regarding the use of photographic evidence as a means of convicting traffic offenders. The main issues, as stated by Fitzpatrick (1991) are the legality of photographic evidence as a means of convicting traffic offenders, the possible violation of the right of privacy of the

individual and the liability for an offence committed by a driver who was not the registered owner of the vehicle.

These issues, although not directly related to actual traffic policing, can nevertheless have a significant impact upon the effectiveness of automated enforcement as a means of deterring traffic offenders. South et al, (1989) highlighted this problem and concluded that the full potential of automated enforcement devices is never fully realised in many countries due to the legal requirements governing their use. Southgate & Mirrlees-Black, (1991) further stated that once legislation has been passed which allows the use of these devices as a means of prosecuting traffic offenders, legislative issues relating to driver and vehicle identification can still have a significant impact upon their effectiveness as enforcement devices.

Fitzpatrick, (1991) provided details relating to the situation in several areas within the United States of America where there is still a requirement, when using automated detection devices, to identify not only the vehicle but also the driver. Blackburn and Glauz (1984) indicated that this legal requirement necessitates the taking of a frontal photograph which can decrease the detection and apprehension probability due to other vehicles being positioned in front of the offending vehicle and the reflective properties of angled front windscreens.

When automated detection devices were first introduced in Australia it quickly became evident that the full potential and utilisation of these devices was not being realised due to ineffective practices, resulting from road traffic regulations that required police to identify the driver of the offending vehicle (South et al, 1989). This often involved considerable labour resources and resulted in low prosecution rates which, in turn, reduced the deterrent effect of the automated devices.

In order to resolve this situation and increase the efficiency and effectiveness of police automated detection operations it was necessary to introduce new legislation. This legislation termed the 'owner-onus legislation', placed the responsibility for camera detected offences on to the owner of the vehicle rather than the driver. The result of the new legislation was a significant decrease in offence processing time and an increase in the number of offenders prosecuted. This, in turn, resulted in an increase in the probability of detection and a reduction in the number of violations. In New South Wales, Australia, the best available estimates of the effect of the owner-onus legislation on police efficiency is that the legislation reduced the costs of processing each offence by approximately 50 per cent (South et al, 1989).

Problems associated with automated enforcement

Due to the high detection and prosecution rates resulting from the use of automated enforcement devices some critics have argued (O'Neill, 1993) about the fairness and morality of such devices and their use as a means of raising revenue. Southgate & Mirrlees-Black (1991) have indicated that the perceived fairness of enforcement is an important variable in police community relations and can have a significant impact upon policing efforts to educate drivers and promote appropriate road user behaviour.

Southgate & Mirrlees-Black (1991) have stated that the use of automated enforcement has a significant deterrent effect due to the increase in detection and prosecution rates but argue that if automated enforcement is to bring about a change in societal attitudes towards deviant road user behaviour then it is essential that public perceptions and acceptance

regarding the use of such devices are high. Experiences in Australia have shown that positive community attitudes towards the use of automated detection devices can be generated by:

- publicity programs which highlight the need to use automated enforcement devices to target specific road safety problems;

- strategic deployment of such devices at locations with a previously documented accident history; and

- community consultation regarding site selection for the deployment of such devices.

Freedman et al (1990), in a survey of public opinions regarding the use of automated enforcement devices, reported considerable support for this form of enforcement. The highest level of support was found in those communities where such enforcement was already in use, indicating that preconceived notions about the use of such devices is an important factor in public acceptance. Another significant survey finding was that only a minority of road users disapproved of the use of automated enforcement devices with the two most reported reasons being the possibility of the wrong person receiving the fine and the 'sneakiness' of the enforcement activities.

In the country where the survey was conducted, wrongful prosecution was extremely rare due to legislation which placed the onus on the owner of the vehicle to identify the driver, and detection procedures which required identified number plates to be cross checked with vehicle registration details such as colour and make. Comments regarding the 'sneakiness' of the program also appear to have been unfounded due to the careful selection of the sites to be enforced, extensive community consultation, the use of clearly marked warning signs, and the highly visible police presence at the enforcement sites. It therefore seems that disapproval of automated enforcement was based on misinformation and general resentment of being policed (Fildes & Lee, 1993).

Immediacy of punishment has also been identified as a potential problem associated with the use of automated enforcement devices. Rothengatter (1990) indicated that existing automated enforcement systems do not provide adequate feedback to the driver that an offence has been committed. The problem arises due to the delay (caused by the time intensive tasks associated with the processing of automatically detected traffic offences) between the detection of an offence and the receipt of offence notification by the offending road user. Rothengatter (1990) has suggested that this time delay and the lack of on-site recognition of an offence can result in a reduction in the potential deterrence effect and does little to reinforce appropriate road user behaviour.

However, the experience with automated enforcement devices in Melbourne, Australia, has shown (Rogerson et al., 1993) that the intensive use of these devices can result in considerable reductions in deviant road user behaviour. Bodinnar (1993) indicated that such behaviour modification may be due to the high level of general deterrence associated with the intensive use of automated enforcement devices. Portans (1988) further suggested that road users modify their behaviour as a result of an increased awareness of how such devices work. This includes the knowledge that the probability of detection and subsequent punitive measures is high and can result without the driver being aware that an offence had been detected.

Another possible means of reducing the problem of delays in notification of an offence is through the use of new automated enforcement technology. Locke, (1993) indicated that new enforcement systems already exist which can lead to a significant reduction in offence notification times. These new systems can theoretically allow the offending motorist to receive notification 'within hours (allowing for processing and verification time) after they have committed the offence (Lock, 1993).

The use of electronic offence notification displays is one further means of solving the problem of insufficient road user feedback. These display boards, situated several hundred meters after the enforcement site can be used in conjunction with automated detection devices to provide traffic law violators with a message indicating that an offence has been detected.

These information displays have a dual benefit in that they not only provide road users with offence notification information but they also serve as a strong visual reminder that enforcement operations are active.

Rothengatter (1990) provided the conceptual framework for an optimal automated enforcement system that combines the use of electronically coded licence plate identification and on-site registration systems as well as providing in-car information to drivers who have committed an offence. Although no such automated enforcement systems are presently in operation the technology is currently available to develop and implement such a system.

2.4.5 Use of Publicity

Road safety campaigns are often used to support traffic enforcement activities and there is strong evidence to support the notion that a change in enforcement practices should always be accompanied by some form of supporting publicity. The main benefit of using publicity is that it can increase the perceived risk of apprehension and hence deterrence by highlighting and raising community expectation that additional or new enforcement activities will be encountered. This increase in the deterrence effect of enforcement is further reinforced when road users actually observe the publicised change in policing practices such as noticeable increase in traffic policing activity.

The combination of publicity and enforcement has been well documented as being an effective means of eliciting a road user behavioural change (OECD, 1993). Riedel, Rothengatter and de Bruin (1988) found that, in certain situations, publicity alone could bring about changes in road user behaviour but that the combined use of publicity and enforcement had a much greater and more lasting effect. This proposition is supported by Elliott (1993) who found a large amount of evidence to suggest that road safety campaigns are likely to be more effective when carried out using a combination of publicity and enforcement.

One further benefit associated with the use of publicity is that it can increase community awareness of road safety issues including the need for and use of enforcement. Community acceptance of traffic law enforcement activities can play an important role in the process of moderating road user behaviour. Elliott (1993) has suggested that publicity can be used to create a desirable supportive climate of public opinion in which new enforcement measures can be introduced.

Designing publicity campaigns to achieve the greatest possible community impact is an important consideration, given the role of publicity in increasing the effectiveness of traffic law enforcement activities. Elliott (1993), in a review of 87 road safety publicity campaigns, used meta-analysis techniques to identify the following effectiveness criteria:

- campaigns with a deliberate persuasive intent are more effective than campaigns with an informative (educative) intent;
- campaigns which use an emotional appeal are more effective than rational /informative approaches;
- campaigns which request /instruct a specific type of road user behaviour are more successful;
- campaigns which start 'with a lower base level (under 40% as a pre measure) have much more effect than those with high base levels; and
- campaigns which use a theoretical model are more effective, as are those which conduct prior research (qualitative and/or quantitative).

The meta-analysis undertaken by Elliott (1993) also provided an indication of the average effectiveness of the eighty seven publicity campaigns examined. The campaign effect result varied considerably depending upon the type of outcome measure and indicated that publicity campaigns should, on average result in a 30% + change in community awareness, a 5% change in community attitudes and a 1% change in actual road user intentions. As a result of his analysis, Elliott (1993) concluded that road safety campaigns can, on average, expect to achieve an attitudinal and behavioural change of the order of 6.1 %.

The type of medium used to convey publicity material has also been identified as an important factor in determining its effectiveness. In a study undertaken by Leidekerken and van der Colk (1990) television was shown to be the most effective medium for eliciting change, in comparison to other mediums such as roadside billboards. The use of local media has also been shown to play an important role in the process of behavioural change as it allows the public to identify more closely with the enforcement activities being conducted.

2.4.6 Use of Different Types of Penalties

When a traffic offence is detected there are a range of possible penalty options available to police which include, in order of severity: no action, verbal or written warning, fixed penalty to prosecution or arrest (Southgate & Mirrlees-Black, 1991). The use of these various penalty options has been shown to effect road user behaviour in a number of different ways.

In addition, the methods used to apply sanctions, such as the implementation of a point demerit scheme, may also effect the deterrent effectiveness of legal sanctions.

Warning Letters

The use of warnings has been advocated by a number of researchers (Roulston, 1973; Armour, 1984; Wilden et al, 1989; Southgate & Mirrlees-Black, 1991) who highlight the potential benefits of such an approach and emphasis the importance of fairness of

enforcement, the need to educate drivers as opposed to punishing them and the potential increase in police efficiency due to the time saved in offence processing.

Wilden et al (1989) suggested that a large proportion of road users are often unaware that they have committed an offence due to lack of local knowledge or poor attention to the road environment. They argued that there may be greater merit and fairness of punishment in issuing a warning to these offenders and issuing more severe penalties to those road users who blatantly breach traffic laws.

Southgate & Mirrlees-Black (1991) have stated that traffic policing is slowly moving away from a punishment based approach and is beginning to focus more on strategies aimed at educating and promoting more appropriate road user behaviour. They suggested that the use of warnings for Less serious traffic offences Call be an effective educational tool that can lead to a more sustained modification in road user behaviour than traditional punishment based strategies. They argued that the issuing of fines for minor traffic offences only causes resentment among road users and that an explanation of the offence committed and a strong warning can create ID-Ore positive community attitudes towards enforcement activities.

The use of warnings has also been advocated as a means of increasing the efficiency and effectiveness of traffic policing (Armour, 1984). It has been argued (Roulston, 1973) that the practice of issuing road users with warnings can significantly reduce the time consuming procedures associated with 'on-the-spot' fines, offence processing and notification tasks as well as the subsequent legal proceedings. Wilden et al (1989) have also argued that the improved efficiency and time savings resulting from the use of warnings can allow policing resources to be targeted at detecting more serious traffic offences.

Fines

The most common type of traffic violation penalty is the use of fixed amount fines. The use of this type of sanction has been shown to have an impact on the level of illegal road user behaviour. If the risk of apprehension is high then increasing the fine amount can also lead to an increase the level of overall deterrence (Ross, 1988). However, if road users believe that the risk of apprehension is low then substantial increases in fine amounts may have only a minimal deterrence threat (Bjornskau & Elvik, 1990).

The use of fines has a number of benefits. Firstly, they provide a means of relating penalty severity to the type of traffic offence committed. Secondly, they can provide needed income for the implementation of enforcement based countermeasures. Thirdly, they provide a meaningful deterrent because financial punishment means that offenders have less disposable income for other purposes. Finally, they can increase the efficiency of offence processing tasks because they are simple to administer and reduce the workload placed upon the legal system.

One problem with fines it that they are usually set in relation to other criminal offences and efforts to increase deterrence by substantially increasing fine amounts (for what are often viewed as relatively minor misdemeanours) may undermine other aspects of the criminal justice system (Evans, 1991). As a result, fines are usually quite low in relative terms and may convey the message to road users that a certain level of illegal driving behaviour is affordable.

One further problem is that fixed fine amounts place-different financial burdens on offending road users. This; has led a number of researchers to suggest the use of variable fine amounts which are proportional to the income of the offender. This ensures that all road users are equally affected financially by the imposition of a traffic offence fine. This type of system has been implemented in Sweden and has been found to be effective and generally well accepted by the community.

Licence Suspension

Licence suspension has been shown to be an effective countermeasure against repeat offenders and those road users who violate more serious traffic laws. Robinson and Smiley (1989), in a review of driver licence disqualifications, concluded that it was a valuable countermeasure due to the strong evidence suggesting that it reduces the amount of driving and level of risk taking behaviour within problem groups of drivers.

The success of licence suspension as an enforcement countermeasure is primarily due to the restrictions it places on the offender's mobility and the subsequent changes it causes in their lifestyle (Leivesley, 1987). These lifestyle changes can often be quite dramatic due to the dependence often placed on- personal transport and the social stigma associated with not being able to drive. The importance of such changes has been highlighted in a number of 'value of life' surveys (Evans, 1991) where freedom of movement and mobility are often given a high rating.

Critics of licence suspension procedures highlight the difficulties of enforcing driver suspensions with estimates: from a number of studies (McGuire, 1978; Matsui et al, 1992; Robinson & Smiley, 1989) indicating that the level of those driving while suspended ranged from between 30 and 60%. In addiction, they also argue that there is overwhelming evidence to show that suspended drivers are over represented in fatal accidents and are more than likely to be over represented in all accident types (US National Highway Traffic Safety Administration, 1986).

Other researchers (Duncan et at, 1990) have suggested that the value obtained from licence suspension as a countermeasure must take into account not only the removal of drivers from the road but that a suspension induces those who continue to drive do so in a more responsible manner. Suspended drivers are said to weigh up the benefits of illegal driving against the risk of detection- and further, more severe, penalties. If such drivers decide to take the risk of driving whilst under suspension they usually adhere to traffic laws in order to reduce the chances of detection.

An increasingly popular countermeasure to reduce the percentage of drivers who continue to drive whilst under suspension, has been to introduce legislation allowing police to confiscate the vehicle of the offending driver. The experience with such laws in New Zealand (Bailey, 1991) and Scandinavia (Riley, 1991) has resulted in reductions of up to 50 percent in the number of drivers who continue to drive during a period of licence suspension. This countermeasure does not completely stop the amount of illegal driving, however, it does make it more difficult for suspended drivers, as they must obtain another vehicle in order to drive, and the overall frequency of such behaviour is therefore reduced.

McGuire (1978) proposed a less stringent countermeasure, advocating the use of highly visible stickers or special licence plates as a means of alerting police as to the presence of suspended drivers in the traffic stream. Although this countermeasure has merit, a number of problems have been identified. Firstly, this countermeasure is difficult to enforce

because the vehicle identification device can be easily tampered with. Secondly, a non-suspended driver may still be able to use a marked vehicle which may lead to a considerable amount of wasted police effort in stopping vehicles in these types of situations.

Point Demerit Schemes

The use of point demerit schemes has become an increasingly popular means of linking road user behaviour to penalty severity. Such schemes involve the allocation of points to various types of traffic offences. When a driver accumulates more points, within a specified time limit, than the maximum number permitted then automatic licence suspension results. Point demerit schemes allow road users to make a certain number of errors before more serious penalties are incurred and have been introduced as a means of differentiating between different types of road users and as a way of providing a regulated deterrent threat to those road users who consistently violate traffic laws (Williams et al, 1992).

Dingle (1985) identified three main types of road user groups and the effect that the point demerit scheme has on the driving behaviour of each group. The first group are those who adhere to the traffic -rules with the receipt of a traffic offence notification being a rare occurrence. The existence of a point demerit scheme may be a factor which influences members of this group to maintain a good driving record, but it provides only a minimal level of deterrence and has no direct impact on driving behaviour other than to provide positive feedback.

The second group of road users are those who usually adhere to the traffic laws but occasionally commit some form of minor traffic offence. Drivers in this group will usually only acquire a small number of points at anyone time. Therefore the effect of the point demerit scheme is to provide them with the necessary incentive to modify their driving behaviour in order to avoid obtaining additional points and risk the chance of receiving a more severe penalty,

The final group of road users are those who consistently violate traffic rules and it is this group who are most affected by the point demerit scheme. They quickly approach, and in many cases exceed, the maximum number of points allowable. Drivers in this group appear to modify their behaviour only when they have accumulated enough points so that the likelihood of licence suspension becomes a real possibility. Experience has shown that drivers in this group may exceed the maximum allowable number of points several times before more lasting behavioural changes occur.

It is the experiences with this last group of drivers that have raised some questions as to the benefits of point demerit schemes. A common problem identified in the literature is that such schemes only appear to have a deterrent effect when a driver has accumulated a sufficient number of points so that the possibility of licence suspension becomes a real threat. Williams et al (1992) argued that point demerit systems can actually reinforce deviant road user behaviour by conveying the message to road users that a certain number of traffic offences can be committed before a serious penalty will result. He further added that some road users may, in fact, use the point demerit system as a guide to the type and number offences they can commit before they must modify their driving behaviour.

However, the effectiveness of a point demerit scheme in deterring traffic offences has been demonstrated by Haque (1987) in an evaluation undertaken in Victoria, Australia. The

empirical results from this evaluation showed that the interval of time between the commission of the second and third offence was statistically longer than that between the first and second offence. Haque (1987) concluded that the demerit points system was responsible for most of the deterrent effect reflected in the increased mean time before the commission of a third offence subsequent to the first and second offence. These results indicate that road users who commit a number of traffic offences, and thereby approach the maximum allowable number of points, do in fact modify their behaviour to avoid further, more severe penalties.

2.5 SUMMARY

Road traffic accidents are a major cause of death in many countries. It has been estimated that there is a global frequency of 50 serious and one fatal accident every 80 seconds. Road traffic accidents also result in significant social and economic costs and it has been estimated that the annual cost of these type of accidents, in OECD countries, is between one and two percent of the Gross National Product (GNP).

The 'human operator' is a central element of the road transport system and reliance on the actions of a large number of individual operators can invariably lead to conflict situations. 'Driver error' is generally considered to be a causative factor in about 60 to 70 percent of all road traffic accidents. Many believe that this value is actually much higher, somewhere between 80% to 90%. Whatever the value, it is reasonable to expect that anything which can be done to influence driver behaviour should help to reduce the large proportion of road accidents involving 'driver error'.

Efforts aimed at reducing and preventing road traffic accidents have traditionally focused on three approaches, namely, environmental / engineering treatments, road user education and traffic law enforcement. The first two of these approaches have been shown to play an important role in the process of modifying road user behaviour. However, when they are unable to bring about sufficient changes in the level of unsafe road user behaviour then reliance is typically placed on the traffic law enforcement system to deter, apprehend and punish such behaviour. The use of enforcement can be an effective means of modifying road user behaviour and reducing road accidents. It has been estimated that the elimination of traffic violations could result in a 40% reduction in the number of road injury accidents.

Traffic law enforcement consists of three step-wise components including, legislation, traffic policing and legal sanctions. All three of these components play an important role in determining the impact and effectiveness of the traffic law enforcement system. It is the manner in which road users perceive the combined effectiveness of these enforcement components which has the greatest impact on road user behaviour. The enforcement system is based on the principle of deterrence which is defined as the omission of an act as a response to the perceived risk and fear for contrary behaviour. The greater the road user's perception regarding, the risk of apprehension, the severity of the resulting penalties, and the immediacy of punishment, the greater the deterrent effect of the enforcement threat.

The perceived risk of apprehension has been shown to have the greatest influence on road user behaviour. Penalty severity and immediacy of punishment are important elements in the deterrence process, however, if motorists believe that the likelihood of apprehension is low then the effectiveness of these other deterrence elements can be compromised. This suggests that the primary focus of enforcement strategies should initially be on methods to detect offending motorists. Once this is achieved, the deterrence effect can be enhanced by increasing penalty severity and ensuring the punishment is initiated quickly and efficiently.

Enforcement deterrence can be either specific or general. Specific deterrence relates to a change in the driving behaviour of convicted traffic offenders due to previous apprehension, prosecution and punishment experiences. General deterrence relates to a change in road user behaviour due to the threat and perceived likelihood of apprehension, prosecution and punishment. The majority of enforcement strategies are designed to increase the level of general deterrence as this has the potential to influence the behaviour of a far greater proportion of motorists.

It is important to distinguish between the perceived (subjective) and actual (objective) risk of apprehension. The perceived risk of apprehension relates to road users' perception regarding the likelihood of being apprehended for committing a traffic offence. The actual risk of apprehension relates to the actual likelihood of a motorist being apprehended as a result of the existing level of police enforcement activity. It is the perceived risk of apprehension which has been shown to have the greatest impact on road user behaviour.

Increasing the actual risk of apprehension is the most effective long-term means of increasing in the perceived risk of detection. However, the available research evidence indicates that the level of policing activity needs to be increased by at a factor of at least three before any significant increase in drivers' perceived risk of detection is observed. The use of publicity to support enforcement activities can play an important role in this process.

However, publicity itself has been shown to have only a minimal long term impact on road user behaviour. It appears that more permanent changes in road user behaviour are highly dependent on sustained and intense enforcement operations.

Increasing the level of policing activity usually implies an increase in financial commitment and human resources. Policing authorities usually have only limited resources and, as a result, sustained increases in enforcement activities are often difficult to achieve. This has led to the development of enforcement strategies designed to increase the effectiveness of enforcement operations whilst ensuring that such activities remain efficient in terms of cost and human resources.

The use of highly visible enforcement operations is one means of increasing the perceived risk of apprehension. Vehicle deployment options can facilitate this process by creating the impression that enforcement is extremely active. A combination of highly visible stationary and mobile enforcement operations as well as the use of a smaller number of unmarked police vehicles appears to be the most optimal deployment option. However, this approach may only have a temporary effect on road user behaviour and more long term and targeted enforcement strategies may be required to have a more permanent deterrence effect.

The use of selective traffic enforcement has the potential to increase the deterrence effectiveness of enforcement operations whilst maximising the use of available policing resources. These operations are designed to target specific traffic locations and road user behaviour so as to obtain the maximum possible deterrent effect. The strategic allocation of policing resources during particular times of day and at particular locations within the traffic network can increase the deterrence effect by maximising the visibility of enforcement operations. Targeting high risk behaviour and accident locations also allows resources to be allocated in such a manner as to ensure the maximum possible accident reduction benefits.

The use of automated offence detection devices is one further means of increasing the overall effectiveness of enforcement operations. These devices have the potential to increase enforcement deterrence by significantly increasing both the actual and perceived risk of detection. When used to form the basis of an intensive and well publicised enforcement strategy, these devices have been shown to be an extremely cost effective means of reducing the overall level of illegal driving behaviour as well as the number of road traffic accidents.

Although a number of researchers have questioned the inability of automated enforcement devices to provide immediate on-site punishment of traffic offences, it has been argued that the significant increase in apprehension rates has a far greater potential to deter illegal driving behaviour. In addition, research has shown that the receipt of an infringement notice, several weeks after an offence has been committed, can still have a noticeable impact on road user behaviour and lead to a reduction in traffic accidents. The use of information display boards may also provide a means of alerting road users to the fact that an offence has been detected.

The use of publicity to support traffic enforcement activities has been found to be an effective means of facilitating the deterrence process by increasing the perceived risk of apprehension. However, it is important that the publicised increases in enforcement activity are actually observed by the road user, otherwise changes in driving behaviour are usually only short term. The use of publicity in isolation with other measures has been shown to increase awareness of road safety issues but appears to have only a minimal long term impact on road user behaviour.

Once a traffic offender has been apprehended there are a number of legal sanctions which can be applied. For minor offences the use of warning letters can be an effective means of modifying driver behaviour especially in situations where it is evident that illegal driving behaviour was not intended. Warning letters can also reduce the administrative workload associated with offence processing and can lead to more positive community attitudes towards traffic enforcement operations.

Fixed amount fines are the most common type of traffic offence penalty and can be an effective and efficient form of legal sanction. The deterrent effectiveness of increased fine amounts are, to a large degree, dependent on the road users perception regarding the risk of apprehension. However, substantial increases in fine amounts are not really viable in the context of the existing legal system. The use of variable penalties in proportion to road user income may be an effective solution to the problem of ensuring that all road users are equally affected financially by the imposition of a fine.

The suspension of a road user's licence has been shown to be an effective type of penalty. It provides a means of relating sanctions to an offender's lifestyle by depriving them of the privilege to operate a motor vehicle. A number of studies have indicated that a large proportion of convicted offenders continue to use their vehicle during the suspension period. However, the available evidence indicates that such offenders drive less, and more safely and have fewer traffic convictions and accidents.

The introduction of a point demerit system has also been found to be an effective means of modify driving behaviour. The benefit of this type of system is that minor traffic offences can still result in more severe sanctions if a certain number of these type of offences are committed in a short period of time. This provides a strong deterrent for repeat offenders who soon learn that only a certain number of traffic offences will be tolerated until more

severe penalties are imposed. Research has shown that once a road user has accumulated a sufficient number of points the threat of licence suspension can result in significantly less illegal driving behaviour.

3. ENFORCEMENT OF ALCOHOL IMPAIRED MOTORISTS

3.1 INTRODUCTION

Alcohol is a drug that affects the central nervous system, resulting in cognitive and psychomotor impairment. In most countries the purchase of alcohol is legal and its consumption is considered to be a normal and socially acceptable activity. However, the ready availability and excessive usage of alcohol in western society has resulted in a significant burden on the public health and welfare sectors. One estimate, from The World Health Organisation, places the burden on European economies of alcohol incurred injuries at between 5% and 6% of the gross national product (Schreiber, 1992).

One group of alcohol related injuries, which are of particular concern to authorities, are those which result from the detrimental impact of alcohol consumption on driving performance. Alcohol related traffic accidents are a frequent occurrence in many countries. The magnitude of the problem is clearly demonstrated by estimates relating to the number of alcohol impaired drivers in the traffic stream which range from 0.2% in Sweden (Laurell, 1989) up to as high as 8% in some American States (Voas, 1987).

Driving whilst under the influence of alcohol is generally accepted (Homel, 1992) as being the single largest contributing factor to road fatalities. It has been estimated (Friedel & Kroj, 1986) that alcohol is involved in 15% to 30% of all fatal accidents in traffic and about 50% of all fatal single vehicle accidents. Voas (1987) has further estimated that over 30% of all road fatalities and serious injuries arise from accidents where at least one driver was found to be adversely affected by alcohol.

Alcohol consumption depresses the reaction time and motor ability of a driver, and has been shown to result in an irregular and risk taking driving style with less precise and reactive movements (Pauwels & Helsen, 1992). Concentration, perception and divided attention information processing have also been shown (Mills & Bisgrove, 1983) to be affected by alcohol consumption. The actual level of alcohol impairment is dependent upon the amount of alcohol in the blood vessels (blood alcohol concentration, BAC) with research consistently showing (Borkenstein et al., 1964; Mayhew, 1983; Got, 1988) that the higher the blood alcohol level, the greater the level of driving impairment and risk taking behaviour.

Alcohol consumption can also result in a greater injury potential once an accident event has occurred. Trinca (1989) stated that alcohol can reduce tolerance to accident impact, affect the physiological response to injury and increase the probability of post traumatic shock. He further indicated that there can be more pathological damage of the brain and spinal cord tissue when alcohol is present in the bloodstream at the time of injury.

The motorist's decision to drive whilst under the influence of alcohol is dependent upon a number of behavioural, social and environmental factors. In a recent survey, Riley (1991) identified the following factors (in order of importance) which influence the decision to drink and drive:

1. Whether drivers perceive drinking and driving as necessary aspects of their social lives;

2. Beliefs that drinking will increase their chances of being detected by the police, the risk of apprehension and their concern about the legal consequences of conviction;

3. Beliefs about the dangers of drinking and driving;

4. Beliefs about the likelihood that family and friends would disapprove of their drinking and driving; and

5. The experienced effects of alcohol on mood and behaviour.

The central role of social attitudes in the decision making process suggests that drink driving behaviour tends not to be an isolated event but forms part of a more general lifestyle. It is therefore not surprising, given the social acceptance of alcohol use in Western society, that the percentage of alcohol impaired drivers in the traffic stream continues to remain at relatively high levels.

The magnitude of the alcohol related road safety problem has led to the development of numerous drink driving strategies. Primary intervention strategies designed to prevent the potential drink driver from undertaking such behaviour are typically implemented through public information and deterrence methods. Secondary intervention strategies, designed to detect and remove the drink driver who is already on the road, are implemented through legislative and enforcement measures. Finally, tertiary intervention strategies designed to reduce recidivism among drivers who have previously been detected, arrested and convicted are usually provided by rehabilitation programmes.

The main focus of this review will be on primary, secondary and tertiary strategies as they relate to traffic law enforcement activities. In recent years, however, there have been increasing moves towards strategies aimed at modifying the social and physical environment in which alcohol is used with a particular emphasis placed on the role of the 'agents' of drink driving namely alcohol and the automobile. Such strategies indirectly relate to enforcement based countermeasures often requiring legislative changes in order to be implemented. Mosher (1985) stated that any attempt to reduce the problem of drink driving should be based on a system wide approach incorporating a range of targeted strategies. In order to provide an understanding of such a system wide approach, the range of non-enforcement based strategies available to authorities will also be briefly examined in this review. However, it is important to stress that any system-wide approach must include a strong enforcement element if it is to bring about changes in drink driving behaviour.

3.2 DRINK DRIVING LEGISLATION

In many countries the control of drink driving behaviour relies heavily on the criminal justice system. Traditional drink driving countermeasures usually place the emphasis on the individual road user to separate drinking and driving activities. If the road user cannot be persuaded or educated to modify their drink driving behaviour then reliance is typically placed on the law enforcement system to deter, apprehend and punish. To speak therefore of 'drink-drive countermeasures' as they currently operate, is by and large, equivalent to discussing the operation of the police, courts, licensing agencies and prisons (Homel, 1983).

It has been argued that the fundamental objective of drink driving legislation is to deter the potential drink driver (Ross, 1982; Zimring, 1988; Homel, 1988). Deterrence can be specific, whereby an impaired driver is removed from the traffic stream to prevent an accident and sanctioned so as to prevent further impaired driving. Deterrence can also be general, whereby potentia] drink drivers, once informed of the high risk and consequences

of conviction, are deterred from engaging in drink driving behaviour (Jonah & Wilson, 1983).

Specific deterrence can be achieved by passing legislation prohibiting impaired driving and then by apprehending those drivers violating the law. The greater the enforcement effort, the greater the actual probability of detecting alcohol impaired drivers and hence, the greater the specific deterrence. To achieve general deterrence it is important that increases in the actual probability of apprehension, resulting from the additional enforcement effort, are communicated to the potential drink driver through the mass media thereby increasing the subjective probability or perceived risk of apprehension (Ross, 1982). It is this subjective probability of apprehension for drink driving which is most critical to the success of legislation and enforcement in abating drink driving behaviour (Jonah & Wilson, 1983).

3.2.1 Traditional Drink Driving Legislation

From the onset of the first motor vehicle it soon became evident that alcohol consumption by drivers would require some form of legislative control due to the adverse effect of alcohol on driving ability. The first laws developed to moderate the level of alcohol impaired driving prohibited the operation of a vehicle whilst a driver was under the influence of, or impaired by alcohol. These laws focused on behavioural impairment and not the actual level of alcohol that could be consumed. The enforcement of these laws required the police officer and the prosecutor to demonstrate that a driver's ability to operate a vehicle was adversely impaired as a result of alcohol consumption.

This 'behaviour based' approach to drink driving enforcement (Voas, 1991) still operates in several American States and has resulted in the development of scientific methods for measuring behavioural impairment which are practical for operational use by police in the field. The benefit of using this type of approach is that it takes into account the known individual inter and intra variations in tolerance to alcohol. It assumes that it is the level of behavioural impairment which leads to an increase in accident risk and that those drink drivers who are more tolerant to alcohol have a lower risk factor than those individuals who consume the same amount of alcohol but are less tolerant to its effects.

However, the effectiveness of a 'behavioural based' enforcement system, as a means of reducing the level of alcohol impaired driving, has been questioned by a number of researchers. Common criticisms relate to poor detection rates due to inadequate levels of enforcement and the fact that only obviously impaired drivers are apprehended (Taubenslag & Taubenslag, 1975; Vingilis et al., 1982; Jones & Lund, 1985; Homel, 1988), increased burdens on the legal system due to the requirement by the police to prove driving behaviour was impaired (Ross, 1982; Jonah & Wilson, 1983; Ross, 1988) and inadequate levels of deterrence due to the low actual and perceived risk of apprehension (Ross, 1982; Snortom, 1984; Homel, 1988).

3.2.2 Scandinavian Per se Legislation

The establishment of the relationship between alcohol consumption and blood alcohol concentration (BAC) by Widmark in 1932, provided the foundation for the use of chemical based alcohol tests in the criminal justice system. The use of chemical testing to determine alcohol impairment, based upon the actual level of alcohol consumed, was seen as a more effective alternative to existing behavioural based enforcement systems. Norway (1936) and Sweden (1941) were the first countries to incorporate BAC chemical testing

procedures into 'driving while impaired legislation' creating the 'Scandinavian model' of per se legislation.

A 'chemical based' enforcement system based upon per se legislation is now commonly used in most Western Countries. Per se laws require that any driver apprehended with a BAC greater than a specific level (e.g. 0.05 g/100ml - usually expressed simply as 0.05) as determined by a breath, blood or urine test, be charged with driving whilst under the influence of alcohol (Jonah & Wilson, 1983). The novel feature of per se legislation is that a driver's BAC is, on its own, evidence of alcohol intoxication; no other evidence (such as tests for behavioural impairment) is necessary to prove legal incapacity to drive.

The process of detecting alcohol impaired drivers using per se legislation was simplified by the development of the Breathalyser unit (Borkenstein, 1953), which allowed the level of alcohol in breath to be established quickly and accurately through the use of a photochemical reaction. The application of the Fuel Cell to measure breath alcohol was another important development. The Fuel Cell is a small, highly specific sensor for alcohol which can be accommodated in a small portable unit allowing police officers to screen drivers for alcohol impairment (Voas, 1992) and to provide an indication of the need for further evidentiary testing procedures. The use of these road side testing devices greatly aided police in detecting impaired drivers and reduced the level of mistaken apprehension.

The implementation and enforcement of per se laws has been recognised as having a number of benefits. Firstly, the evidentiary status of the blood alcohol reading increases the likelihood that an alcohol impaired driver, detected over the legal BAC limit, will be found guilty of the offence and incur the associated penalties (Homel, 1988). Secondly, it provides a reliable, quick and accurate means of determining alcohol impairment (Havard, 1990) with the driver's appearance, behaviour and manner in which they operate a vehicle not entering into the enforcement process. Finally, it allows a high level of testing to be undertaken thus increasing the actual probability of detection and creating higher levels of deterrence.

However, regardless of the reported benefits and the fact that they are commonly used, per se laws have been criticised by a number of researchers (Williams, 1992) on the following grounds:

- No regard is made to the known individual inter and intra variations in tolerance to alcohol; and

- The assumption is made inferentially that drivers have some readily available means of determining their own alcohol level (indeed, how else could they be expected to comply with such legislation).

In regard to these criticisms, proponents of per se legislation (Snortum, 1984) argued that using legal BAC limits, based upon average performance impairment levels, is extremely efficient, easily enforced and sets common standards for all drivers. Votey (1982) stated that, apart from the obvious technical and administrative difficulties in determining different tolerance levels for each driver, such legislation would only serve to a reinforce the drink driving behaviour of those individuals who have developed a greater tolerance to alcohol.

The argument relating to drivers not being able to determine when they are over the legal BAC limit has also been countered (Snortum, 1984). It is argued that per se laws are

designed to discourage all forms of drink driving behaviour and not, as is implied by the critics of such laws, to encourage drivers who wish to consume alcohol to do so until they are just below the legal limit. Legal BAC limits are set at levels that allow for only light drinking and drivers who drink more heavily know that they face the risk of impairment and the legal consequences (Grasmick & Green, 1980).

3.3 COUNTERMEASURES TO DETECT THE ALCOHOL IMPAIRED DRIVER

The detection and apprehension of alcohol impaired drivers has long been recognised as a weak link in the process of drinking-driving deterrence (Ross, 1984). Deterring drink driving behaviour is dependent upon creating a high level of perceived risk that such behaviour will be detected and result in some form of punishment (Homel, 1988). This is difficult to achieve if a high proportion of alcohol impaired drivers over the legal limit remain undetected. Strategies resulting in a low detection probability may also convey the message that enforcement is ineffective, which may only serve to reinforce the behaviour of drink drivers (Liban et al., 1987).

In jurisdictions relying on a 'behavioural based' approach to alcohol enforcement the primary means of detection is dependent on the subjective judgement of police officers to determine whether or not a driver's ability to operate a vehicle is significantly impaired. The effectiveness of this method of detection has been questioned by a number of researchers (Taubenslag & Taubenslag, 1975; Vingilis et al., 1982; Jones & Lund, 1985; Kiger et al., 1993) who have shown that a high proportion of alcohol impaired drivers were able to avoid attracting the attention of the police. It was found that these drink drivers, who have developed strategies for avoiding detection, perceive the risk of being apprehended as very low (Havard, 1990). Homel (1988) stated that strategies resulting in a low actual and perceived risk of apprehension compromise all other aspects of the deterrence process.

In contrast, the use of per se legislation, allowing the results of chemical testing devices to be used as evidence of alcohol intoxication, has led to the development of more effective deterrence based strategies (Cashmore, 1985). The use of breath testing devices can significantly increase the level and efficiency of detection and when combined with increased enforcement activities can also create a high level of deterrence (Homel, 1983; Williams & Lund, 1984; Homel & Wilson, 1987; Carseldine, 1988). The benefits of increased deterrence have been identified in a number of studies relating to the impact of increased enforcement. These studies have shown that when the probability of detecting a drink driver is markedly increased, then the number of such offences falls dramatically (Ross, 1984).

However, the deterrent effect of breath testing devices is, to a large extent, dependent on the legislation governing their use. The power of police to require a driver to undergo a test for alcohol impairment is extremely important but varies considerably between jurisdictions and may take one of several levels, including:

- Stopping only obviously impaired drivers;
- Stopping drivers at roadblock or sobriety checkpoints and testing only those suspected of alcohol impairment;
- Stopping drivers at random and testing all those stopped.

3.3.1 Testing Drivers on the Basis of Behavioural Impairment

The first level of police power is the right to breath test only if there are reasonable grounds to suspect that the driving performance of a motorist is impaired by alcohol. The common grounds for suspicion are irregular driving behaviour, involvement in an accident or the commission of a traffic violation. The reasons for testing a driver, due to suspicion of alcohol impairment, must be clearly established as this can be subject to questioning in a court of law and lead to a non-conviction.

This level of police power has been shown to have an impact on the level of drink driving behaviour. The British Road Safety Act of 1978, based upon this type of legislative approach (allowing for breath testing of every individual who committed a traffic infraction or was involved in an accident), was shown to have an impact upon the number of accidents (Riley, 1991). Further evidence for the use of this legislation is provided by Voas and Hause (1987) who reported a 43% reduction in the number of drivers exceeding the legal BAC limit in Stockton, California as a result of an increased enforcement program. In addition, the number of night time accidents decreased by 13%, during the period in which the program was operating, with a large proportion of this reduction being attributed directly to the increased night-time enforcement activities.

The use of this legislative approach has however, been criticised by Ross (1982) because it does not provide any real sustained level of deterrence. This view is supported by road side survey showing that the number of alcohol impaired drivers detected using this legislative approach can be quite low (Vingilis et al., 1982; Jones & Lund, 1985). Jonah and Wilson (1983) have also indicated that the decision to apprehend solely on the basis of driving cues can result in a considerable loss in efficiency with police officers only targeting those drivers displaying obvious signs of impairment.

3.3.2 Roadblock and Sobriety Checkpoints

The second level of police powers enables the stopping of motorists at a 'roadblock' for licence inspection or other checks, including 'sobriety checks' (Ross, 1984). Drivers suspected of having consumed alcohol, for reasons such as smell and impaired behaviour, can be required to take a breath test. Roadblock techniques differ from those relying solely on driving cues as they allow police to make direct contact with a driver regardless of whether or not signs of alcohol impairment are present (Jonah & Wilson, 1983). These type of enforcement techniques can also increase the risk of apprehension, and hence the level of deterrence, because drivers soon realise that they may be stopped at any time and checked for alcohol impairment.

Sobriety checkpoints have been shown to reduce the number of alcohol impaired drivers in the traffic stream and the number of alcohol related fatal accidents. In a review of the Canadian experience with the use of such programs, Liban et al. (1987) found associated reductions in alcohol related fatalities in the range of 10% to 20%. The American State of Delaware reported a 32% drop in alcohol related injury accidents during an eight month period between 1982 and 1983, when sobriety checkpoints were in use (National Transport Safety Board, 1987).

In a review of drink driving countermeasures which have been implemented in a number of countries, Ross (1982) also found evidence of significant initial reductions in alcohol related accidents and fatalities. He concluded, however, that there were questions regarding the long term deterrent benefit of roadblock techniques, indicating that such

countermeasures can have a significant short-term deterrence effect on drink driving but that the deterrent effect is only short lived. Ross (as cited in Cashmore, 1985) explains the evanescent nature of the effect as a result of the initial overestimation by the public of the risk of apprehension, with the effect waning as the public re-evaluates the risk. Ross (1982) does point out, however, that his results might reflect the fact that some of the enforcement strategies examined were intended only as short term blitzes and others were not implemented with vigorous enforcement.

The effectiveness of roadblock and sobriety checkpoint procedures has also been questioned due to the fact that these measures still rely on the subjective judgement of police officers to determine if a driver is impaired by alcohol, and whether a breath test is warranted. Evidence from Sweden (Aberg et al., 1986) found that over half of those drivers who were over the legal BAC limit were able to pass through such checkpoints without being tested. Homel (1990) stated that the deterrent effects of roadblock programs are almost certainly undermined by the level of police discretion involved in determining which drivers should be administered breath tests. Homel (1988) provides the example of a roadblock program in Queensland, Australia where less than 1% of drivers who were stopped were administered a roadside breath test. He stated that this type of procedure does little to facilitate the level of deterrence because drivers soon realise that, although, the risk of being stopped is high the actual risk of being tested for alcohol impairment is low.

3.3.3 Random Breath Testing

The third and most extensive level of policing powers allows a police officer to stop and breath test any driver without having reason to suspect that the driver has been drinking. This method of enforcement is commonly referred to as random breath testing (RBT) due to the random selection of drivers for testing. RBT is generally regarded as an extremely effective deterrence strategy and Dunbar (1990) has stated that over the past ten years it has proved to be the central countermeasure against drinking and driving.

RBT, as an enforcement tool, stands in marked contrast to roadblocks or sobriety checkpoint programs and other forms of less stringent testing procedures. The critical difference with RBT is that all drivers who are stopped are required to take a breath test whereas with other procedures only drivers who are judged to have been drinking, or are obviously impaired, are required to take a test.

The purpose of random breath testing (RBT) is to deter drivers from drink driving because they know that it is possible for any person to be tested, and that the risk of detection and apprehension is present regardless of behaviour or apparent alcohol impairment (Havard, 1990). A major argument in favour of RBT (Homel, 1990) is that motorists know that they may be tested whether or not they appear to have been drinking and that when the threat of detection is potent and credible, fewer drivers will risk driving when their BAC may be over the legal limit.

Homel (1990) has stated that the success of RBT as a drink driving countermeasure is dependent on creating a high level of deterrence. Maximising the level of deterrence requires the creation of a sense of unease amongst potential offenders about drinking and driving. Homel (1990) stated that this can be achieved through:

- Highly visible police enforcement which gives the impression that RBT is unpredictable, unavoidable and ubiquitous;

- Sustained high levels of publicity focusing on RBT enforcement activities and their deterrent impact, especially at the onset of RBT operations;

- Creating an awareness among drivers that RBT checkpoints may be encountered at any time and in any location;

- Certainty of punishment which reflects the severity of the crime committed; and

- The stopping of a large proportion of drivers and ensuring that all are breath tested for alcohol impairment.

These deterrence criteria are supported by Ross (1982) who indicates that the three main factors influencing the deterrent effectiveness of drink driving countermeasures are the level of publicity associated with the countermeasure, the level of enforcement, and the influence of the combined publicity and enforcement on the actual and perceived certainty of the threatened punishment.

As might be expected, there are important constitutional and civil liberty issues associated with RBT operations that allow police to stop and breath test any driver without due cause. As a result of such issues, RBT has been introduced in only a few countries, including The Netherlands, France, Denmark, Finland, Norway, Sweden and Australia. Determining the true impact of RBT as a means of deterring drink driving behaviour can be a difficult task due to the effect of conflicting road safety initiatives, the influence of numerous exogenous variables and the need for reliable enforcement and alcohol involvement data.

To date, some of the most conclusive evidence that RBT can achieve a sustained reduction in alcohol related accidents and fatalities comes from Australia, where RBT procedures, in various forms, have been adopted in most States and Territories. The reported success of RBT in Australia has generated considerable international interest and Havard (1990) has suggested that the Australian RBT experience may provide sufficient evidence to justify the constitutional amendments necessary for its introduction in other countries.

3.3.4 Random Breath Testing in Australia

Perhaps the most clear and well documented evidence of the effectiveness of RBT comes from the Australian State of New South Wales where RBT operations were introduced in December 1982. The factor which differentiated the introduction of RBT in New South Wales from other Australian States (with the exception of Tasmania which adopted a similar approach) was the intensity of the policing operations and the associated publicity. The distinctive elements of the New South Wales RBT Program, as described by Homel et al. (1988) were:

- At least one random test was carried out for every three licensed drivers each year, resulting in high levels of exposure to RBT;

- Extensive formal or informal publicity focused specifically on RBT and the probability of detection;

- Highly visible policing activities, that were difficult to predict when and where they would be encountered and difficult to evade once in sight, thus increasing the perceived probability of apprehension; and

- The enforcement and focused publicity were maintained at permanently high levels, with provision for special additional local or seasonal campaigns.

The impact of RBT operations in New South Wales has been well documented with strong evidence of a long term and sustained reduction in the level of drink driving behaviour (Arthurson, 1985; Homel et al., 1988; Homel, 1990). Coinciding with the introduction of RBT, Homel et al. (1988) reported a 22% reduction in total fatal accidents (compared with the average for the previous 6 years) and a 36% reduction in alcohol related fatal accidents. The greater reduction in alcohol related fatalities as compared to overall fatalities supports the conclusion that. RBT was the main cause of the decline (Homel, 1988). Further analyses (Homel, in press) suggest that these effects have been sustained into the 1990's.

Results from RBT operations in Tasmania, Australia (where a RBT program similar in intensity to that of New South Wales was introduced in 1983) provide further support for the accident reduction potential of RBT. Although the small population of Tasmania makes an examination of fatality data difficult, the evidence, three years after RBT operations began, indicated a 29% reduction in total road fatality accidents and a 42% reduction in alcohol related fatal accidents. It is also noteworthy to mention that RBT in Tasmania has been enforced at a high testing level which is illustrated by 1985 figures showing a testing rate of three out of every four licensed drivers.

Victoria, was the first Australian State to introduce RBT operations in 1976. The first ten years of RBT operations in Victoria, were characterised by relatively low annual testing rates (1 in 20 licensed drivers) and the use of intensified periods of testing (RBT blitzes) in areas selected according to a pre-determined experimental design. There is some evidence to suggest that this approach to RBT did have a deterrent effect (Cameron & Strang, 1982; South & Stuart, 1983) but the existence of sustained benefits are unclear (Homel, 1988).

In 1989, in response to a rising road toll, the Victorian police modified their RBT operations, implementing a new program based upon the principle of high intensity, highly publicised policing activities. By 1993 roadside testing rates had escalated to a rate of almost one in every two licensed drivers. The estimated benefits of the new RBT operations were also encouraging. Three years of post 1993 road fatality data (Victorian Police, 1993) indicated a reduction in alcohol related fatalities of the order of 40% (compared with the average for the previous 6 years). The new RBT operations were also estimated to have resulted in a 30% reduction in the total number of road accident fatalities-(Cameron et al., 1992).

Further evidence supporting the benefits of increasing the intensity of RBT operations comes from South Australia. A doubling of the number of RBT tests undertaken, associated with an extensive publicity campaign, was found to have led to initial reductions of 31% and 34% in the number of drivers, detected at roadside surveys, with BAC levels in excess of 0.05 and 0.08 respectively (McCaul & McLean, 1990).

Behavioural effects of Random Breath Testing

The manner in which RBT modifies driver behaviour has been highlighted in several surveys undertaken in New South Wales, Australia, (Carseldine, 1985; Road and Traffic Authority of New South Wales, 1982, 1983, 1984, 1987) of drivers who reported drinking at least once per year. The results indicate that the number of drivers self-monitoring the number of drinks consumed before driving had increased from 24% to 53%, with a corresponding reduction in those who relied upon symptoms of alcohol impairment. This

second finding is encouraging because, for the majority of drinkers, symptoms of alcohol impairment are more often than not associated with a higher BAC limit than that legally allowed (Homel et al., 1988).

In response to a request to rank alternative courses of action before attending social functions, where alcohol was being served, the number of drivers who selected the option "arrange beforehand not to drive home" increased steadily from 35% to 51% in the first two years after the introduction of RBT (Carseldine, 1985). One further important finding of these surveys was that the proportion of drivers supporting RBT had increased from 65% to 97% within five years of its introduction (Havard, 1990).

However, perhaps the most significant behavioural finding from the surveys is the increase in the percentage of respondents willing to label a drink driver who is involved in an accident or is stopped by police as "irresponsible, a criminal, or a potential murderer".

Homel (1990) indicates that this is the first piece of quantitative evidence that moral attitudes towards drinking and driving may be changing. Homel (1990) adds that it is, of course, difficult to prove that RBT is the major cause of this positive shift in moral attitudes, but since RBT is known to have had a major impact on behaviour, it provides a plausible explanation for at least some of the change in attitudes.

Exposure to Random Breath Testing operations

Driver exposure to RBT is essential if it is to produce a deterrent effect (Homel, 1988). In 1989 the proportion of motorists who had been breath tested was 64%, with 12% of motorists having been tested five or more times. Although about a third of motorists had never been breath tested, approximately 88% reported having seen RBT operations within the last six months (Homel, 1990).

The New South Wales driver surveys also provide an indication of the effects of exposure to RBT. The proportion of drivers who indicated that the risk of apprehension due to RBT had become either 'higher' or 'much higher' had risen to 86% five years after RBT had been introduced (Homel et al., 1988). In addition, the proportion of drivers who indicated that they could do something to reduce their chance of being detected decreased from 33% in 1982 to 24% in 1987.

The surveys also indicated that the most common tactic used by drivers to avoid RBT was to drive on back streets. The use of this tactic by drink drivers is supported by data from South Australia (McLean et al., 1984) which showed a 40% increase in the number of late night accidents on back streets after the introduction of RBT in that Australian State. This problem was found to be widespread and in 1987, the New South Wales Government introduced an adjunct to RBT, called 'Mobile RBT' which was, to some extent, a response to concern about drink drivers using backstreet routes to avoid RBT (Homel et al. 1988).

Stationary versus mobile random breath testing

In Australia, there are two major forms of RBT: Stationary and Mobile. Stationary RBT operates in all States and Territories and can involve up to 20 police officers with a special bus or mini-van containing necessary equipment to undertake RBT operations. Stationary RBT is usually performed at arbitrarily selected, highly visible check-points (often on main roads) which are varied from day to day and week to week (Homel, 1993).

Mobile RBT was introduced, in the Australian States of New South Wales and Victoria in the late 1980's, and involved the introduction of legislation allowing routine police patrols to pullover any motorist at any time, regardless of driving behaviour or whether a traffic offence had occurred. Mobile RBT legislation was introduced as a means of countering any possible waning in the effectiveness of stationary RBT operations (such as the problem identified in roadside surveys of those drivers who indicated that they could avoid RBT by using back streets).

It was originally envisaged and recommended (Carseldine, 1988) that mobile RBT be used only to support stationary RBT operations and be conducted in streets in the near vicinity of stationary RBT stations. However, it soon became the dominant form of RBT due to the results of initial trials in New South Wales, Australia, showing that mobile RBT operations had resulted in higher apprehension rates than stationary RBT operations. Other factors leading to the increased use of mobile RBT operations included increased political pressure to justify RBT effectiveness and a lack of understanding regarding the principles of general deterrence (Homel, 1993). It is important to note, that high testing rates (using mobile RBT) were still maintained in New South Wales (Havard, 1990) by ensuring that all regular police patrol units conducted RBT for at least one hour during every shift.

Homel (1993) has criticised the over emphasis placed on mobile RBT operations. He indicates that one of the primary objectives of RBT is to create a high level of general deterrence through the use of highly visible policing operations and concludes that mobile RBT compromises this general deterrence process because it is much less visible to other motorists. Homel (1990) explains the higher detection rate resulting from mobile RBT as being due to the fact that police may target intoxicated drivers on back streets who are trying to avoid detection. He stated that as a result, mobile RBT is even less 'random' than stationary RBT, and on its own is almost certainly a less potent deterrent.

As a result of concerns regarding mobile RBT, the Australian State of Victoria has now implemented an RBT program centred around the use of thirteen, purpose built, highly visible and well publicised 'booze' buses. Approximately 80% of all breath testing is now carried out using these buses (Victorian Police, 1993). The remaining 20% of testing is still carried out using mobile RBT, which has been shown to be effective when used in conjunction with stationary RBT (Carseldine, 1988). In addition, there are plans to fit specially illuminated RBT signs to all mobile RBT units to increase the \risibility of such enforcement operations and thus continue to maintain a high level of general deterrence (Moloney, 1993).

Cost effectiveness of random breath testing

Few benefit-cost studies of random breath testing have been conducted, and once again the most reliable evidence comes from New South Wales, Australia. In 1990, the estimated annual cost of the New South Wales random breath testing program, including media publicity, was $3.5 million (approximately 2.7 million $U.S.). At the same time the RBT program was conservatively estimated to save 200 lives per year, with -savings to the community of at least $140 million (approximately 110 $U.S.). These values indicate a benefit cost ratio of over 50:1. Camkin and Webster (1988) estimated a 14:1 benefit cost ratio for the same RBT program, although they did indicate that this value was conservative.

As would be expected, due to the reduction in road fatalities, the majority of these savings have been in the area of health services (Dunbar, 1990) with the cost savings in operating

time, intensive care units, ambulances, and other elements of health resources being directly attributable to RBT. Other benefits resulting from accident reductions have been lower insurance premiums and in Victoria, Australia, as a partial result of accident reductions resulting from RBT and other countermeasures the Government Insurer was able to return $750 million to treasury (Moloney, 1993).

Problems with random breath testing

Police commitment to RBT is essential to ensure its continued success. However, problems relating to police morale and professionalism can impact on the effectiveness of RBT operations (Moloney, 1993). Such problems arise due to the fact that RBT can be very boring and the low number of offenders apprehended (typically between 0.20% and 0.50%) results in little or no immediate reinforcement (Homel, 1993).

In Victoria, Australia, the solution to these problems was found to be the assignment of probationary constables, for a short period (4 weeks) after their graduation, to undertake a large proportion of RBT operations. The involvement with RBT was, for many of the probationary constables, their first contact with the public and their level of enthusiasm was made evident by a significant initial increase in both testing and detection rates (Moloney, 1993). In order to maintain enthusiasm and create a high level of understanding regarding the objectives of RBT every probationary constable was individually informed of the positive results of their efforts. The involvement with RBT operations also had other benefits in that it provided the probationary constables with a good level of in-field training.

Homel (1993) indicated that another problem hindering effective RBT operations is the inability of researchers to convey the message to authorities regarding the deterrence impact of RBT. Homel (1990) has stated that continuous feedback to police on the goals and effectiveness of RBT is necessary, to counter inevitable trends for apprehension based enforcement policies to displace RBT. It must be stressed that RBT is not a technique to be used for apprehending offenders, but rather for deterring them. Homel (1993) concludes that it is important to ensure that politicians, public servants and police are made to understand the principles of deterrence upon which RBT is based, and that it is necessary to implement procedures which actually produce the conditions which will cause drivers to change their drink driving behaviour.

The level and type of publicity associated with RBT operations is another factor which can impact on the overall effectiveness of RBT. Homel (1993) highlighted the problem of drink drive publicity which emphasizes the social harm caused by the offence or the moral culpability of the drink driver. He indicated (1988) that there are grounds for believing that such publicity is at best ineffective and is at worst harmful, partly because it fails to reinforce directly the deterrent impact of RBT, and partly because drink drivers know from experience, and from the opinions of their friends and the wider society that their behaviour is neither particularly dangerous nor particularly immoral.

Conclusions from random breath testing in Australia

The experience in the Australian States of New South Wales, Tasmania, and Victoria underlines the importance of 'high visibility' RBT accompanied by a concentrated publicity campaign. Without these elements, the introduction of laws permitting RBT is unlikely to be effective and any initial benefits are unlikely to be sustained (Havard, 1990). For RBT to be truly effective there also has to be a high level of testing (Homel et al., 1988), with

the evaluations undertaken in a number of Australian States providing clear evidence of the benefits associated with intensive enforcement activities.

Well designed evaluations should also be an integral component of all new countermeasures with those carried out on RBT in Australia providing a better basis for future planning than is often the case in this field (Homel et al., 1988). Finally, Homel et al. (1988) stated that the evidence that RBT in New South Wales, Australia may be beginning to achieve 'moral deterrence' encourages optimism that rehabilitation and education programs may have an increased impact. They suggested that as deeply held beliefs about drinking and driving are gradually modified, and as the social environment is transformed through RBT, educators are faced with an audience that may be more receptive to their message.

3.3.5 Random Breath Testing in The Netherlands

Australia is only one of several countries which has introduced random breath testing. The intensity of the RBT operations in Australia is extremely high and in many countries the level of available policing resources do not allow for such high testing rates. In the Netherlands, less intensive RBT operations have been found to be relatively successful at reducing the level of drink driving behaviour. Several studies have been undertaken in the Netherlands to examine the effectiveness of RBT operations.

In order to discover if drink driving in the Netherlands could be substantially reduced at a realistic level of police enforcement using RBT operations, the city of Leyden and surrounding municipalities were subjected to a one-year enforcement experiment in 19881989. The experimental area represented approx. 200,000 inhabitants.

The most significant characteristics of the experimental enforcement included:

- a high enforcement level at the start of the experiment, followed by a gradual tapering off: in the second half of the experimental year, police effort was less than half the effort expended during the first half of the year (71 versus 152-man days);
- controls by small investigation teams of 2 to 4 policemen;
- stopping motorists at random, all of whom had to undergo a breath test (random breath testing);
- very conspicuous controls at places and times with a high traffic volume and a small number of offenders;
- unobtrusive controls at places and times with a low traffic volume and a large proportion of offenders;
- great continuity in enforcement during the entire experimental period; at least once a week, random alcohol control took place somewhere inside the area of enforcement;
- extensive publicity surrounding increased police enforcement; the major aims included:

    (a) to increase the subjective risk of getting caught; emphasising the continuity of enforcement, also by regularly publicising control results; emphasising the

accuracy and reliability of detection equipment, and the ensuing certainty of being caught if stopped;

(b) to increase public knowledge about the legal limit, the risks of driving under the influence and about sanctions against those offenders caught;

(c) to keep the public informed about positive developments concerning driving under the influence (through regular publication of an 'alcometer' graph);

- unpredictability of control locations and times for the public, through frequent relocation of control teams.

During the experiment, the police tested 7250 motorists at random for alcohol consumption. This is equivalent to 1 test per 28 inhabitants of the enforcement area, or 1 test per 14 motorists. After one year, the proportion of motorists with a BAC over the legal limit (0.05%) had dropped from 8.1% to 6.0% during week-end nights. This lower level, however, had already been achieved after six months (Mathijssen, 1991). The expenses of the enforcement program are estimated at about *f*100,000 (US$50,000), the resulting savings at about *f*1,000,000 (US$500,000).

An evaluation study in the Dutch province of North Brabant showed substantial local differences in drink driving levels, corresponding with differences in police enforcement levels. The study regarded a large scale enforcement and publicity campaign, which was conducted between the end of November, 1989, and the end of February, 1990. During the campaign, the North Brabant police checked 80,000 drivers at random for drink driving. This is equivalent to approx 1 control per 25 inhabitants of the province. By means of a before and after measurement, the effects of the campaign on the alcohol consumption of motorists during weekend nights have been determined (Mathijssen, 1990).

During the before measurement, 1212 motorists were tested at random, and 1337 during the after measurement. The sample included eight enforcement areas; four of these were already subject to a relatively high level of enforcement prior to the campaign, while in the four other areas the level of enforcement was relatively low. In the areas with a low level of enforcement, 9% of motorists were found to be over the legal limit, compared to 4% in the areas with a high level of enforcement. In two adjoining areas, the importance of enforcement was even more marked. In one area, where the police hardly exercised any control, 17% of the motorists were over the legal limit. In the other area, which was subject to a high level of control, the recorded level of drink driving was only 3%.

During the campaign, all eight areas were subject to intensive police enforcement. Upon completion of the campaign, no difference was found between the two area groups: after measurement showed that for both groups, 4% of motorists had a BAC of > 0.5 pm. Evaluations of alcohol campaigns held in 1990/1991 and in 1991/1992, showed that drink driving had stabilised at the relatively low level found after the 1989/1990 campaign. (Mathijssen, 1990; 1992). In the periods between the campaigns, drink driving control in North Brabant tended to be at a low to very low level.

The study results for Leyden and North Brabant demonstrate that intensive, random alcohol controls by the police can have a marked effect on drink driving. Such an effect can be achieved within a short period of about 3 months, and can subsequently be maintained over a fairly prolonged period (at least 9 months) at a considerably lower level of police enforcement (Mathijssen & Wesemann, 1993).

3.4 IMPROVING THE EFFICIENCY OF DRINK DRIVING COUNTERMEASURES

In many countries the implementation of random breath testing legislation and associated policing operations, similar to those in Australia, is not possible due to civil liberty issues, insufficient resource allocations and the need to justify the high additional resource costs in terms of tangible road safety gains. In addition, there are still some researchers who question the reported benefits of RBT and the necessity to implement such high intensity RBT programs (Ross, 1988). As a result there have been a number of other alternative strategies proposed for increasing deterrence which include the use of strategic planning methods to allow better allocation of available resources, and the use of passive alcohol screening devices to increase detection rates.

3.4.1 Improved Spatial Deployment of Resources

Elliott (1992) has indicated that improved spatial deployment of existing policing resources is one possible means of increasing the effectiveness of drink driving countermeasures. He stated that when developing drink driving strategies it is important to establish whether or not additional policing resources are required to better cover the essential part of the road network, or whether existing policing resources can be more effectively deployed using randomised scheduling techniques over time and space covering all key parts of the entire network (Leggett, 1988).

The underlying principle of random scheduling is the systematic deployment of available resources at various times and locations on the basis of where enforcement is most required and where it can result in the maximum possible road safety benefits (Leggett, 1990). With regard to drink driving enforcement, this is usually accomplished by allocating available resources to activities which maximise deterrence and increase the risk of apprehension for both potential and actual drink drivers in the traffic stream (Jernigan, 1986).

Mathijssen (1991) has described the use of a targeted enforcement strategy, during weekend and other known high drinking times, which involves the use of two distinctive yet complimentary enforcement phases. The first enforcement phase is characterised by highly visible policing operations and lower testing rates with enforcement activities being undertaken on high volume traffic routes several hours before known high drinking times.

The emphasis is placed on creating general deterrence through the use of highly visible enforcement, with less emphasis on high testing rates due to the low proportion of drink drivers in the traffic stream. The objective of this first phase is to convey a strong message to potential drink drivers when they most require that message (i.e. before they drink and drive) that enforcement is active and that if they decide to drink and drive then there is a high risk of detection.

The highly visible enforcement activities may then be followed by a second phase which is characterised by high testing rates and less visible enforcement activities which are undertaken during times of known high alcohol consumption with testing occurring in numerous locations but limited to only a short period of time at each location. The emphasis is on creating both general and specific deterrence through high testing and detection rates but is accompanied by less visible, frequently moving enforcement operations to increase the unpredictability of enforcement and make it difficult for drink drivers to avoid testing checkpoints due to having been informed about testing locations by friends. The objective of this phase is the detection of alcohol impaired drivers which is

accompanied by less visible enforcement operations due to the fact that the undeterred drink drivers are already present in the traffic stream.

This approach provides a good example of the way in which strategic planning techniques can be used to result in an efficient utilisation of resources whilst allowing a high level of deterrence to be maintained. In hours of known low alcohol consumption the level of resources (including associated costs) allocated to alcohol enforcement activities is not excessive (2-4 testing officers) but is highly visible thus creating general deterrence. In hours of known high alcohol consumption when the percentage of drink drivers in the traffic stream is greatest, there is increased enforcement (10 or more testing officers divided into smaller teams to increase exposure) with the emphasis being on the detection and deterrence of drink drivers through both specific and general deterrence mechanisms.

3.4.2 The Use of Publicity

The use of publicity campaigns and the role of the media has also been identified as a means of increasing the effectiveness of drink driving countermeasures. When using enforcement strategies based upon a process of deterrence, Elliott (1992) indicated that the role of publicity targeted at drink driving is to raise awareness regarding the likelihood and inevitability of detection and its severe consequences. This proposition is supported by Ross (1990) who indicated that the primary functions of drink driving publicity, through the media, are to introduce information, create awareness, set drink driving agendas and affect risk perceptions.

Homel (1988) also indicated that media publicity, in association with enforcement operations, is essential in order to raise community awareness of the risks of detection which, in turn, contributes to the process of creating a deterrence effect. Cashmore (1985) stated that negative publicity which highlights controversial aspects of enforcement operations can also be beneficial to the deterrence process. This proposition is supported by Ross (1982), who found evidence that drink driving countermeasures which were more controversial, more publicised and more newsworthy were also more effective. He concluded that this finding was understandable given that the fundamental variables in the deterrence model are perceptual.

The importance of using publicity in association with the enforcement of drink driving countermeasures has been demonstrated by the findings of a number of studies (Mercer, 1985). Saunders (1977), in a study examining the impact of increased enforcement operations in the Australian State of Western Australia, found no evidence of a reduction in the number or severity of accidents when the increased policing activities were given no publicity by the mass media. Vingilis and Coultes (1990) stated that publicity, when used in association with legislation and enforcement has been shown to affect self-reported behaviour and in a few instances, has actually been found to affect accident rates. Mercer (1985) has also demonstrated that large increases in publicity, and more contact with enforcement can lead to behavioural changes.

There is also evidence to suggest that publicity alone may be able to bring about changes in drink driving behaviour. In roadside surveys conducted approximately eight weeks after the implementation of an intensive and highly publicised drink driving campaign, McCaul and McLean (1990) found significant reductions in both the number of drivers who had been drinking (20%) and the number of drivers with a BAC over the legal limit (34%). They indicated that in such a short period of time it was unlikely that drivers would have noticed the increase in drink driving enforcement activities without the associated

publicity. They further concluded that the change in drink driving behaviour was primarily, if not entirely, due to the publicity component of the enforcement campaign.

Ross (1988) indicated that publicity does bring about initial changes in driving behaviour but stated that if it is not supported by visible enforcement activities then the initial overestimation, by the public, of the risk of apprehension soon reverts back to pre-publicity levels. The inability of publicity to produce significant behavioural change has been demonstrated by Elliott (1993), in a review and analysis of eighty seven road safety publicity campaigns. He found that publicity campaigns could result in relatively high changes in community awareness (30% +) but that they had only a small impact on changing attitudes and actual behaviour (5% and 1% respectively).

The majority of literature supports the notion that publicity should be used in support of and not separately from alcohol enforcement activities. Riedel et al., (1988) found that, in certain situations, publicity alone could bring about changes in road user behaviour but concluded that the combined use of publicity and enforcement had a much larger and more lasting effect. This proposition is supported by Elliott (1993) who, in his analysis of road safety campaigns, found evidence to suggest that those campaigns carried out using both publicity and enforcement are likely to be more effective.

3.4.3 Passive Alcohol Sensors

Passive alcohol sensors are alcohol screening devices designed to alert police to the need for more careful assessment of alcohol impairment. Passive alcohol sensors are non-intrusive, detecting the presence of alcohol by sampling the exhaled air in front of a driver. The driver who is tested with a passive sensor is required to do nothing other than talk when the device is placed in front of them. These devices can be used independently or in conjunction with standard roadside breath testing instruments, and are specifically designed to supplement and increase the efficiency of police drink driving operations.

Passive screening devices can also be used in several ways to increase the efficiency of police testing procedures. Firstly, in jurisdictions where initial alcohol screening procedures are based on behavioural assessments of impairment, the use of these devices can significantly reduce the incidence of 'impairment misjudgements' and wrongful arrest made by police officers (Kiger et al., 1993). Secondly, in jurisdictions where roadside breath alcohol screening is permitted, the use of passive devices can reduce the testing delay to motorists by a providing a quick and non-intrusive assessment of the presence of alcohol (Land Transport Division Ministry of Transport, New Zealand, 1991).

In Field Trials, in the United States (NTHSA, 1985), the use of passive alcohol screening devices has been shown to significantly increase detection rates of drivers who are over the legal BAC limit. The detection rate of drivers with a BAC limit over 0.10 increased from 45% to 68% and for drivers with a BAC limit between 0.05 and 0.10 the rate increased from 24% to 45%. Improved efficiency due to these devices was also demonstrated by a reduction of over 50% in the number of drivers being unnecessarily detained (NTHSA, 1985).

In controlled laboratory conditions, passive alcohol sensors have accurately identified over 90% of all subjects with high BAC limits (Lestina & Lund, 1990). However, the accuracy of these devices, as used in the field, has been questioned (Riley, 1991) due to the possible adverse impact of environmental conditions (especially wind) which may lead to false negative readings. The performance of passive sensors in the field has been tested in trials

undertaken in the American State of Ohio (Kiger et al., 1993). The results showed that passive alcohol sensors were able to correctly identify over 80% of drivers at or above the legal BAC limit. One additional advantage of these devices is that, in jurisdictions where only the road side testing of those drivers suspected of alcohol impairment is permitted, the detection rate can be much higher (over 95%) if the mere presence of alcohol is used as an indication to initiate a more accurate breath test (Lund & Jones, 1987).

3.5 LEGISLATIVE CONTROL OF DRINK DRIVING

The policing activities targeted at the drink driver are an essential element in the process of controlling and reducing the negative impact of alcohol impairment on our roads. Of equal important are the legislative controls of drink driving which not only help to support the activities of police, making the task of deterrence and detection easier, but can, in their own right, create deterrence and reduce the level of drink driving behaviour. Legislative controls for drink driving can take many forms, including: setting the level and type of punishment administered to the drink driver, defining the drinking and driving level which is considered illegal and regulating the social and physical environment in which alcohol is consumed.

3.5.1 Legal Sanctions for Drink Driver

Legal sanctions are a central component of deterrence-based polices for reducing the level of alcohol impaired driving. It is generally regarded that legal sanctions can reduce the incidence of drink driving behaviour through both general and specific deterrence mechanisms. General deterrence can result from the knowledge of drink driving sanctions and be due to the resulting fear of receiving such punishment and belief that it would be personally unpleasant (Homel, 1988). Specific deterrence can result from convicted drink drivers modifying their behaviour due to the experience of receiving sanctions and the accompanying financial and social consequences.

Legal sanctions for drink driving behaviour can take one of several forms, including: fines, licence actions such as suspension and revocation, jail sentences and community services. The type of sanction applied to the drink driver and the way in which they are administered are two variables considered to be important in the development of effective drink driving countermeasures. Deterrence theory posits that drink driving sanctions will be effective in modifying road user behaviour to the extent that they are perceived as being certain, swiftly applied and severe (Ross, 1982).

In recent years the use of severe sanctions, as a means of reducing drink driving behaviour, has been questioned. In a review of deterrence based policy, Ross (1990) concluded that if the probability of detection and punishment was perceived by drink drivers as being low then the effect of penalty severity would be negligible. This proposition is supported by Homel (1986) who found that only when the perceived chances of arrest are high, does perceived penalty severity have a deterrent impact additional to that of arrest certainty. The fact that this was particularly the case among those road users who had already suffered legal punishment for drink driving, highlights the combined impact of arrest certainty and penalty severity on specific deterrence.

Homel (1988) concluded that the main predictor of deterrence was perceived risk of apprehension and recommended that drink driving strategies be based upon activities which increased the risk of detection and not legislation which increases the severity of penalties. This proposition is supported by Scandinavian research (Aberg, 1986; Assum,

1986) which found that enforcement strategies which emphasise the perceived probability of detection rather than the severity of punishment had a much greater impact on road user behaviour.

Nichols and Ross (1990) stated that the criminal justice system may hinder the effectiveness of penalty severity as a deterrence. The more severe the penalty administered the more legal representations usually required and this may, in turn, lead to a delay in receiving punishment and even uncertainty about receiving any punishment at all. This punishment delay may, in turn, compromise all other aspects of the deterrence threat (National Institute of Justice, 1984). Rothengatter (1990) also stated that the judicial response to traffic law enforcement was a largely ineffectual deterrent because, in the majority of cases, the penalties issued are paltry in comparison to the types of traffic offences committed.

Fines

There are only a few studies relating to the use of fines as drink driving sanctions but the available evidence does suggest that substantial fines can be an effective deterrent for alcohol impaired driving (Nichols & Ross, 1990). Fines also have the added benefit that they can provide necessary income for drink driving countermeasure, although strategies based solely on revenue raising can have negative social and political implications.

Current levels of fines for drink driving are, in real dollar terms, less than they were several decades ago (Nichols & Ross, 1990) and this probably reflects the increasing use of other types of sanctions. It is generally regarded that fines should correspond to the perceived severity of the crime committed. This has implications for increasing the severity of drink driving fines if such behaviour is to be portrayed as a serious and socially unacceptable activity (Ross, 1985). However, Ross (1988) stated that unless road users perceive the risk of apprehension and punishment for drink driving as being sufficiently high then there may be only minimal deterrence benefits to be gained by introducing more severe penalties.

It has also been recommended that some consideration be given to imposing fines which are proportional to the income of the offender so that all offenders are equally affected financially, by the imposition of a fine (Klette, 1983). A penalty system based upon this approach has been introduced in several Scandinavian countries where it has been found to be both effective and generally well accepted by the community (Votey & Shapiro, 1985).

Imprisonment

Imprisonment, often regarded as the most severe of drink driving sanctions, is an integral component of many deterrence based strategies targeted at the potential and convicted drink driver. The use of such sanctions is best typified by the experience in the United States of America where, in some States, first offenders can receive a mandatory two day jail sentence. It has been suggested that such sanctions provide the ultimate weapon for deterring repeat offender drink drivers, and may also provide needed 'shock value' for first time offenders. Howland (1988) has also suggested that imprisonment sanctions produce a gradual long-term effect, whereby the public comes to learn that drink driving is a serious and undesirable behaviour because of the severe penalties associated with it.

Some support for punishment severity, as it relates to the deterrent effect of jail sentences for more serious traffic offences, has been documented by Zador et al (1988). However, the effectiveness of imprisonment as a drink driving deterrent has been questioned by a

number of researchers (Homel, 1986; Voas, 1986; Nichol & Ross, 1990; Ross et al., 1990). Homel (1988) and Ross et al (1990) in similar methodological studies to that of Zador et al (1988) found no evidence that jail sentences had an impact on subsequent levels of recidivism.

In a review of the literature relating to legal sanctions for drink driving, Nichols and Ross (1990) indicated that there was little evidence to support the deterrent effectiveness of imprisonment and even referred to some evidence (Homel, 1988) which indicated that long periods of imprisonment increase, rather than decrease, the probability of reconviction for a drink driving offence. They concluded that policies based on increasing the certainty and swiftness of punishment have a greater deterrent impact than policies based upon severe punishments and highlighted research relating to the potential benefits and effectiveness of using licensing sanctions such as suspension and revocation.

Licence suspension

Licence suspension is often regarded as the 'teeth' of the driver-improvement system. Historically it has been, in effect, the ultimate sanction and often administered as the last resort in attempts to deal with high-risk or problem drivers (Simpson, 1990). In recent years it has become one of the principle sanctions for dealing with drink drivers and has been shown to be an effective countermeasure with a high deterrent effect (Ross, 1991).

Licence suspension is administered for two primary reasons: punishment and safety. As a punitive measure, licence suspension is assumed to work as both a specific and general deterrent (Simpson, 1990). As a specific deterrent, it is assumed to punish the drink driver (by removing a cherished privilege - driving) thereby, reducing the likelihood of subsequent drink driving behaviour, when the privilege is reinstated. As a general deterrent, the threat of licence suspension is believed to decrease the likelihood of drink driving because drivers are not prepared to risk the chance of losing the privilege of driving.

As a safety measure, the use of licence suspensions removes the high risk drink driver from the driving population, to prevent them from being a danger to themselves and to other road users. In addition, once the period of licence suspension is over, there is strong evidence of a reduction in traffic violations and accidents among convicted drivers (Mann et al., 1991).

Ross (1990) has explained this effect in terms of specific deterrence, stating that the experience of licence suspension leads to a modification in drink driving behaviour because convicted drivers avoid driving actions which may lead to further licence sanctions.

Ross (1991), in a review of legal sanctions indicated that only measure supported in the research literature as being truly effective in reforming the drink driver is licence deprivation. He further indicated that licence sanctions have a greater deterrence potential because when they are administratively applied they are more certain and swift than traditional sanctions which depend to a large degree on the criminal justice system for their application.

The evidence of the effectiveness of licensing sanctions has been well documented. Mann et al. (1991) undertook an examination of three years of post court appearance data for a group of drink driving offenders who had received some form of licence suspension. When

compared to a control group, the results for the licence suspension group showed a significant reduction in the total number of road accidents, for first and multiple offenders as well as a reduction in the number of repeat drink driving charges for first offenders.

Similar evidence of the effectiveness of licence suspension procedures has been documented by Blomberg et al. (1987) in a study of the experience with such sanctions in the American State of Wisconsin. They reported that between 1982 and 1985, when 100% of convicted drink drivers had their licences suspended for 90 days or more, there were significant reductions ill both the number of alcohol-related accidents and repeat offences of driving whilst impaired, among those drink drivers who had been convicted.

Licence suspension does not necessarily ensure compliance and it has been well established (Ross & Gonzales, 1988) that a large proportion of suspended drivers continue to drive during the suspension period. This problem is commonly identified by critics of licensing sanctions who argue that the inability of authorities to enforce such sanctions results in them being ineffective. Mann et al. (1991) argue against this proposition, highlighting compelling evidence that shows that although many individuals drive whilst under suspension, their rates of violation and accident involvement are substantially decreased either because they drive less, or more cautiously, or under conditions of lower risk.

This problem, in some jurisdictions, has led to the introduction of harsh sanctions aimed at reducing the percentage of suspended drink drivers who continue to drive. Such sanctions allow an offender's vehicle to be confiscated and, in the case of repeat offenders, even sold at public auction (Bailey, 1991). However, it is generally regarded that these sanctions are too severe and may actually result in negative social consequences (Mann et al., 1991) due to the effect on the offender’s family, financial hardship and possible unemployment.

It has also been argued that licence suspensions can place an excessive burden on drink driving offenders. However, Wells-Parker and Crosby (1988) found little evidence that excessive economic hardship is caused by such sanctions. Ross (1991) reported that suspended drivers did not, as a rule, find themselves rejected by family and friends, and were able to continue driving for work related purposes under special licence provisions allowed by the court. In addition, relatively few suspended drivers (11 %) claimed that the licence suspension had resulted in loss of employment.

Waller (1985) has argued that licence suspensions should be waived in favour of more constructive alternatives such as rehabilitation. However, Mann et al. (1991) have argued that whilst, under appropriate conditions, education and rehabilitation countermeasures may have road safety benefits (Mann et al., 1988; Wells-Parker et al., 1988), reduction or elimination of licence suspension as an incentive to enter such programs cannot be supported on road safety grounds due to the compelling evidence regarding the deterrence potential of licensing sanctions.

Roadside licence suspensions

The use of roadside licence suspensions, which allow police to immediately suspend the driving privileges of an alcohol impaired driver, has also been shown to have a number of benefits (Simpson, 1992). Firstly, the most important feature of this legislation is swiftness of punishment and by satisfying the principles of immediacy and certainty of punishment it has a strong deterrent potential. Secondly, it is extremely efficient, because it allows legal

sanctions to be administered by the police thus reducing the reliance on the criminal justice system for their application.

Vingilis et al. (1993) reported on the use of a 12-hour licence law introduced in the Canadian province of Ontario. This new law provided police with the authority to immediately suspend a driver's licence for 12 hours if the driver registered a 'warn' (0.05 to 0.08g/100ml) on an approved screening device or a reading above 0.05g/100ml on an evidentiary breath testing device. They stated that the primary purpose of the 12-hour licence suspension was to introduce some form of immediate punishment for drink driving behaviour without the time-consuming tasks associated with arrest procedures, nor the high costs associated with adjudication.

Few evaluations of the impact of roadside suspensions have been conducted. One carefully designed study, undertaken by Vingilis et al. (1988), was able to detect a small short-term reduction in alcohol related fatalities associated with the introduction of such a law.

However, low levels of enforcement and associated publicity may have reduced the deterrent impact. They concluded that roadside suspensions can significantly increase the immediacy and certainty of punishment and therefore have a high deterrence potential. However, they cautioned, that this may only be possible only when roadside suspensions are accompanied by high levels of enforcement and publicity.

3.5.2 Blood Alcohol Concentration

The adoption of per se laws has resulted in considerable debate regarding the level of alcohol intoxication at which a person's ability to drive should be considered impaired. Blood alcohol concentration (BAC) is usually measured in terms of grams of alcohol per 100 millilitres of blood. The maximum allowable BAC varies with jurisdiction and in Western countries the legal limit ranges from 0.02g/100ml to 0.10g/100ml. The variation in the quantitative definition of alcohol impairment adopted by different countries raises the question as to the appropriate BAC level which should be used to determine legally impaired driving.

A number of studies (Borkenstein et al., 1964; Mayhew, 1983; Got, 1988) have been undertaken to establish the relationship between blood alcohol level and the risk of being involved in an accident. The results of these studies indicated that accident risk was exponentially related to blood alcohol concentration with the accident risk at a BAC level of 0.05g/100ml found to be two times greater than that at a zero BAC level and the accident risk at 0.10g/100ml almost eight times greater than that a zero BAC level.

Much of the debate, regarding the appropriate BAC level to be used, centres around these derived relative risk curves. Legislators use this information, in conjunction with accident statistics, to determine a socially responsible and acceptable level of alcohol impaired risk.

There is however, increasing pressure in many countries to lower existing BAC limits. A comprehensive review undertaken by Moskowitz and Robinson (1988), of over 200 hundred studies on the effect of alcohol on performance, concluding that even very low BAC levels (less than 0.02g/100ml) can reduce driver performance.

The strongest evidence for adopting a lower BAC limit comes from studies which have examined the effect of legislative changes which have lowered existing BAC limits. Homel (1994) undertook an examination of the impact of lowering the BAC limit in New South

Wales, Australia, from 0.08 to 0.05. He found a significant 12% reduction in fatalities on Saturday nights and reductions, although not significant, ranging from 6.0% to 1.4% on other nights of the week.

Smith (1987), in an evaluation of the reduction to a 0.05 BAC limit in two Australian States (New South Wales and Queensland) found an overall reduction in fatalities in the order of 5%. The lower BAC limits also realised significant financial saving in both States as a result of reduced accident costs. In New South Wales the savings were $76 million ($59 million U.S.), with $32 million ($25 million U.S.) saved in Queensland (Federal Office of Road Safety, 1990).

There is also an increasing amount of evidence which suggests that the most important effect of a lower BAC limit may be a reduction in the incidence of drink driving at higher BAC levels. Smith (1988) found a 12 % reduction in the number of accidents involving drivers with BACs above 0.15 and an 8% reduction in the 0.08 to 0.15 BAC range. Brooks and Zaal (1992) undertook a review of the effect of the reduction to a 0.05 BAC limit (from 0.08) in the Australian Capital Territory. They found a 41% reduction in the incidence of drink driving at BAC levels above 0.15 as well as a reduction of approximately 90% in drink driving at BAC levels between 0.05 and 0.08.

The decision of whether or not to adopt lower BAC levels is partly determined in many countries by the current political and social climate. Legislators are often hesitant to introduce laws that may have a dramatic impact upon lifestyle especially in those countries where alcohol consumption is considered to be a normal and accepted social activity.

However, if the aim of drink driving legislation is to deter potential defenders, then the rationale for setting the legal BAC limit should conceptually be that which maximises deterrence (Snortum, 1988) and not that which allows, for social and political reasons, a certain level of acceptable risk taking behaviour.

Laurell (1991), in an examination of the experience with BAC legislation in Sweden (which now has a 0.02g/100ml legal limit), stated that any legal BAC limit can be defended with scientific support, and that the choice of a legal BAC limit is almost entirely a political issue.

He concluded questioning the practice of Governments which allow high legal alcohol limits and posed the important question of what amount of freedom is society willing to sacrifice for an unknown, or at least uncertain, number of saved lives.

3.5.3 Targeting High Risk Drivers

Research has indicated that there are certain categories of road users, especially the young and inexperienced, who face or pose a greater risk on the roads (Jonah, 1986). Mayhew (1983) has shown that young drivers have twice the accident risk of older drivers and when alcohol is present the risk factor is four times greater for young drivers at a BAC limit of 0.05 and eight times greater at a BAC limit of 0.08. The reasons for this high accident risk are complex with the range of influencing factors including inexperience, driving exposure, life-style, greater risk-taking behaviour and peer group interactions (Homel, 1988).

Lower BAC limits for young drivers.

As a result of the higher alcohol related accident risk of young drivers there have been increasing moves in some countries (particularly Australia and North America) to legislate for lower legal BAC limits for young drivers. Lower BAC limits allow the accident risk for young drivers to approximately equate to the risk of older, more experienced, drivers at existing legal BAC limits. In Australia, most States and Territories have legislated for a nominal zero BAC limit for young drivers during their first year of licensure. Several Australian Police authorities have indicated that they strictly enforce the zero limit (Moloney, 1993), however, due to practical and technical difficulties the actual detection limit used in most jurisdictions is 0.02.

Maisey (1984) analysed the impact of legislation in the Australian State of Western Australia which introduced a BAC limit of 0.02 for provisional licence holders. He found a 17% reduction in the number of drivers under 18 years of age involved in night-time casualty accidents. Smith (1986) evaluated the effect of the introduction of similar legislation in a number of other Australian States. He found a reduction in the number of less severe casualty accidents, but no reduction in the number of drivers admitted to hospital. Although the results were positive, Smith (1986) concluded that due to various methodological problems, lower BAC limits should be regarded as a promising, rather than a proven, countermeasure against alcohol related accidents among young drivers.

There have also been attempts to evaluate the impact of lower BAC limits in Victoria, Australia (Haque & Cameron, 1989) and in the American State of Maine (Hingson et al., 1987). The results of these studies, although positive, failed to reach any definite conclusion regarding benefits, due mainly to an inability to produce a study design statistically powerful enough to detect the expected level of effect.

Lower BAC limits for other groups of drivers

In Australia, drivers of heavy vehicles and public passenger vehicles, such as buses and taxis are also subjected to lower legal BAC limits. This legislation was introduced not because such drivers are over represented in alcohol-related accidents but because their jobs have special risks and responsibilities (Makeham, 1993). In the case of heavy vehicles, the greater size, weight and rigidity, means that there is a greater likelihood that they will cause injuries or fatalities to other motorists when they are involved in an accident.

Australian road fatality statistics (FORS, 1992) clearly show that the small minority of heavy vehicle drivers who drink and drive have a relatively high risk of causing a fatal accident. Even at BAC readings below 0.05 they are much more likely than sober drivers to be responsible for an accident.

Raising the legal drinking age

Raising the legal drinking age has also been identified as one possible means of reducing the incidence of alcohol related fatalities among young drivers. This type of legislation is common in the United States of America where, as a result of a high proportion of accidents involving young drivers who were impaired by alcohol, 50 States, in the mid 1980s, raised the legal drinking age to 21 (Sweedler & Stewart, 1992). The common use of this legislation may also reflect the large number of American States that have not adopted per se legislation, making the lowering of BAC limits for young drivers a non-proposition.

The results of the U.S. legislation were dramatic. In 1980, the percentage of teenage driver fatalities in highway accidents, where the BAC reading was 0.10 or higher, was 53%. By 1987, that percentage had been reduced by almost half, dropping to a level of 28% (Institute for Highway Safety, 1990). Further evidence of the effectiveness of these laws comes from the National Highway Traffic Centre which has estimated that such legislation has saved more than 12,000 lives since 1975 (Sweedler & Stewart, 1992).

Graduated licences for novice drivers

Another possible strategy is the use of graduated licences, which combine a range of restrictions so that novice driving takes place in less dangerous circumstances until the young driver has had the opportunity to gain experience (Hingson & Howland, 1986). Restrictions are gradually lifted after the successful completion of the learning period. Williams (1986) stated that any structured licensing system which places controls on the manner in which driving skills are learnt and the level of initial driving exposure must lead to road safety benefits, given that inexperience and driving exposure are two of the key factors which influence accident rates among young drivers.

Graduated licence schemes have been implemented in New Zealand and in most Australian States and Territories. The graduated licence scheme may include restrictions on the number and age of passengers a novice driver is allowed to carry (in order to reduce possible peer pressure to engage in risk taking behaviour), night-time curfews, lowered legal BAC limits, speed restrictions, compulsory seat belt use and a special licence plate for probationary drivers (Hingson & Howland, 1986).

Evaluation of the graduated licence program in New Zealand has shown a dramatic reduction in the number of accidents involving young drivers between the age of 15 and 17 years (the main target of the program). Whilst accidents resulting in injury have dropped by approximately 12% overall in New Zealand, accidents involving young drivers have dropped by 40% (from an average of 120 per month to about 70 per month (Insurance Bureau of Canada, 1991).

3.5.4 Rehabilitation Programs

Rehabilitation programs are commonly regarded as necessary for drink drivers (Wieczorek, 1992) due to the high rate of alcohol abuse and/or dependence amongst this group (Vingilis, 1983; Miller & Windle, 1990). The objective of such programs is to reduce the incidence of drinking and driving, by influencing the attitudes of offenders and hence their behaviour.

This is typically achieved by educating offenders about the way in which alcohol affects the body and impairs driving ability and by encouraging them to examine their drinking behaviour and consider the need for change. Courses also aim to motivate and assist offenders to separate drinking and driving and increase awareness of how to resist social and group pressures to undertake such behaviour.

In many Western countries, insisting that the drink driver attend some form of rehabilitation program, as a condition of re-licensing and in some cases as a condition of sentencing, is becoming an increasingly popular measure (Barthels, 1991). As a result, efforts to evaluate the effectiveness of rehabilitation programs are often confounded by the deterrent effect of other legal sanctions (Lauer, 1988). It is often difficult to determine which component of the legal sanctions had the greatest impact on drink driving behaviour.

Siegel (1990) has stated that the evidence of the effectiveness of short term treatment strategies, such as rehabilitations programs, is inconclusive. The majority of studies supporting the benefits of rehabilitation programs focus on evidence showing reduced recidivism rates for convicted drink driving offenders (Perrine et al., 1989; Nickel, 1990).

The results from many of these studies suggest that the reduction in recidivism rates is due primarily to the fact that offenders gain a greater understanding of the problems of drink driving and learn new strategies to deal with their drink driving behaviour. A number of other studies have concluded (Spoerer et al., 1987; Wieczorek, 1992) that the effectiveness of rehabilitation programs is, to a large extent, dependent upon the individual skills of the course leader, and the relationship of the leader with course participants and not on the information content of the program.

A number of researchers have questioned the effectiveness of rehabilitation programs because they do not provide meaningful and consequential sanctions to the drink driver. Lauer (1988) stated that because rehabilitation programs provide no real level of deterrence their resulting impact on subsequent drink driving behaviour is minimal. A similar view has also been expressed by Arthur (1989) who found no evidence of reduced recidivism amongst a group of offenders who had attended a rehabilitation program. In a follow-up survey, 86% of respondents thought that the rehabilitation program had some value but indicated that changes in their subsequent drink driving behaviour were primarily the result of the threat of other more formal legal sanctions and not the direct result of the rehabilitation program.

Perhaps the strongest evidence for the effectiveness of rehabilitation programs and their positive effect on reducing recidivism rates comes from studies examining the use these programs as a supplement to licence suspensions. Tashima and Peck (1986) found that, for first time offenders, a combination of rehabilitation and licence restrictions had the strongest impact on recidivism rates and the number of alcohol related accidents than did either of the two measures alone. These findings were explained to be a result of the rehabilitation course providing offenders with a greater understanding of the problems caused by alcohol and drink driving as well as the reasons and necessity for having received licence sanctions.

3.6 MODIFYING THE SOCIAL ENVIRONMENT

Mosher (1985) has argued, that if drinking and driving is to be prevented, authorities must do more than "threaten, cajole or persuade individuals to act more responsibly". He emphasized that enforcement based strategies, aimed at modifying drink driving behaviour, can provide some but not all of the answers to the problem and should therefore be developed in conjunction with other prevention strategies which focus on the environment and the role of the 'agents' of drink driving, namely alcohol and the automobile.

3.6.1 Alcohol Control Policies

There are a range of strategies, identified in the literature, designed to modify the social environment in which alcohol is consumed. Apart from initiatives directed specifically at drink driving, developments in alcohol policy aimed at reducing general levels of consumption have also been shown to have the potential to reduce the incidence of alcohol impaired driving. Evidence that the incidence of alcohol-related problems, including drink driving, is related to the level of per capita alcohol consumption has been provided by Kendell (1984). In relation to drink driving, he found a significant correlation (r=0.7)

between per capita consumption and the number of drink driving convictions during the years from 1970 to 1982. These results suggest that it may be possible to reduce the level of drink driving by using alcohol control policies promoting lower consumption. The type of policies, which have been examined, include restrictions on the availability of alcohol and the use of excise duties to increase the cost of alcohol in real terms.

Alcohol availability

In a review of recent literature relating to the alcohol control policies, Homel and Wilson (1988) indicated that the majority of research points to the sizeable impact that the increased availability or ease of access to alcohol can have on drink driving and traffic accidents involving alcohol. They cautioned, that strategies designed to reduce the availability of alcohol have significant social, economic and political implications and found that most of the research in the area of alcohol control policy, fell short of demanding drastic policy changes, preferring rather to highlight the need for additional research to establish causal relationships. However, Homel and Wilson (1988) stated that the strong evidence linking alcohol availability to traffic accidents is sufficiently compelling to demand a response from Governments.

The evidence relating to alcohol availability typically focuses on the negative impact of increased alcohol consumption which is usually the direct result of legislative changes. Holder and Blose (1986) were able to demonstrate an increase in alcohol related traffic accidents resulting from the introduction of new laws that increased the availability of distilled spirits in the American State of North Carolina. Wagenaar (1984) also found a significant positive relationship between the sale and distribution of certain types of alcoholic beverages in a particular month and alcohol related traffic accidents in the following month.

Smith (1987) found that legislation increasing the trading hours that licensed drinking establishments were allowed to sell alcohol led, not only to increased consumption, but also resulted in an increase in the number of alcohol related accidents. In a study examining the relationship between traffic accidents in Australia and the days and time of sale of alcohol he found that legislation allowing longer opening hours and later closing times resulted in an increase in the number of traffic accident casualties.

In an additional study, Smith (1987) examined the impact, in New South Wales, Australia, of new legislation allowing Sunday hotel trading. He found that there was an overall increase in the number of traffic accidents occurring on Sunday and concluded that the new law was the major factor responsible for the sizeable increase in accidents resulting in both injuries and fatalities.

Restricting and regulating the number of locations where alcohol may be purchased is one further means of reducing consumption. Mosher (1985) argues that locations where alcohol is sold which may lead to an increase in drinking and driving such as hotels, sport stadiums and service stations, should be strictly regulated. He also suggests that each community should be allowed to determine appropriate densities of outlets and their alcohol availability structure. The use of such policies and their effectiveness is best demonstrated by the Scandinavian experience.

In most Scandinavian countries there is a State monopoly system on the distribution and sale of alcoholic beverages. Beverages with a high alcohol content, including beer (over 4.7% vol), wine and spirits (over 21% vol), may only be purchased in State alcohol outlets.

These policies have been shown to impact not only on consumption but also on the level of drink driving (Pikkarainen, 1990). In Finland, communities have also been given the right not to allow off-premise outlets in their region. Pikkarainen (1990) stated that this power has been used by many communities to reduce the number of outlets authorized to sell medium beer only.

Alcohol taxation

Increasing the level of taxation on alcohol, which has the effect of increasing the cost to the consumer and reducing consumption, has also been identified as another possible means of reducing alcohol related traffic accidents. Cook (1981) was able to clearly demonstrate that increasing the tax rates on alcohol in the United States of America led to a significant reduction in the number of road traffic accidents. Using econometric methods to study State tax changes occurring between 1960 and 1975, Cook (1981) estimated that the effects of a 20% increase in the alcoholic beverage price (due to taxation) would be likely to be measured in terms of thousands of lives saved per year and billions of dollars saved in medical and related expenses.

Further evidence for the benefits of raising the level of taxation on alcohol have been documented by Saffer and Grossman (1987). They estimated that a doubling of federal tax, on beer alone, would reduce the number of road accident fatalities by more than 25% among road users aged between 18 and 20 and by almost 20% for road users in adjacent age groups. In a review of this evidence, Ross (1990) concluded that such accomplishments have seldom been credibly claimed on policies based on deterrence principles alone.

Opponents of proposals to initiate policy changes which increase taxation levels on alcohol, including the powerful and influential alcohol manufacturers have identified the negative economic consequences of increasing the cost of alcohol to the consumer. Riley (1991) has suggested that there are alternatives to reducing the level of alcohol consumed without using politically unpopular fiscal measures to influence prices and to discourage drinking.

The promotion of the consumption of low alcohol beverages is by far the most popular of these alternative methods. Riley (1991) has suggested that if the behaviour of drinkers remained otherwise unchanged, reductions in the alcohol content of beverages would lead to lower BAC levels even if the number of drinks consumed stayed constant. He stated that instead of relying on behavioural changes, which can be difficult to achieve, the lower alcohol content should be relied upon to reduce the actual amount of alcohol consumed.

Persuading drinkers to switch to low alcohol beverages can be achieved through pricing mechanisms which use alcohol content as a determinate for the level of taxation to be placed on different alcohol products. Moreover, making high alcohol products more expensive would encourage manufacturers to reduce the alcohol content of their products to attract a lower taxation rate and so maintain or improve price competitiveness (Riley, 1991).

The use of this form of alcohol taxation is becoming increasingly popular and is used in number of countries including most of those in Scandinavia. In Norway, the rate of taxation on 'strong beer' is about five times that on 'light' beer. In Australia, the introduction of lower legal blood alcohol limits together with increased enforcement activities has coincided with an increase in the market share of low alcohol beer. There is

also some anecdotal evidence suggesting that mid-range low alcohol beer is appealing to people who would otherwise drink regular strength beer (Makeham, 1993). As a result, there is increasing pressure on the Australian Government to make these beverages even more attractive by using taxation measures to lower the prices.

Advertising

Legislation, targeted at regulating the use of alcohol advertising may also have the potential to reduce the level of alcohol consumption and hence the number of alcohol related traffic accidents (Homel & Wilson, 1987). Mosher (1985) has stated that advertising provides a powerful tool for normalising drinking behaviour and the fact that its use is so prevalent in modern society is a good indicator of its effectiveness in maintaining or increasing alcohol consumption.

Elliott (1992) suggests that the advertising of alcoholic beverages only serves to reinforce some undesirable images of alcohol in modern society such as 'essential to a good time', 'essential for friendship' or 'essential to showing prowess'. He stated that, over time, the nexus between excessive alcohol consumption and social problems needs to be broken and that achieving this through regulation and legislative controls would assist in eventually changing undesirable norms in relation to alcohol.

Atkin (1988) has stated that, given the effect of advertising on drinking behaviour, it makes intuitive sense that laws regulating the amount and type of alcohol advertising, or even policies encouraging the use of counter-advertising strategies, may lead to reduction in overall alcohol consumption. One further, simple measure that may also result in reduced consumption is the introduction of legislation requiring all manufacturers to provide health warning messages (similar to those used with tobacco products) on all advertising material and alcohol products (Pikkarainen, 1990).

3.6.2 Server Intervention Programs

Server intervention programs which place a greater emphasis on those who sell and serve alcohol to have greater control over the environment in which alcohol is consumed, have also been identified as one additional means of reducing the level of drink driving behaviour. These programs, which originated in the United States of America, have now been adopted in a number of countries including Australia, where several experimental programs are presently being trialed (Homel et al, 1988).

The underlying principle of server intervention programs is the modification of the environmental and social conditions which precede drink driving events (Mosher, 1983). This is achieved by educating those who sell and serve alcohol about their responsibilities towards their patrons and may include aspects such as, ways in which to reduce the risk of intoxication among patrons, methods to recognise and deal with patrons who are intoxicated, and the problems and social consequences of excessive consumption. Saltz (1985) stated that in broad terms the goal of server intervention is to create an environment for drinking that would:

- reduce the risk of intoxication; and
- reduce the risk that intoxicated drivers will harm themselves or others.

The emergence of server intervention programs in the United States of America, and to a lesser degree, Canada has resulted primarily from successful lawsuits brought against licensees by individuals involved in road accidents after being served alcohol to or past the point of intoxication (Impellizzeri, 1990). In some jurisdictions specific legislation linked to licensing provisions ensure that server intervention programs are implemented. However, in other jurisdictions there has been an increase in the voluntary implementation of such programs. Riley (1991) suggests that factors such as the moral obligation of the server to the patron, increasing community and Government pressure, the possible reduction in the level of drunken and disruptive behaviour, and the potential to increase sales and reputation due to an increase in the number of more moderate drinkers, are the main reasons for the increase in the level of voluntary implementation of server intervention programs.

The available evidence, though limited, suggests that server intervention programs generally result in positive reactions from patrons and can have a marked decline in the proportion of customers becoming legally intoxicated (Saltz, 1985). Impellizzeri (1990), in an evaluation of the effectiveness of a specially designed server intervention program for use at a number of sporting venues in several American States, found a decrease in sales and consumption of alcohol, an increase in overall food and non-alcoholic beverage sales and an increase in the number of people attending such venues. Similar results, showing substantial decreases in both alcohol consumption and levels of alcohol intoxication, were found (Carlson, 1990) in an evaluation of several Canadian server intervention programs.

One final benefit of such programs may be the role which they play in reducing the number of alcohol impaired pedestrians who are involved in traffic accidents (Parliament of NSW Joint Standing Committee on Road Safety, 1992). Alcohol impaired pedestrians pose a particular road safety problem because their behaviour is often unpredictable, their reactions and movements are slow, and they usually fail to make use of appropriate pedestrian crossing facilities.

Unfortunately, none the above studies of server intervention programs provided specific evidence relating to the impact that such programs have on reducing the number of alcohol related traffic accidents. However, the underlying implication is that any countermeasure that reduces alcohol consumption, and hence the level of alcohol impairment, will indirectly lead to these types of road safety benefits.

3.6.3 Public Education Programs

The main objective of drink driving education programs is to dissuade potential drinking drivers from engaging in such behaviour. Underlying the majority of such programs seems to be the assumption, as in classical deterrence theory, of a 'rational being' in which knowledge is viewed as fundamental to the decision making process of behavioural choice (Mann et al., 1988). Thus, the knowledge of drink driving issues is perceived as an important component in appropriate driving behaviour formation or behavioural change (Vingilis, 1990).

The underlying philosophy of drink driving education programs is that once an individual becomes aware of the dangers involved in drinking and driving, they will be less likely to combine the two behaviours. Vingilis (1990) stated that the knowledge of the issues and consequences of drink driving is a necessity, but most likely not a sufficient condition for the formation of appropriate driving behaviour. He points to the evidence relating to the effectiveness of drink driving education programs, whether they be driver or school based

programs, which shows that these programs have the potential to change knowledge, occasionally attitudes, but rarely behaviour.

The majority of evaluations relating to the effectiveness of education programs support the conclusion by Vingilis (1990) that changes in drink driving behaviour are uncommon and in the few studies where small effects have been documented they are usually only short term (Wright, 1990). In a review of school based education programs, Mann et al. (1986) concluded that the main benefits of such programs appear to be the resultant increase in awareness of the problems associated with drink driving and a better understanding of methods of resisting social and group pressures to undertake such behaviour.

3.6.4 Public and Personal Breath Testing Devices

The introduction of per se legislation which specifies quite stringent legal BAC limits has meant that there is a need to assist and educate drivers to stay within the law (Makeham, 1993). Educating drivers about their expected level of intoxication in relation to alcohol consumed, is normally undertaken through the use of education programs and publicity campaigns. One further solution, which is increasing in popularity, is the promotion of the use of both public and personal alcohol breath testing devices.

However, encouraging the public to test their own BAC level has generated a certain amount of controversy. Opponents of such a proposition have cited a number of problems including, the difficulties experienced by intoxicated persons in attempting to measure their own BAC level due to physical impairment, a false sense of driver security because measurements in the late-absorption phase might be much lower than those in the post-absorption phase and the possibility of encouraging competitive drinking (Stamer, 1985). Proponents of these devices have argued that it is not ethical to impose a law and give drivers no accurate means of determining whether they may be breaking it (Williams, 1992). Regardless of the controversy surrounding self testing devices, the increased range and availability of such devices has resulted in their increased popularity and more widespread use.

Public (coin operated) breath testing devices

Elliott (1992) has stated that the majority of the public often believes that the Government has a responsibility to ensure that drinkers are provided with a means of determining whether they would be breaking the law by driving. He suggests that the introduction of legislation compelling outlets, which serve alcohol, to provide breath testing devices may be one possible solution. Elliott (1992) indicates that reliable coin operated devices do exist which could be justified not only in terms of cost but also due to their ability to provide drinkers with impairment feedback.

In Australia, the use of coin operated breath testing devices is becoming increasingly popular and the Federal Government actively encourages and assists local manufacturers to develop and improve breath testing devices. However, no specific legislation relating to the compulsory use of such devices, in establishments which serve alcohol, has been introduced. Homel (1992) has suggested that such devices may be one way of reducing consumption among some patrons, especially with random breath testing as an incentive.

Mackiewicz (1988), in a formative evaluation of coin operated breath testing devices in Victoria, Australia, has identified a number of benefits associated with the use of such devices. Breath testing devices were placed in thirty establishments for a six month trial

period during which time usage and interview data was collected. The results indicated that the devices received a great deal of use with 64% of the recorded BAC readings over the legal 0.05 limit. Acceptance of these devices by patrons and staff was very high with the level of misuse reported (i.e. for drinking competitions) quite low. The devices were also considered to have a high educative value by allowing drinkers to relate drinking rates and the amount of alcohol consumed to precise BAC levels. However, the most significant result of the evaluation was that a third of all users who registered a reading over the legal BAC limit changed their mind about driving. This last result shows the potential of breath testing devices to change the driving intentions of legally impaired patrons.

Personal breath testing devices

The use of coin-operated breath testing devices may be a solution for those drivers who drink at licensed establishments but when drinking occurs at locations where such devices are not available some other form of self assessment is required. The issue of providing the public with some form of reliable, portable method of self assessment has been addressed by providing predictive charts and calculators, education and publicity material and "personal breath testing devices.

Predictive charts have had some reported success, particularly when used in conjunction with education material (Worden et al., 1989). Publicity campaigns have also been shown (Riley, 1991) to increase general awareness regarding the relationship between drinking rates, alcohol consumption and BAC levels. However, Williams (1992) indicates that these methods are generally too inaccurate to be credible and suggests that the only reliable method of self assessment is through the use of a personal breath testing device.

Williams (1992) has stated that the major problem with personal breath testing devices is cost and indicates that in order to be priced low enough for general public sales, such devices have generally been based on poor alcohol detection technology and lack of control. The use of such devices is also hard to evaluate because those drivers who would purchase them are likely to be more responsible drivers.

Williams (1992) has reported on one new self testing device that is reliable, easy to use and reasonably priced. The device called the 'Alcoprobe' is similar in shape, size and appearance to a medical thermometer. This device is also used in the same way as a thermometer, providing an accurate impairment measurement based upon the alcohol level in saliva. It is hoped that the availability of the 'Alcoprobe' will increase the level of self assessment for alcohol impairment and thus have similar benefits to those reported for coin operated breath testing devices (Williams, 1992).

3.7 MODIFYING THE PHYSICAL ENVIRONMENT

Strategies aimed at modifying the physical environment in which alcohol is consumed have been highlighted as a possible means of reducing the incidence of drink driving and the total number of alcohol related accidents and resulting injuries. The underlying philosophy of such strategies is that if all other countermeasures fail to stop or deter the drink driver then controlling the 'agents' of alcohol related accidents, namely the vehicle and the roadside environment, may lead to accident reductions. Interest in this area of research has mainly focused on possible improvements to the physical roadside environment and methods of physically preventing a legally intoxicated driver from starting the vehicle.

3.7.1 The Roadside Environment

Several researchers (Johnston, 1980, 1983; Armour et al., 1989) have identified a number of possible methods of modifying the physical roadside environment, so that an alcohol impaired driver is less likely to have an accident, or is less likely to be injured if an accident situation occurs. Johnston (1980), in an analysis of accident related accidents in Victoria, Australia, found that alcohol was involved in a high proportion of single vehicle accidents and that a significant number occurred on curved sections of road. He suggested that improvements to the roadside environment, such as better roadway delineation, might be one possible solution for reducing the frequency of these types of accidents.

A second major finding in the analysis undertaken by Johnston (1980) was that almost 75% of all traffic accidents, in which a vehicle struck a fixed object, such as a utility pole or a tree, involved a driver with some level of alcohol impairment. He suggested that action to remove, relocate or provide guardrails in front of such objects may also help to reduce the high number of these alcohol related accidents. Programs aimed at identifying and removing potential roadside hazards, such as unsealed shoulders and trees close to the traffic, have been implemented (Armour et al., 1989 as cited in Homel, 1990) but as yet no evaluation of their effectiveness have been undertaken.

3.7.2 Alcohol Ignition Interlocks

One countermeasure targeted at the recidivist drink driver, which has considerable potential, is the compulsory installation of alcohol ignition interlocks into the vehicles of drivers found guilty of multiple and high BAC category offences (Makeham, 1993). Such schemes have been introduced in a number of jurisdictions in the United States of America where they have been shown to be an effective means of reducing recidivism rates and the level of drink driving behaviour of convicted offenders (Morse & Elliott, 1990).

The alcohol ignition interlock is a technical device which is attached to a vehicle's ignition system and prevents the operator from starting the vehicle if their BAC level exceeds a predetermined threshold. Before starting the vehicle, the driver is required to provide a breath sample by blowing into an alcohol-sensing device that determines the BAC level of the driver and compares the results with the pre-set limit. A BAC level lower than the specified limit allows the driver to start the vehicle.

Popkin et al. (1992) has stated that the ignition interlock is unique among countermeasures because it targets the vehicle as a point of intervention. Because the interlock bypasses any decision-making requirement, the driver is prevented from operating the vehicle regardless of any personality or situational factors that might influence that decision. The possibility of incapacitating the vehicle so that the drink driver cannot operate it also has intuitive appeal given the difficulties in educating or coercing drinking drivers to change their behaviour and with changing the social environment.

Morse and Elliott (1990) reported significantly lower rearrest rates for drivers with a ignition interlock fitted to their vehicle (3.4%) when compared to a control group who had received licence revocation sanctions (9.8%). They concluded that the 65% difference in recidivism rates for the two groups suggest that while sanctions are still in effect, the alcohol interlock is an extremely effective means of reducing drink driving behaviour. The EMT Group (1990) in an evaluation undertaken in the American State of California reported similar lower rearrest rates for those drink driving offenders with an ignition interlock fitted to their vehicle (3.9%) when compared to a matched control group (5.9%).

Reductions in recidivism rates were also reported by Popkin et al. (1992) in an evaluation of the ignition interlock program in the American State of North Carolina. The evaluation compared three groups of drivers who had received different types of sanctions, and included: those with an ignition interlock fitted to their vehicle, those who had their licence revoked and those who were granted a conditional licence. The results indicated that the recidivism rate for the interlock group was 42% lower than the corresponding rate for the licence revocation group and 52% lower than the rate for the conditional licensure group. They concluded that the use of ignition interlocks should be encouraged in all jurisdictions due to the greater potential to reduce recidivism in drink drivers -when compared to more traditional, court imposed sanctions.

Problems with alcohol interlock devices.

The main problem with the effectiveness of interlock devices as a means of deterring the drink driving behaviour of convicted offenders is the ease with which such drivers can use a vehicle other than the one in which the interlock is installed. Jones (1992) suggested that this may be a significant problem, finding that 40% of drivers in one interlock program, who were involved in a reported accident, were not driving the vehicle stipulated by the courts.

One additional problem is that alcohol interlock devices are not foolproof. Marques and Voas (1992) indicate that it is relatively easy to construct a cotton or paper filter to trap alcohol before the sensor, to concoct a non-human or stored source of air to deliver to the sensor (e.g. with a balloon), or to enlist the cooperation of another person at curbside to blow into the device. They conclude that in all these cases, driver motivation is obviously not yet out of the causality loop since anyone willing to drive whilst legally impaired can still do so, with or without an interlock device.

In addition to compliance factors there are also technical problems with alcohol interlock devices. The normal vehicle environment (hot/cold, dusty, vibrations etc) is hostile to precise chemical analysis even with the best of equipment and factors such as alcohol vapour being absorbed by dust or condensed by cold can affect the accuracy of impairment measurements (Marques & Voas, 1992). In addition, when technical problems do occur, the time interval between notification, identification and correction of the problem, may provide drivers with an opportunity to use their vehicle whilst legally impaired.

As the use of alcohol interlocks becomes more widespread, Governments are placing increasingly stringent requirements on manufacturers to produce more reliable devices that are less susceptible to the methods drink drivers use to conceal alcohol impairment (Collier & Comeau, 1992). Popkin et al. (1992) suggest that the results of increased Government pressure appear to be encouraging, with the development of new devices which, although more expensive, show promise of providing an effective means of preventing further drink driving by convicted offenders.

3.7.3 Vehicle Monitoring Devices

A less costly alternative to the use of performance or alcohol ignition interlocks is the fitment of simple vehicle monitoring device which is able to record information relating to the time and date of vehicle use. Frank (1992) suggests that such a device may be used to monitor and limit the actual amount of driving undertaken by convicted drink drivers and may have a potential use in jurisdictions where convicted offenders are allowed, by the court, to use their vehicle for work related purposes.

Voas (1992) has reported on the use of vehicle monitoring devices in the American State of Ohio. He found that the fitment of such devices reduced the level of illegal driving during non-working hours. He reported that offenders were modifying their behaviour due to the knowledge that they would be required to explain any unauthorised driving. Offenders also believed that a breach of the imposed driving restrictions would more than likely result in more severe penalties. He concluded that the monitoring device appeared to have led to the establishment ora specific driving pattern and reinforced compliant behaviour.

3.7.4 Performance Interlocks

Performance interlocks are similar in operation to alcohol interlocks but differ in relation to the way in which driver impairment is determined. Instead of requiring the driver to provide a breath sample to determine the level of impairment the driver must instead successfully complete, within a set time limit, a specially designed psychomotor task which is sensitive to small variations in performance impairment (Stamer, 1985).

Performance interlocks initially attracted interest as a possible means of controlling the impaired driver because they are less susceptible to methods of concealing impairment and, in addition, are potentially sensitive to reduced impairment, no matter what its cause. Frank (1992) indicated that ability of such devices to detect any form of impairment meant that they could be used to control not only alcohol impairment, but impairment caused by other drugs, fatigue or disease.

However, Frank (1992) indicated that research carried out on alcohol impaired subjects using these performance devices resulted in too much variability in performance, both between and within individuals, and produced an unacceptable number of errors (i.e. false positives or false negatives). He concluded that, although such devices were partially effective in preventing the operation of a vehicle by an impaired driver, they would require a great deal of refinement and testing before being made operational.

3.7.5 Summary

Alcohol is a drug which effects the central nervous system and its use by motorists can lead to significant road safety problems because it impairs driving performance. Driving whilst under the influence of alcohol is regarded as being the single largest cause of road accident fatalities. It has been estimated that over 30% of all road fatalities and serious injuries involve at least one driver who was impaired by alcohol. The magnitude of the problem is evident from estimates relating to the number of alcohol impaired drivers in the traffic stream which range from between 0.2% to 8%.

In many countries the control of drink driving behaviour relies heavily on the criminal justice system. Traditional drink driving countermeasure place the emphasis on the individual road user to separate drinking and driving activities. Education and publicity have ensured that the combination of drinking and driving is regarded by society as being an unacceptable form of road user behaviour. However, the use of enforcement is generally regarded as being the most effective means of deterring the level of drink driving behaviour.

The effectiveness of drink driving enforcement is dependent on the legislation which governs the manner in which police can target and deter drink driving behaviour. Legislation needs to be structured in such a way so as to allow for the development of

enforcement strategies which can generate a high level of perceived apprehension risk. The most effective form of legislation is that which allows police to test motorists for alcohol impairment based upon the actual level of alcohol consumed. Legislation based upon behavioural impairment, in which the emphasis is placed on the police to prove that driving behaviour is significantly impaired, has only a minimal impact on reducing the level of drink driving behaviour.

The power of police to stop motorists is also an important factor which can determine the effectiveness of drink driving enforcement operations. Legislation allowing police to stop and test drivers only on the basis of obvious behavioural impairment has been shown to have only a minimal deterrent effect. The use of roadblock or sobriety checkpoints which allow police to stop drivers regardless of whether signs of alcohol impairment are present can be an effective means of deterring drink driving behaviour. However, the decision to administer a test is still dependent on the subjective judgement of the police and the fact that a large number of impaired drivers (up to 50%) can avoid being tested reduces the level of perceived apprehension risk.

The most effective legislation is that which allows police to randomly stop and test any driver for alcohol impairment. These type of enforcement operations, commonly referred to as random breath testing, have the greatest potential to deter drink driving behaviour and reduce the level of alcohol related fatalities and injuries. To maximise the benefits of such enforcement operations it is essential that a large proportion of drivers are stopped and ALL are tested for alcohol impairment. Enforcement operations should also be highly visible, accompanied by sustained high levels of publicity, rotated among numerous FIXED locations and undertaken for no longer than a one hour period at each location. These requirements maximise the perceived risk of apprehension by creating an awareness among road users that enforcement is highly active and can be encountered at any time and any place.

The most effective random breath testing operations are those which are highly intensive and maintained over a long period of time. These type of enforcement operations are cost effective in terms of their accident reduction potential but are extremely resource intensive. The strategic deployment of less intensive random breath testing operations may provide a more cost effective enforcement option, however, the accident reduction potential may be somewhat reduced. Examples of strategic deployment operations include the use of periodic, intensive enforcement 'blitzes' and the use of targeted enforcement programs which involve less intensive activities during low alcohol hours (the focus is on enforcement visibility) and more intensive activities during high alcohol hours (the focus is on apprehension).

The use of publicity can significantly increase the effectiveness of drink driving enforcement operations. Publicity is most effective when it is designed specifically to raise awareness of the likelihood and inevitability of apprehension as well as the severe consequences in terms of both punishment and increased accident risk. Publicity as a stand alone measure can initially bring about substantial reductions in drink driving behaviour, however, such benefits are usually only short term.

Passive alcohol sensors can also increase the efficiency of roadside testing operations. They provide a quick and relatively effective means of screening road users for the presence of alcohol. The use of these devices can ensure that the delay to motorists, due to roadside stopping and testing procedures, is minimal. The reduction in roadside stopping time also increases the capacity of police to screen a greater proportion of drivers. These

devices are relatively inexpensive and many existing alcohol screening devices can be used as both a passive and active alcohol sensor.

There are a range of legal sanctions that can be administered to the drink driver. These sanctions are usually quite severe, reflecting the low social acceptability and high risk nature of drink driving behaviour. However, the most severe drink driving sanction, that of imprisonment, has been found to have only a minimal impact on recidivism rates. The most effective drink driving sanction is the combined use of fines and licence actions such as suspension and revocation. The deterrence potential of licence actions has been well documented and they not only provide a means of punishing offenders but can also improve the level of road safety by removing potentially high risk drivers from the traffic stream.

There can often be long delays between the time a drink driving offender is apprehended and the imposition of licensing sanctions by the courts. The use of roadside licence suspensions provides a means of significantly increasing the immediacy and certainty of punishment. The particular use of such sanctions for drivers apprehended with relatively low blood alcohol levels (up to 0.02g/100ml above the legal limit) has the potential to reduce the time-consuming tasks associated with arrest procedures as well as the high costs associated with adjudication.

The introduction of special legislation for more high risk road users can be an effective means of reducing the level of alcohol related accidents. Young drivers are a particular group of road users that have been shown to have a significantly higher alcohol related accident risk than that of older drivers (> 25). The introduction of lower blood alcohol concentration (BAC) limits for young drivers during their first three years of licensure has been shown to be an effective drink driving countermeasure. Lower BAC limits for road users who have a higher traffic exposure as well as special risks and responsibilities (drivers of heavy vehicles and public passenger vehicles) may also warrant further consideration.

The fitment of alcohol ignition interlocks in the vehicles of recidivist drink drivers is one countermeasure that has considerable potential. The use of these devices has been shown to be an extremely effective means of reducing the level of alcohol impaired driving behaviour among convicted drink driving offenders. The main benefit of this type of device is that it bypasses any decision-making requirement by the drink driver and targets the vehicle as a point of intervention. One problem with early model interlock devices was that they could be easily bypassed, however, increasingly stringent Government requirements have resulted in the development of new tamper-proof devices.

A less costly alternative to the fitment of an ignition interlock is the use of some type of vehicle monitoring device. These devices provide a means of ensuring that offenders adhere to the driving restrictions imposed by the courts, and have been shown to be an effective means of reducing the level of illegal driving during licence suspension periods. These devices have a particular application in jurisdictions were courts can provide offenders with a special licence that allows them to use their vehicle for work related reasons.

Traffic law enforcement should never be relied upon as the sole means of modifying drink driving behaviour. There are a range of other preventative strategies that can be used in conjunction with enforcement to target the problem of alcohol impaired driving. The implementation of alcohol control policies and taxation measures, designed specifically to

reduce the availability of alcohol as well as the total amount consumed, have been shown to have the potential to significantly reduce the level of alcohol impaired driving.

Server intervention programs are designed to place a greater emphasis on those who sell and serve alcohol to be more responsible for their actions and have more control over the drinking environment. These programs are generally popular with patrons, can increase profitability for establishments and have been shown to significantly reduce the number of customers who become legally intoxicated. These programs can result in less drink drivers and can also reduce the level of alcohol impaired pedestrians.

The increased availability of public and personal breath testing devices provides a means of allowing drivers to obtain an indication of their alcohol consumption level. The installation of coin operated breath testing devices in drinking establishments has been shown to change driving intentions if a reading over the legal BAC limit is registered. A large proportion of drinking occurs at locations where coin operated testing devices are not available. The provision of some form of self-assessment device may also have the potential to lead to less drink driving behaviour.

4. ENFORCEMENT OF SPEEDING MOTORISTS

4.1 INTRODUCTION

The term 'speeding' is used to describe the behaviour of a driver who is operating a vehicle at a speed which is considered too fast for the prevailing conditions or at a speed greater than that specified by the posted speed limits. In Western society this type of driving behaviour is extremely common and Maroney and Dewar (1987) have estimated that well over 90% of all motorists will, at some stage during their driving career, exceed the recommended or posted speed limit.

The reasons for the high incidence of speed violation can be quite complex. Elliott (1992) has suggested that as motorists build up a history of safe driving at higher speeds their behaviour is reinforced because accidents are a rare event and they fail to establish the relationship between speed and accident occurrence. Fuller (1990) has suggested that one additional reason that speeding behaviour is so prevalent in society is because it tends to be intrinsically rewarding to drivers, that is, it may save time, feel exciting or give the individual the opportunity to demonstrate skill or courage.

Hillman and Plowden (1986) have suggested that the tolerant attitude to speeding, and the laxity with which offending drivers are dealt with, may also reinforce speeding behaviour.

They found that in Britain in 1983, only one driver, per 940,000 vehicle kilometres travelled, was convicted of a speeding offence which, they stated, was equivalent to a one in two chance of being apprehended in a lifetime of driving. They also suggested that the low penalties incurred (on average between £20 and £30) reflected the concessionary attitude towards speeding drivers taken by legislators and magistrates alike.

Mäkinen and Oei (1992) suggested that speeding behaviour might be a reflection of societal life-style values. They stated that in Western society the notion of speed is often portrayed as a positive quality, associated with an active, powerful, dynamic and fast life-style. In contrast, attributes such as slowness, passivity, staticity and weakness are considered to be negative aspects of Western culture. They concluded that such societal life-style values led to a kind of contradiction to efforts aimed at reducing the level of speeding behaviour. This proposition is supported by the results of an attitudinal survey conducted in New South Wales, Australia, in 1985 which showed that speeding behaviour was widespread, deeply entrenched and socially condoned (Croft, 1993).

Lay (1984) identified a range of behavioural and environmental factors which may influence the decision to speed. These include: perception of the safety and comfort of the road, personal characteristics such as, age, driving experience and risk taking behaviour, travel motivations, vehicle characteristics, the imposed speed limit and the perception of the level to which\ that limit is enforced. In addition, he also identified a number of reasons why speeding behaviour may compromise road user safety; stating that as speed increases the following four major results occur:

- the vehicle becomes less stable and more difficult to control in certain driving situations (e.g. cornering, heavy braking);

- the driver of the vehicle has less time to react to a potentially hazardous situation;

- other road users similarly have less time to react to the detected presence of the speeding vehicle; and

- the severity of the, consequent accident increases.

The Department of Transport (1992) has also identified a number of ways in which excessive speed may affect driving behaviour. Firstly, as speed increases the probability of being able to react successfully to an unforseen incident or to correct a misjudgement decreases sharply. This occurs because the 'thinking distance', defined as the length of road covered whilst the driver is assessing the situation, increases linearly with speed. Secondly, perception is affected because the faster the travel speed the more difficult it is to estimate the speed of other road users and the approach speed towards fixed road side objects. Finally, divided attention skills are also affected because as speed increases information is received at a faster rate and must therefore be processed in a shorter time period.

The magnitude of the speeding problem in Western society has led to the development of numerous strategies designed to reduce the level of speeding behaviour. A large number of these strategies rely on enforcement and legislative measures to bring about behavioural change. However, a number of researchers are of the opinion that speeding is essentially different to most other road safety behaviours both qualitatively and quantitatively (Fuller, 1990; Elliott, 1992). As such, it has proven far more resistant to change and many researchers have questioned the over reliance on enforcement, stressing instead the need for a coordinated approach to the problem of speeding. The use of engineering, environmental, educational and promotional measures, have all been identified as possible additional means of modifying speeding behaviour (Moroney & Dewar, 1987; Cairney & Townsend, 1991). Croft (1993) has suggested that speed control strategies should be structured in such a way that behavioural changes arise from attitudinal modifications as well as from driver adjustments to more tangible elements such as enforcement and engineering measures.

The primary focus of this review will be on speed control measures as they relate to traffic law enforcement. However, the increasing emphasis placed upon non-enforcement based strategies and the need to initiate a system wide approach to the problem of excessive speed has led to the development of strategies which target the 'agents' of speed namely the vehicle and the roadside environment. In order to provide an understanding of how a system-wide approach can be adopted, the range of non-enforcement based options will also be briefly examined. However, before reviewing the range of speed control strategies available to authorities it is important to examine the research evidence relating to the reasons that strategies have been introduced, namely the relationship between speeding behaviour and accidents.

4.1.1 Speed and Accidents

The problem of excessive speed has long been recognised as a major factor in road traffic accident causation (Plowden & Hillman, 1984). The majority of research examining the relationship between speed and road traffic accidents has traditionally focused on two aspects, namely speed consequence (injury severity) and speed causation (accident involvement). While the consequential effect of speed is well accepted the role of excessive speed in causing road traffic accidents is still generally regarded as being somewhat unclear.

Speed consequence

The evidence relating to the consequence of speed in road traffic accidents is conclusive: the greater the collision speed the greater the likelihood of injury, severe injury or death (Cowley, 1987). These findings are supported by the laws of physics showing that kinetic energy is a function of mass times velocity squared. In a road traffic accident the mass of a vehicle always remains constant and it is the speed at which the vehicle is travelling which has the greatest influence on impact energy. For example, a 10% increase in speed will result in a 21% increase in impact energy.

Studies examining vehicle speed in relation to the level of injury sustained in a road accident have typically reported a curvilinear relationship. The higher the impact speed in an accident the greater the probability of more serious injury or death. Solomon (as cited in Fildes & Lee, 1993) concluded that this increase in injury severity risk was extremely rapid at travel speeds in excess of 96 km/h and that the probability of death markedly increased above 112 km/h. A more recent study (Mackay, 1987; Evans 1991) has shown that the risk of serious injury can also be quite high at lower speeds (less than 80 km/h) depending upon driver and vehicle characteristics. From these results it was evident that speed was the main causal factor in injury level sustained and in a recent review of the available evidence Fildes and Lee (1993) concluded that it was clearly evident that reducing the level of speeding behaviour will reduce the level of road trauma.

Speed causation (accident records)

Whereas the relationship between speed and accident severity is well understood the same cannot be said for the role of speed in accident causation. A number of studies (Solomon, 1964; Munden, 1967; Hauer, 1971; Lave, 1985), have used accident and insurance claim data to establish speed involvement relationships. The results from these studies suggested that it may, in fact, be speed variance and not mean travel speed which leads to higher accident involvement rates. These studies established the existence of a U-shaped relationship indicating that both slow and fast speeding behaviour, as related to the mean speed, was the cause of increased accident risk.

Hauer (as cited in Fildes and Lee, 1993) suggested that drivers travelling at slow speeds may, in fact, have a greater accident risk than drivers travelling at higher speeds. This study examined the relationship between speed, accident involvement rates and the level of overtaking manoeuvres. The conclusion of this study was 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 accident involvement rates.

Studies highlighting the existence of the U shaped relationship between speed and accidents have led a number of researchers to argue that reducing the speed variance and not the mean speed will have the greatest reduction effect on accident rates. Lave (1985) suggested that traditional speed control strategies, targeted at excessive speeding behaviour, may need to be replaced by more balanced speed management strategies which emphasise the dangers of both fast and slow driving behaviour.

However, changing the emphasis of speed control strategies, in this manner, may actually led to negative road safety consequences. Fildes and Lee (1993) have indicated that reducing speed variance would result in an increase in the travel speed of low speed motorists which would, in turn, result in greater injury severity for this category of drivers. Cumming and Croft (1971) summarised the situation, stating that if the objective of speed control is to reduce the total number of accidents then speed variance may need to be

targeted, however, if the aim is to reduce the level of accident severity, then absolute speed should be targeted. In addition, Fildes et al. (1991) have questioned the existence of a U-shaped relationship. In a study undertaken in Victoria, Australia they established the existence of a positive linear relationship between speed and accidents and also reported that excessively slow travel speeds appeared to be a rare event on the sections of rural highway which were examined. This led these researchers to raise questions regarding the way in which slow speeding behaviour has in fact been defined in previous studies. They suggested that the inclusion of accident data associated with slowing-down manoeuvres (i.e. before turning) and slow speed turning manoeuvres may not provide an accurate reflection of the true relationship between speed and accident occurrence.

On the basis of these empirical functions, he concluded that the change in accident occurrence resulting from a change in mean travel speed can be expressed as the change in velocity to the 4th power for fatal accidents, the 3rd power for serious injury accidents and the 2nd power for all injury accidents. Thus, a 5 km/h reduction in mean speed from 100 km/h to 95 km/h, on a particular stretch of road, would result in an 18.5% reduction in fatal accidents, a 14.3% reduction in serious injury accidents and a 9.0% reduction in all injury accidents. Using these derived functions he was able to provide a reliable means of determining the increase or decrease in accident occurrence (as related to accident type) based upon increases or decreases in mean travel speed.

Probably the most reported evidence for the relationship between speed limits and accident causation comes from studies undertaken in the United States of America and Canada relating to the increase in speed limits on rural highways from 55 mph to 65 mph. The Insurance Institute for Highway Safety (1988) estimated that this 10 mph speed limit increase, on rural highways in 38 American States, resulted in a 22% increase in road fatalities when compared to other rural highways. This estimate is supported by Baum et al. (1990) who reported that the increased speed limit resulted in a 26% to 29% increase in rural highway fatalities.

Two studies were also undertaken in Michigan, Canada to examine the impact of a 10 mph speed limit increase (from 55 mph to 65 mph) on rural interstate highways. Wagenaar et al. (1989) reported that the speed limit increases resulted in the following impact on accidents: 48% increase in fatalities, 32% increase in serious injuries, 30% increase in moderate injuries and a 30% increase in property damage only accidents. Similar results were reported by Streff and Schulz (1991) in Michigan, Canada, in a follow up study to that undertaken by Wagenaar et al. (1989). They reported a 28% increase in fatalities, a 39% increase in serious injuries and a 24% increase in moderate injuries.

However, a recent study undertaken by Lave and Elias (1994) has raised a number of questions regarding the reported negative accident consequences of higher speed limits. They suggested that the majority of studies only measured the local effect of the speed limit changes and did not take in to account 'system-wide' effects. They examined the system-wide impact of the 10 mph speed limit increase (from 55 mph to 65 mph) in the United States of America, comparing those States that introduced the new speed limit with those that did not. They concluded that the 65 mph speed limit had actually resulted in a system wide reduction in fatality rates of between 3.4% and 5.1 %. They explained these results in terms of a number of factors, including, a shift in the number of drivers using the safer highways (attracted by the higher speed limits) as compared to less safe, more high risk secondary roads, a shift in enforcement resources from the higher speed highways to target more high risk behaviour on other secondary roads, and an overall reduction in speed variance as the slower drivers caught up with the speeders.

Regardless of the methods used to determine the role that speed plays in accident causation, or the size of the accident involvement estimates derived, the overwhelming evidence indicates that speed is a significant problem and that changing driver behaviour and attitudes towards speeding is an important priority. However, many authorities have been somewhat reluctant to make a concerted effort at tackling the problem of speed. Enforcement is generally not popular in the community and changing attitudes is considered to be a difficult task due to the complex and widespread nature of the speeding problem. Fildes and Lee (1993) reported that at the 1991 Experimental Safety Vehicles Conference in Paris, government representatives from Europe and North America listed speed involvement in accidents as one of the major challenges now facing authorities in making further reductions in the road toll.

4.1.2 The Mechanism of Deterrence

According to rational choice theory, road users will abide by the law if the expected utility of law-abiding actions is greater than the expected negative consequences of committing an offence (Palmer, 1977). The utilities of speeding are considered to be varied and include travel time saved, the thrill of taking risks, the urgency of the trip and even the pure exhilaration of speed. The disadvantages of speeding include the consequences of being apprehended, the increased likelihood of becoming involved in an accident, increased wear and tear on the vehicle and increased fuel consumption (Fildes & Lee, 1993).

Speed enforcement strategies, based upon the principles of deterrence, are designed to increase the risk of apprehension so that the disadvantages of speeding outweigh the advantages. In assessing the costs and benefits of speeding, the would-be offender is said to weigh up three factors: the perceived risk of being caught, the fear of being caught and the fear of likely punishment (Corbett & Simon, 1992). With regard to speed enforcement, it is the first of these factors, namely, the perceived risk of being caught, which has been identified (Shinar & McKnight, 1985) as a crucial determinant in the decision to speed.

Fildes and Lee (1993) have suggested that the deterrent effect of speed enforcement operates through a number of processes, which include, on-site effects, memory effects, and general risk-of-detection effects. On-site effects refer to reductions in speed for a finite time and distance after encountering enforcement. Memory effects are any reductions in speed which occur at the site where enforcement activities have been previously encountered. 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 speeding drivers and the prevalence of speed enforcement activities.

It is generally regarded that the primary objective of speed enforcement is to deter motorists from speeding and the type of deterrence mechanism which operates in such situations may be either specific or general. Specific deterrence, as it relates to speed enforcement, is based on the assumption that drivers who are apprehended and punished for speeding will be discouraged from committing further speeding offences. General deterrence is based on the assumption that drivers who are exposed to enforcement and informed about the risk of apprehension will modify their speeding behaviour to avoid the risk of detection and the resulting consequences.

Specific deterrence can be achieved by setting maximum speed limits on various types and sections of roads and apprehending those drivers who travel at speeds higher than those specified. The greater the enforcement effort, the greater the actual probability of detection and the high the number of speeding drivers apprehended, and hence, the greater the level

of specific deterrence. General deterrence can be achieved by increasing the level of enforcement activity and by informing the public, via the media, of the increased probability of detection. The greater the actual level of enforcement and associated media publicity the higher the perceived probability of apprehension, and hence, the greater the level of general deterrence.

However, increasing the actual probability of detection alone, does not necessarily mean that the perceived probability of detection will increase at the same rate. Ostvik and Elvik (1990), in a review of a number of Scandinavian studies, reported that increases in the level of enforcement activity are often underestimated by motorists. They found that increased enforcement efforts which were less than three times the previous level, appeared to have only a minimal effect on the perceived probability of detection and little or no impact on speeding behaviour. They concluded that if enforcement was to be used to bring about significant reductions in speeding behaviour it would need to be sustained at a high level of intensity for a long period of time and supported by high levels of associated publicity.

According to Ostvik and Elvik (1990) increasing the perceived risk of detection is one of the most important objectives of all speed enforcement strategies. However, to achieve this objective, it essential to significantly increase the actual risk of detection and hence the intensity of enforcement operations. If motorists are to be deterred from speeding they must be made aware of the fact that there is a high probability that such behaviour will be detected and result in some form of punishment. This proposition highlights the need to introduce enforcement techniques designed specifically to increase detection rates. These techniques would also need to be sustained over a long period of time and be accompanied by high levels of associated publicity in order to highlight the enforcement operations and the increased risk of detection. These requirements have major implications for enforcement based speed management strategies, suggesting the need to re-evaluate traditional policing methods and adopt more intensive enforcement practices.

4.2 SPEED LEGISLATION

The first step in the process of moderating speeding behaviour is to develop legislation which specifies the speeds which are applicable to different types of road sections. The implementation of such legislation is an essential element of all enforcement based speed control strategies as it provides motorists with a clear indication as to what is deemed to be law abiding speed behaviour. Enforcement of this legislation can also increase the efficiency of policing operations as it allows the speed of the motorist to be used as the sole means of determining illegal driving behaviour.

4.2.1 Speed limits

The primary legislative means of imposing some control over the speeds at which motorists travel is through the use of speed limits. The primary function of speed limits is to provide drivers with information regarding what is considered to be the safest speed for the road environment in which they are travelling. Speed limits can be specified as 'absolute' (the maximum speed at which a driver is permitted to travel) or 'prima facie' (the speed above which a driver would have to prove that their speed was compatible with prevailing conditions). Absolute speed limits are more commonly adopted than 'prima facie' speed limits. They also appear to exert a greater influence on the distribution of speeds and have been reported as resulting in less excessive speeding behaviour (Fildes & Lee, 1992).

The introduction of maximum speed limits has significantly increased the effectiveness of speed enforcement operations by providing police with a simple means (travel speed) of determining inappropriate speeding behaviour (Evans, 1987). This was considered to be a marked improvement on traditional enforcement techniques which relied upon the subjective judgement of a police officer to determine if speeding behaviour was inappropriate or dangerous for the existing road environment conditions. In many situations this was difficult to prove and often relied on the occurrence of some type of road accident.

Although speed limits are often associated with police enforcement activities, they can be an effective speed countermeasure in their own right. Plowden and Hillman (1984) stated that speed limits provide legislators with a powerful tool not only for modifying speeding behaviour but also for reducing the number of road traffic accidents. In a comprehensive review of speed limit control, they concluded, that the international evidence has shown that the number and severity of road accidents increases in relation to vehicle speed and that substantial reductions in road accidents are brought about by imposing or lowering existing speed limits.

The literature relating to the effect of speed limit changes on driving behaviour and accident and fatality rates has been reviewed in the previous section relating to speed and accidents. The general conclusion from these studies was that lower speed limits result in a reduction in mean travel speed and a corresponding reduction in the number of road traffic fatalities. Although speed limits are commonly regarded as an effective speed management tool they can actually result in road safety problems especially when motorists do not believe that the posted speed limits are appropriate for the road environment in which they are travelling.

Reasons for setting speed limits

Although, in the majority of Western countries, speed limits have been applied in some form or other for many years, it was the international oil crisis in 1973 which provided the main impetus for the widespread use and implementation of speed limits. This crisis led many countries to develop a range of energy conservation measures which included legislation for the introduction of new or lower speed limits. A somewhat unexpected result of the speed limit changes was a significant reduction in the number of road accidents, and associated injuries and fatalities. As a result of the reduction in the level of road trauma the use of speed limits became recognised as an effective road safety countermeasure.

However, speed limits are not set solely on the basis of safety. The mobility needs of society must also be taken into account. The underlying principle of speed limits is to optimise both these aspects to the best degree possible, bearing in mind that ultimately, mobility and safety requirements will often be in conflict (Fildes & Lee, 1993). The most appropriate speed limit is one where the majority of drivers believe that authorities have made an acceptable compromise between their mobility needs and the need to maintain a relatively high level of road safety.

Fildes and Lee (1993) stated that balancing these two needs can be extremely difficult. They suggested that the mobility needs of the driver are continually changing. In rational terms, mobility is a function of the vehicle and roadway, trip purpose, duration, economic consequences, utility, and so on. Anyone of these variables may change from moment to moment thereby altering the immediate mobility needs of the driver. However, a driver's

perception of safety (accident or injury risk) is not always immediately apparent from an increase in travel speed because accidents are relatively rare events. They concluded that it is therefore not surprising that authorities are often accused of erring on the side of safety. That is, they are often criticised for setting speed limits that do not always reflect a credible balance between the many factors affecting speed choice under optimal driving conditions.

Setting speed limits

Speed limits are traditionally set using the 85th percentile method which is defined as the speed at or below which 85% of motorists choose to travel. The method was introduced as a result of research undertaken by Witheford (as cited by Fildes & Lee, 1993) who stated that the 85th percentile speed is that most desirably approximated by a speed limit. He argued that 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 result in a large number of drivers violating that limit.

The benefit of using this method is that it reflects the speeding behaviour of all motorists due to the fact that it is based solely upon the speed limit that motorists perceive to be acceptable. It also allows enforcement activities to be targeted only at those motorists at the high end of the speed distribution and, as such, it is generally accepted by the public and does not place an excessive burden on policing resources. However, Fildes and Lee (1993) indicate that the use of this method may not provide a true reflection, or an unconstrained measure, of the speed that the majority of motorists perceive as being acceptable. They suggest that a driver's choice of speed is never truly unconstrained and that the 85th percentile is actually an expression of the speed at which motorists are prepared to travel on that road, influenced by factors such as the prevailing speed limit, enforcement activity, the amount of traffic and time of day.

A number of researchers have recommended the use of alternative methods of setting speed limits. Nilsson (as cited in Cameron, 1993) has suggested that speed limits be set on the basis of transport economics, where accident and injury cost savings must compete with travel time and vehicle costs. He suggested that this would allow speed limits to be set in relation to some predetermined level of acceptable road trauma. This proposition has been supported by a number of other researchers (Cowley, 1981; Salusjarvi, 1981) who have suggested that setting speed limits based upon reductions in transportation costs would not only reduce the level of road trauma but would also result in significant financial savings.

Problems with speed limits

One of the main problems associated with speed limits is that motorists often perceive them to be inappropriate for the existing road environment conditions. The credibility of speed limits plays an important role in the process of encouraging safe driving speeds and it is generally accepted that speed limits should match the expectations of drivers to some degree (Schnerring, 1985). Credible speed limits ensure that there is an adequate level of voluntary speed compliance which in turn reduces the reliance on limited police resources to enforce speed limits. However, if motorists believe that speed limits are not appropriate then the likely result will be an increase in the level of speeding behaviour. Ruschman et al. (as cited in Fildes & Lee, 1993) claimed that excessive speeding can, in part, be attributed to improper speed limits. Drivers may believe that their behaviour in exceeding the speed limit is not risky and they therefore do not perceive it as being illegal.

The aim of authorities is to set speed limits that are not only appropriate to the road environment but are also consistently applied. Doing this educates drivers to understand the reasons why certain speed limits apply in different situations and allows them to identify speed zones based upon previous experience of the relationship between speed limits and road environment (Jarvis & Hoban, 1988). However, the criteria for setting speed limits can be extremely complex and the result is that there are often many inconsistencies in the speed limits which are applied in different road environments.

One such inconsistency relates to the discrepancy between posted speed limits and 'design speeds' for particular types of roads (Fildes & Lee, 1993). Roadways are often designed by engineers to accommodate higher speeds than those stipulated by the posted speed limits. The primary reason for this engineering design practice is to provide the driver with a certain 'safety' margin. However, because these roads are designed to accommodate higher speeds it is not surprising that many drivers exceed the posted speed limit and travel at a speed closer to that for which the road was designed. Fildes et al. (1991) have also reported that some speeding motorists (who were not intentionally speeding) found it quite difficult to maintain their speed at the legal limit. Their research questioned the validity of building roads with high design speeds, stating that effective speed management on these roads places an unnecessary strain on enforcement resources.

There are a number of ways in which authorities may be able to improve the credibility of speed limits. A number of possible solutions, including the use of 'expert' speed zoning systems and the introduction of some form of variable speed limit system, are detailed in a later section within this review. Regardless of the perceived credibility of speed limits there will inevitably be a number of road users who choose to travel at speeds greater than that nominated. In such situations enforcement may be the only possible solution for deterring these motorists.

Traffic law enforcement is generally regarded as the final step in the process of moderating the level of speeding behaviour. If the road user cannot be encouraged to drive at a speed which is appropriate for the road conditions, or which corresponds to the specified speed limits, then reliance is typically placed on the law enforcement system to deter, apprehend and punish. To provide a review of speed control strategies, as they currently operate is, by and large, equivalent to examining the impact of policing operations and legal sanctions on the speeding behaviour of road users. There are two commonly adopted approaches to speed enforcement. The first approach involves the use of traditional enforcement methods and the second approach involves the use of automated speed detection devices. These two approaches differ in a number of fundamental ways and each will therefore be reviewed in two separate sections.

4.3 TRADITIONAL SPEED ENFORCEMENT

Traditional approaches to speed enforcement usually involve activities associated with the on-site detection, apprehension and punishment of the speeding driver. Speeding motorists are detected via the use of some form of speed measuring device (which can include the police vehicle itself), stopped by the police at the location where the speeding offence occurred, and are then issued with some form of penalty notice depending upon the severity of the speeding offence committed.

Deterring speeding behaviour is generally based upon two different enforcement philosophies (Shinar & Mcknight, 1985). Firstly, speed enforcement can be based on the principle of high visibility, active policing operations. This type of approach leads to a

general speed reduction effect, because the visual presence of the police reinforces the driver's perceived risk of apprehension. It also results in a specific speed reduction effect because drivers modify their speeding behaviour at the visible enforcement site. Secondly, speed enforcement can be based upon the principle of low visibility, active policing operations. This leads to a general speed reduction effect due to the unpredictability of the enforcement and, accordingly, drivers modify their speeding behaviour because they realise that they cannot take measures to avoid being apprehended. The type of method used and the enforcement philosophies on which they are based have been shown in a number of studies to have differing effects on speeding behaviour.

4.3.1 Deterring the Speeding Motorist

One commonly identified problem with traditional methods of speed enforcement is that when drivers do actually encounter this form of policing activity the resultant effect on speeding behaviour is usually only temporary. Fildes and Lee (1993) have described two different types of temporary enforcement effects. The first effect relates to the distance from the enforcement site over which speeding behaviour is modified and is referred to as the 'distance halo effect' of enforcement. The second effect relates to the change in driving behaviour at a previously known enforcement site in anticipation of again encountering enforcement, and is referred to as the 'time halo effect' of enforcement.

Enforcement strategies are often designed to maximise these halo effects of enforcement so that speeding behaviour is not only deterred at the enforcement site but also for a certain time and distance after exposure to enforcement (Fildes & Lee, 1993). A number of studies have attempted to quantify the temporary effect of enforcement on driving behaviour. The results from these studies clearly show that speeding motorists do in fact modify their driving behaviour when they encounter some form of enforcement but that once having left the enforcement area they soon revert back to their pre-enforcement travel speeds.

Barnes (1984) found that many speeding drivers modified their behaviour approximately two kilometres before an enforcement site (due to being warned by other motorists) but that the effect on speeding behaviour only lasted for about four to six kilometres after the enforcement site was encountered. Hauer et al., (1982) found that mean speeds were reduced by up to 28% at an enforcement site but concluded that the effect on speeding behaviour only lasted for several kilometres. Nilsson and Sjorgen (1982) found that repeated exposure to enforcement at a particular site resulted in changes in speed behaviour once the enforcement had been removed. They reported that six days of continued exposure to enforcement at one particular location resulted in reductions in the level of speeding behaviour, due a memory effect, that were still being observed for between 10 to 17 days after the enforcement had been removed. However, further long term reductions in speeding behaviour were not observed.

The methods used to maximise deterrence and the halo effect of enforcement have traditionally focused on methods of increasing both the visibility and unpredictability of enforcement operations (Armour, 1984). There are various enforcement options which can be used to achieve these objectives including the use of visible or unmarked police vehicles, the use of stationary or moving police patrols and various combinations thereof. The effectiveness of these enforcement options and their impact on speeding behaviour has been the subject of numerous studies. However, the findings of these studies have often been inconclusive and have resulted in considerable debate regarding the optimal use and deployment of available policing resources.

Enforcement Visibility

The use of highly visible enforcement strategies has long been recognised as a means of deterring speeding behaviour because it reminds road users that enforcement is present and increases both the actual and perceived risk of detection (Fildes & Lee, 1993). Numerous studies have shown that visible policing operations have an immediate impact on speeding behaviour. However, Axup (1990) has suggested that the impact is only short term and that highly visible enforcement strategies are often compromised by drivers simply adapting their behaviour at the site of enforcement activity.

This proposition has led a number of researchers (Sanderson & Cameron, 1982; Dix & Layzell, 1983; Barnes, 1984; Ostvik & Elvik, 1990) to advocate the use of enforcement that is not visible to the road user. Enforcement is still given a high profile but individual enforcement sites are not visibly highlighted. The main advantage of this type of enforcement approach is that it prevents drivers from modifying their behaviour only at the site of enforcement (Barnes, 1984). In addition, this approach not only serves to increase the uncertainty as to the location, manner and time enforcement might be encountered but also reduces the possibility that offenders will feel confident that vigilance will prevent them from being apprehended (Fildes & Lee, 1993).

However, the results of several studies have raised questions regarding the benefits of strategies based upon the deployment of non-visible police vehicles. Galizio et al., (1979) found that while the presence of a visible police vehicle had a significant impact on road user behaviour, the presence of an unmarked vehicle resulted in no apparent behavioural change. Similar results were also reported by Nilsson & Sjorgen, (1982) who found no evidence of a 'time halo' effect resulting from the deployment of an unmarked police vehicle.

Parker and Tsuchiyama (1985) stated that the deterrent effectiveness of unmarked police vehicles is dependent on creating a high level of awareness among motorists that any vehicle in the traffic stream could be a potential police patrol. They stressed the need for such policing activities to be highly publicised and to ensure, that when a speeding driver is stopped by an unmarked police vehicle, this fact should be brought to the attention of all other road users through the use of some form of portable flashing light. They concluded that motorists may learn that the probability that a police patrol is in the traffic stream is quite low, but the fact that the risk is present may lead to some level of deterrent effect.

The available evidence indicates that both visible and non-visible enforcement have a role to play in the process of deterring speeding behaviour. As a result many police organisations have developed enforcement strategies which incorporate both of these elements. The aim of this strategy is to maximise the deterrence potential of both deployment methods by ensuring that enforcement is not only visible but that it also results in a level of uncertainty regarding the manner, location and time it will be encountered.

Enforcement mobility

The deterrence potential of both stationary and moving police vehicles in speed enforcement operations has also been examined. Shinar & Steibel (1986) found that the deployment of a stationary vehicle had a more immediate effect on speeding behaviour at the site of enforcement but that the deployment of a moving police vehicle, within the traffic stream, had a greater effect on individual road user behaviour over a longer time and distance. However, they suggested that the benefits of deploying moving vehicles may be offset by a reduction in the level of visible deterrence because the potential influence on

speeding behaviour is limited to only a small number of road users. They concluded that the use of stationary police vehicles had a greater potential to influence road user behaviour because they were seen by a larger number of road users. Several other earlier studies (Council, 1970; Nilsson & Sjorgen, 1982) also found that the deployment of a stationary visible police vehicle had a greater speed reducing effect on driver behaviour.

Armour (1984) has questioned the benefits of stationary vehicle deployment. She suggested that such policing operations may become predictable because the locations suitable for stationary vehicle deployment are often limited. She also indicated that drivers, having seen a stationary vehicle, may revert back to previous speeding behaviour because they are aware that policing resources are limited and that there is a good chance that no additional police vehicles will be encountered. She suggested that a mobile police vehicle may in fact have a greater deterrence impact because it creates a high level of uncertainty regarding the location and movement of enforcement. Fildes and Lee (1993) have also suggested that a moving police vehicle can create a higher level of deterrence because the increased mobility may be perceived by road users as a greater preparedness to apprehend.

Axup (1990) stated that unmarked patrols can be an effective deterrent and targeting tool. However, in order to be effective such patrols need to be used consistently on a particular road, in a particular area or for a specific purpose to increase the expectation of drivers that there is a strong chance of detection. He added that the ad hoc use of unmarked patrols in the general traffic policing situation is a waste of valuable resources. He reported on the use of unmarked patrols in Victoria, Australia stating that although such patrols represent only 1.45% of the police traffic component they were responsible for 3.9% of all 'on-site' traffic infringement notices issued. He concluded that such patrols were especially effective in the policing of heavy vehicles, on highways, resulting in 22% of all 'on-site' speeding offences recorded.

Southgate & Mirrlees-Black (1991) have proposed a simple solution to the problem of site specific deterrence associated with the use of stationary vehicle deployment. They suggested that speed enforcement operations should incorporate the use of two or more stationary units located a short distance apart. They argued that this type of deployment option can increase deterrence in two ways. Firstly, the additional number of police vehicles encountered can create a perception of increased enforcement activity and secondly, the deployment of additional police vehicles can create a level of enforcement expectation which increases the uncertainty about the possible deployment of yet another vehicle further along the road.

The arguments relating to the best type of vehicle deployment option have been reviewed by Bailey (1987). He stated that both stationary and moving vehicle deployment had the potential to influence road user behaviour in different situations. Stationary vehicle deployment has a high deterrence potential at the site of enforcement and is therefore best suited to fixed-site operations at known accident locations. Moving vehicle deployment has a greater area-wide deterrence potential and should therefore be used on stretches of road where behaviour modification over longer distances is required. He concluded that both types of deployment methods should be incorporated into an integrated enforcement strategy.

4.3.2 Problems with Traditional Enforcement

One of the main benefits of traditional enforcement is that speeding behaviour is punished immediately. It has been suggested, by Ross (1982), that the knowledge that punishment

will be swiftly administered may be an important element in the process of deterring speeding behaviour. However, perceived certainty of apprehension is also regarded as an essential element in this process of behavioural change (Homel, 1988) and one of the most commonly reported problems of traditional speed enforcement methods is that they do not create a sustained, high level of perceived apprehension risk (Hauer et al, (1982).

Perceived risk of apprehension is regarded as one of the main factors determining the level of speeding behaviour. To deter such behaviour it is essential that a high proportion of speeding motorists are apprehended (specific deterrence), and that potential speeding motorists are also made aware that apprehension is likely if they decide to speed (general deterrence). If the risk of apprehension is low then speeding behaviour can actually be encouraged because motorists learn that such behaviour is unlikely to be detected (Ostvik & Elvik, 1990). Low apprehension risk can also compromise other aspects of the deterrence process and increased penalty severity has been shown to be a relatively ineffective deterrent if motorists perceive the risk of receiving such a penalty as being low (Ross, 1988).

Increasing the perceived risk of apprehension is dependent upon the level of enforcement activity, the use of associated publicity and whether or not motorists actually observe the reported increase in enforcement. Although publicity can facilitate this process, it is the sustained increase in the level of enforcement activity (which results in an increase in the actual risk of apprehension) which is the primary means of increasing the perceived risk of apprehension (Homel, 1988). A significant reduction in the level of speeding behaviour is dependent on increasing both the actual and perceived risk of apprehension which, in turn, requires a large and sustained increase in enforcement activity.

However, the problem with traditional enforcement methods is that the limited policing resources available, as compared to the relatively high number of speeding motorists, results in a low perceived risk of apprehension. Therefore, traditional enforcement methods have only a minimal impact on speeding behaviour (Armour, 1984). Drivers soon realise that at anyone time only a small part of the entire traffic network is subject to enforcement, and hence, the risk of apprehension is extremely low. The solution to this problem would be to significantly increase policing resources so that all offending motorists are apprehended, however, this is difficult to sustain over a long period of time and the additional resources required make the cost of such activities prohibitory.

Alternative solutions to this problem have focused on the development of enforcement strategies which increase the level of deterrence without substantial increases in existing policing resources. This is achieved by increasing both the visibility of policing operations and/or the actual number of speeding motorists apprehended. Enforcement strategies based upon the use of automated speed detection technology have been consistently identified as the most effective way of achieving these objectives because they can significantly increase apprehension rates and generate a high level of media interest.

4.4 AUTOMATED SPEED ENFORCEMENT

Automated enforcement devices have the potential to reduce the requirement for traffic policing resources whilst providing an efficient and effective means of detecting and deterring speeding drivers. Enforcement strategies, based upon the use of some form of automated enforcement device are in many ways similar in application to traditional enforcement methods. The difference is the enforcement technology used and the resulting ability of the police to detect and deter a far greater proportion of speeding motorists.

Automated speed enforcement devices typically consist of detection equipment, a processing unit and a camera, video or digital image recording device. When a vehicle is detected the processing unit determines whether or not the vehicle is exceeding a predetermined speed limit and if so an image is recorded. The image typically records information about the vehicle and driver and the time and date of the offence. The information is then used to identify the owner and, if required, the driver of the vehicle. A speed infringement notification or warning letter is then mailed to the owner of the vehicle.

Rothengatter (1990) has described several ways in which automated enforcement devices can contribute to the effectiveness and efficiency of speed enforcement operations. Firstly, such devices increase the probability of detection when committing a speeding offence (in theory the detection probability can be equal to one) without the necessity for substantial increases in police resources. Secondly, such devices can significantly increase the level of deterrence because drivers soon learn, through direct observation and associated publicity, that there is an increased probability of being detected when speeding. Thirdly, such devices can increase the amount and relevance of information or feedback provided to the road user, and thus, can result in a decrease in the likelihood of an offence being committed. Finally, such devices are able to produce definite evidence that a speeding offence has been committed which can increase the 'fairness' and objectivity of enforcement.

Automated enforcement devices also provide a range of other benefits relating to the simplification of notification and prosecution procedures. When a motorist is stopped by the roadside for a speeding offence there is often an enforcement 'pause' whilst the offence details are being recorded. The problem with this enforcement 'pause' is that other speeding motorists who pass the enforcement site are not apprehended during this time. Axup (1990) stated that the use of automated enforcement devices negates the requirement to write out on-site speed infringement notices, thereby allowing a continuous and sustained level of enforcement. He concluded that this not only increases the efficiency of policing operations but also increases the level of deterrence due to the resulting increase in detection and prosecution rates.

Fitzpatrick (1991) has suggested that automated enforcement devices may also lead to a greater level of efficiency in the area of offence prosecution. He stated that the existence of definite photographic evidence showing that a speeding offence had been committed would result in more offending motorists agreeing with the nominated penalty, rather than trying to appeal against it. This proposition is also supported by Rothengatter (1990) who suggested that the reluctance of motorists to dispute offences could lead to the simplification of court procedures or even make them superfluous.

Automated speed detection devices have a range of benefits but it is important to emphasise that the main benefit of such devices is the substantial increase in detection rates. Reducing the level of speeding behaviour is generally regarded as being dependent upon increasing the perceived risk of apprehension (Rothengatter, 1990; Ostvik & Elvik, 1990). The widespread and highly publicised use of automated speed detection devices can result in a sustained increase in both the actual and perceived risk of apprehension. Once motorists become aware that the risk of apprehension for speeding is high, the receipt of a speed infringement notice will become a strong reminder that speeding behaviour is not only inappropriate but will be detected and will result in some form of punishment.

Information relating to the application and reported effectiveness of automated speed enforcement cameras is an important consideration, given the increased reliance placed

upon this type of enforcement device. The majority of evidence supports the conclusion that such devices can have a significant impact on speeding behaviour and result in a significant reduction in the number of speed related accidents and injuries. The evidence also indicates that speed camera devices can be a highly cost effective means of enforcing speed even taking into account relatively high initial purchase and deployment costs.

4.4.1 Speed Cameras

The majority of speed measuring devices presently used by police may be fitted with some form of photographic processing unit to allow for automated enforcement operations. These automated enforcement systems commonly referred to as speed cameras are considered to be the most effective means of deterring speeding behaviour due to resulting significant increases in both detection and apprehension rates. As speed cameras have become more commonly used, an increasing amount of evidence has been reported relating to the impact of such devices on reducing speeding behaviour as well as the associated reductions in the number speed related accidents and the level of injury severity.

There have been several studies which have examined the impact of speed cameras on driver behaviour. One of the first studies (Dreyer & Hawkins, 1976) was undertaken in the American State of Texas over a three month period in 1976. This study examined the effectiveness of speed cameras on four different road types including, residential, rural, urban and urban thoroughfare. The greatest impact in reductions of the proportion of speeding drivers (up to 50%) was realized on the urban roadways at areas of high levels of enforcement. Significant, but less dramatic reductions, were also observed at the rural and residential sites. Speed distribution profile data showed a small decrease in mean speeds at three of the four sites, with the impact of the speed camera unit lasting for some time after the equipment had been removed from operation.

Lamm and Klockner (1984) have also examined the long-term effect of speed cameras on a dangerous section of a German motorway. In 1972 a 100 km/h speed limit was introduced on this section of motorway in response to a high accident rate. The immediate effect of the speed limit was a 30 km/h reduction in mean travel speed. One year later, speed cameras were introduced to enforce the new speed limits and the effect of the automated enforcement was a further 20 km/h reduction in mean travel speed. Ostvik and Elvik (1990) estimated that there was a 91% reduction in accidents on this stretch of motorway compared to a 56% reduction in accidents on all other sections of German motorways. They did, however, caution that this reported reduction in accidents was due to the combined effects of two countermeasures, namely, the introduction of new speed limits and the use of speed cameras.

Blackburn and Glauz (1984) also reported on the reduction in accident rates on this same stretch of German motorway. They found that the annual number of accidents decreased from 300 to 9 following the introduction of automated speed cameras. They also reported that the number of accident related injuries fell from 80 to 5 and that the number of fatalities fell from 7 to no deaths at all. They concluded that a large proportion of the reported accident reductions were likely to have resulted from the enforcement operations because compliance with the new 100 km/h speed limit was extremely low before the introduction of the speed camera enforcement system.

Nilsson (1992) reported on the use of automatic speed surveillance cameras in Sweden between 1990 and 1992. 16 sections of road (each with two fixed camera sites), comprising 110 km of rural main roads (90 km/h speed limit) and 17 km of urban main roads (50 km/h

speed limit) were enforced using automatic speed surveillance cameras. The speed level at the camera sites, in the direction of the surveillance, fell between 5 km/h and 10 km/h.

Mean travel speeds, over all test sections, on both rural and urban roads, decreased by just over 3 km/h. This was compared to speed measurements on control sections showing a 0.5 km/h increase on rural main roads and a 0.5 km/h decrease on urban main roads. The effects of the automatic speed surveillance cameras on accidents was also examined. However, the observed reduction of 5% in the number of injury accidents and 9% in the number of casualty accidents was not statistically significant due to the limited number of accidents in the study and control areas.

One of the most extensive evaluations, relating to the accident reduction effects of automated speed surveillance cameras, has been undertaken by Cameron et al. (1992). They reported on the speed camera program operating in Victoria, Australia, which is regarded (Ogden et al., 1992) as being the most intensive speed camera based enforcement strategy in the world. Due to the interest in the use of intensive speed camera operations and the significant reported reductions in accident and injury rates (Cameron et al., 1992), a brief overview of the Victorian speed camera program will be provided.

Speed Camera Operations in Victoria, Australia

In 1989, in response to a rising road toll, the Victorian Government implemented a number of new enforcement based road safety initiatives. The two main enforcement initiatives targeted the key problem areas of alcohol (Random Breath Testing -RBT program) and speed (speed camera program) and were based upon the principle of deterring motorists through increased detection rates and high levels of associated publicity. The speed camera program involved sustained long term enforcement operations and high levels of associated publicity with the objective being to discourage speeding behaviour by substantially increasing both the actual and perceived risk of apprehension. The program also generated a large amount of media interest and several post evaluations have shown it to be a highly successful enforcement strategy.

General Operations

Speed cameras were first introduced in Victoria in March 1986 but were not extensively used until several months after the speed camera program was commenced in December 1989. This is reflected by that fact that at the beginning of the program there were only 4 units operating but by August 1990 (9 months later) this number had progressively increased to over 60 units. The extent to which these devices were used is clearly indicated by statistics prepared by the Victorian Police (1993). During the two year period from July 1991 to July 1993, the speed cameras were used to carry out almost 46 million vehicle speed checks. This equates to almost 64,000 vehicle speed checks per day over the two year period. In the same two year period there were over 1.05 million speed infringement notices issued, which equates to over 44,000 speed infringement notices per month or 1450 per day.

Ogden et al., (1992) provided an indication of individual driver exposure to automated speed detection equipment which highlights the deterrent effect of the Victorian speed camera program. They stated that there were 2.9 million registered vehicles in Victoria and that at the time of publication, 2.4 million vehicles were currently being checked for speeding each month. On the basis of theses figures, they stated that every vehicle was likely, on average, to have its speed checked once in every six week period (almost 9 times

per year). They also indicated that the one million speed infringement notices issued in the 18 months to June 1992 meant that every driver in Victoria had either received a speeding fine or knew someone who had.

Infringement processing

The high number of speeding motorists detected and the resulting high level of speeding infringement notices issued, made it necessary to develop special processing facilities and vehicle identification techniques. The Traffic Camera Office (TCO) was set up specifically for this purpose (Bodinnar, 1993) and handles all post issue infringement processing as well as all client contact business, including collections, plea representations and preparation of court briefs. An innovative software management system, called the Traffic Infringement Management System (TIMS), was also developed to process the large volume of infringement notices and improve the efficiency of vehicle identification procedures.

TIMS allows traffic camera film to be scanned by high-speed video into a computer. The system then presents each image to a trained verification officer, whilst simultaneously using specially designed Optical Character Recognition software to data block and determine vehicle registration details. The system is also linked to the State vehicle registration database so that vehicle registration details can be cross checked with vehicle identification features (colour, make, model etc.) to ensure that offending motorists are correctly identified (Bodinnar, 1993). Registration details are also used to provide vehicle owner information so that an infringement notice can be issued.

Effect on speeding behaviour and accidents

The effect of the Victorian speed camera program on speeding behaviour was quite impressive. In December 1989, when the speed camera program commenced, 23.9% of vehicles checked were above the enforcement threshold speed. This steadily declined to 13% in December 1990,9.4% in December 1991,5.0% in December 1992 and eventually to 4.0% in July 1993 (Bourke & Cooke, 1991). The proportion of drivers exceeding the posted speed limit by more than 30 km/h (in Victoria this offence results in loss of licence) also sharply declined from 1.6% in December 1989 to 0.5% by mid 1993.

The effect of the Victorian speed camera program on casualty accident frequency and injury severity, has been examined in a comprehensive series of evaluations undertaken by Cameron et al. (1992). Their evaluation, based upon multivariate time series analysis, examined reported accident reductions during low alcohol consumption times between July 1990 and December 1991. The evaluation was restricted to low alcohol consumption times in order to minimise the impact of the accident reduction effects resulting from the RBT program (82% of speed camera operations occurred during low alcohol consumption times).

They estimated that the speed camera program had resulted in State-wide reductions of 18% in the number of casualty accidents and state-wide reductions of between 28% and 40% in the severity of injuries resulting from casualty accidents. They also found significant relationships between the reported reduction in the number of casualty accidents and both the number of speed camera infringement notices issued, and the level of speed related publicity. Similar significant relationships were found between the injury severity in casualty accidents, the number of speed camera infringement notices issued and speed camera operating hours.

In a follow up study, Rogerson et al. (1993) examined the localised effects of the Victorian speed camera program on casualty accidents and injury severity. They reported a significant reduction in casualty accidents (10.4%), within one kilometre of a speed camera site. This was attributed to a reduction in speed as a result of the receipt of a speed infringement notice. They also indicated that the receipt of a penalty affected the speeding behaviour of drivers in the vicinity of the camera site for two weeks or longer. This indicates that the receipt of a penalty two weeks after a speeding offence has occurred still has a significant impact on speeding behaviour. No evidence of a significant reduction in accident severity was reported.

Cost effectiveness

To date, no specific benefit cost evaluations of the Victorian speed camera program have been undertaken. However, Vulcan (1993) has attempted to provide an indicative estimate of the potential savings of the speed camera program based upon the derived accident reduction estimates provided by Cameron et al. (1992) and Rogerson et al. (1993) as well as reported State-wide road fatality information and estimated program expenditure.

In 1989 there were 776 reported fatalities on Victorian roads (Vulcan, 1993). In 1992 the number of fatalities had dropped to 396 which represented a reduction of 49% over three years (Bodinnar, 1993). On the basis of derived accident reduction estimates, Vulcan (1993) estimated that the speed camera program may have contributed to approximately 30% of the total reductions in fatalities and serious injuries in 1990 and 1991. He further estimated that the saving to the community due to the total reduction in road fatalities and serious injury, from 1989 to 1992, was approximately $1.6 billion (1.3 billion $U.S.). Based upon estimated savings and total program expenditure costs (including publicity, establishment and running costs), he concluded the estimated savings of the speed camera program were likely to be more than ten times the estimated maximum cost of implementing it.

The primary objective of the Victorian speed camera program is to deter and reduce the level of speeding behaviour. However, one consequence of the program, due to the high proportion of speeding drivers apprehended, is that it has generated a large amount of speeding fine revenue. From July 1990 to June 1993 the speed camera program resulted in approximately 1.47 million traffic infringement notices (TINS) being issued, of which 1.267 million TINS were issued for speeds between 0 km/h and 15 km/h over the speed limit; 197,000 TINS for speeds between 16 km/h and 29 km/h and 8,365 for speeds over 30 km/h (Victorian Police, 1993). The corresponding fines for these speed limit violations are $105, $165 and $220 respectively. The Victorian Police (1993) also reported that approximately 92% of offending motorists pay the nominated penalty within the 56 day period provided. Compared to many European countries this an extremely high fine payment rate. Based upon these payment figures it is estimated that over the three year period more than $154 million (123 million U.S. dollars) has been raised in speeding fine revenue. Given that the annual operating cost of the Victorian speed camera program is estimated (Vulcan, 1993) to be less than $10 million (8 million U.S. dollars) the program pays for itself five times over.

4.4.2 Issues Relating to The Use of Automated Enforcement

The increased reliance placed upon the use of automated speed detection cameras as the primary means of deterring speeding behaviour has raised a number of issues relating to the overall benefits of such devices. Those issues which have generated the greatest level

of research debate include the effect that speed cameras have on modifying driving behaviour, immediacy of punishment, the impersonal nature of speed camera enforcement operations and community reactions to the widespread use of such devices.

Immediacy of punishment

The primary objective of automated speed enforcement devices is to deter drivers from speeding by significantly increasing the probability of apprehension. The resulting increase in the proportion of drivers apprehended for speeding offences, increases the level of specific deterrence and the knowledge that the risk of apprehension has increased results in a higher level of general deterrence (Fildes and Lee, 1993). The use of automated enforcement devices to detect speeding means that drivers are usually not stopped and, in many instances, are not even aware that they have been detected (Shinar & McKnight, 1985). The failure of this enforcement method to provide adequate feedback to speeding motorists has, however, caused some researchers to question the behavioural benefits associated with the use of automated enforcement devices.

Rothengatter (1990) indicated that the problem of inadequate driver feedback arises due to the delay between the time an offence is detected and the time the offence notification is received by the offending road user. The use of traditional enforcement methods allows offence recognition and punishment to be immediate, with drivers stopped when and where the offence was detected. However, with the use of automated enforcement devices offending drivers do not become aware that an offence has been detected until they receive a traffic infringement notice several days or even weeks after the event. Rothengatter (1990) has suggested that this time delay and the lack of on-site recognition of an offence can result in a reduction in the potential deterrence effect and does little to reinforce appropriate road user behaviour.

The main debate arising from the use of automated enforcement devices centres around the question of immediacy of punishment which has been pin-pointed in both laboratory and field experiments as a crucial factor in behavioural change. With regard to traffic law enforcement, Ross (1982) has indicated that swiftness of punishment is also an important determinate in the process of deterring unlawful behaviour by road users. However, numerous studies (Homel, 1988; Ross, 1990; Riley, 1991; Harper, 1991) have indicated that the most important requirement in this process may in fact be certainty of punishment.

Proponents of the use of automated enforcement have suggested that such devices can create a high level of punishment certainty and, if used as part of a coordinated enforcement strategy, can not only increase deterrence but can also educate drivers about appropriate road user behaviour. They argue that swiftness of punishment may be an important consideration, however, if motorists do not perceive the risk of apprehension as being high then its deterrent impact may only be minimal.

The experience with automated enforcement devices in Melbourne, Australia, has shown (Rogerson, 1993) that the intensive use of these devices can result in considerable reductions in speeding behaviour. Bodinnar (1993) indicated that such behaviour modification is due to the high level of general deterrence associated with the intensive use of automated enforcement devices. Portans (1988) further suggested that road users modify their speeding behaviour as a result of an increased awareness of how such devices work. This includes the knowledge that the probability of detection and subsequent punitive measures is high, including the fact that punishment can result without the driver being aware that an offence has been detected.

If the perceived and actual risk of apprehension are high the immediate punishment of an offence may not be such a crucial factor in behavioural change because drivers soon become aware of the fact that if they speed they will be detected and that some form of punishment will result. This proposition is supported by Rogerson et al. (1993) who found that the receipt of a speed infringement notice two weeks after the offence had been committed still had a significant impact on speeding behaviour and therefore injury reductions. This is an important finding as it suggests that speeding behaviour is modified even when receipt of punishment is not immediate.

Oei (1993) has suggested that the use of electronic offence notification displays may be one possible solution in overcoming the problem of insufficient road user feedback. These display boards, placed several hundred meters after the enforcement site, can be used in conjunction with automated detection devices to provide speeding drivers with immediate feedback indicating that they have been detected committing an offence and that some form of punishment will be received. These portable information display boards have a dual benefit. Firstly, they provide speeding drivers with immediate notification that an offence has been detected. Secondly, they serve as a strong visual reminder to potential speeders that enforcement operations are active.

Oei (1994) has reported on automatic local speed warning that was applied in 1991 in the province Friesland, in the Netherlands, on a 2-lane rural priority road with a speed limit of 100 km/h at the approach of an intersection. The measure consisted of lowering the speed limit near the intersection to 70 km/h in both directions, an *automatic speed warning sign* lighting up when this speed limit was exceeded and occasional visible posting of police at the intersection. These measures were preceded by an information campaign directed to the local and regional inhabitants and this was continued periodically. The results were a decrease in 85 percentile speed from around 95 to 70 km/h in both directions. This decrease remained stable until recently, police posting being very sporadically continued. Though the number of accidents was statistically very small, it was reduced drastically (minus 60%).

Oei (1992) has also reported on four experiments that were conducted on 2-lane rural road stretches, with a length between 10 and 20 km, having a speed limit of 80 km/h. The measures consisted of fixed warning signs at the beginning of the road stretch, *automatic speed warning signs* that lights up automatically when a car is speeding and *radar and camera* from fixed posts along the road side. On a road stretch 3 to 4 posts were installed, in which one set of radar and camera could be inter-changed. On two roads the signs show a safe *speed interval* of 60-80 km/h. The objective was to decrease the percentage of speeders and of cars driving slower than 60 km/h. On the other two roads speeders are warned automatically with a sign 'You are speeding' lighting up. These measures were preceded by an information campaign and this was continued during the experiment of 8 months. The average result on the four roads was a reduction of speeders from 40% to 10%, an increase of cars driving slower than 60 km/h and a *reduction of 35% in accidents* on the four roads together. The speed measurements were conducted before and a couple of months after the operation of the enforcement system.

One further possible means of reducing the problem of delays in offence notification is through the use of new automated enforcement technology Locke, (1993) indicated that new enforcement systems already exist which can lead to a significant reduction in offence notification times. He described the use of video imaging technology which makes it theoretically possible to produce a digital image of an offending motorist within seconds of the offence being detected. The transmission of this offence information to a police vehicle

located further along the traffic stream would allow speeding motorists to receive notification within minutes of an offence being committed.

Rothengatter (1990) provided the conceptual framework for an optimal automated enforcement system which incorporates the use of electronically coded licence plate identification procedures, on-site registration systems and automated penalty payment systems as well as some form of in-car information display to inform drivers that they have been detected and penalised for the commission on an offence. Although no such integrated automated enforcement systems are presently in operation the technology is currently available to develop and implement such systems.

Community acceptance of automated enforcement devices

Due to the high detection and prosecution rates resulting from the use of automated enforcement devices some critics (O'Neill, 1993) have raised questions about the fairness and morality of such devices and their use as a means of raising revenue. Southgate & Mirrlees-Black (1991) have indicated that the perceived fairness of enforcement is an important variable in police/community relations and can have a significant impact upon police efforts to promote and educate road users about appropriate behaviour. They argue that if automated enforcement is to bring about a social change in attitudes towards speeding behaviour then it is essential that public perceptions and acceptance regarding the use of such devices are high.

The experience in Australia has shown that positive community attitudes towards, and acceptance of the use of automated speed detection devices can be generated by:

- publicity programs which highlight the problem of speed and the need to target speeding behaviour using such devices;
- the deployment of such devices only at those locations with a previously documented accident history and where speed has been identified as a problem;
- community consultation regarding the sites to be selected for the deployment of such devices; and
- an initial penalty free period to allow motorists to become accustomed to speed camera operations.

Freedman et al (1990), in a survey of public opinions regarding the use of automated speed enforcement devices, reported considerable support for this form of enforcement. The highest level of support was found in those communities where such enforcement was already being used, indicating that preconceived notions about the use of such devices is an important factor in public acceptance. Only a minority of road users disapproved of the use of automated enforcement devices with the two most reported reasons being the possibility of the wrong person receiving the fine and the 'sneakiness' of the enforcement activities.

The most significant finding of the survey was that approximately 50% of all survey participants, who were aware of the use of automated speed enforcement devices, indicated that they were driving more slowly as a result.

4.5 DETECTING THE SPEEDING MOTORIST

Detecting the speeding motorist is generally regarded as a relatively easy task given the array of electronic detection equipment presently available. The real challenge is not the detection of the speeding motorist, but the methods used to increase the rate of detection (Axup, 1990). The level of speeding behaviour at anyone time is usually quite high and increasing detection rates is generally regarded (Shinar & McKnight, 1985) as the most effective way of deterring speeding behaviour. There are a range of detection devices available to police but Elliott (1992) stated that unless the high levels of enforcement are a result of technology (speed cameras), a major problem is reliance on increased manpower which is rarely sustainable.

4.5.1 Speed Measurement Devices

The measurement of the speed of a motorist can be undertaken using one of several different methods including time/distance measurement devices, radar devices and laser devices. The majority of these devices have the capability of being linked to some form of automated photographic detection unit. All three types of speed measurement devices are presently used by policing authorities in different situations and all have been reported as having a high level of speed measurement accuracy.

Time/Distance measuring devices

Time/distance measurement devices use sensors near, on, or in the road surface to determine the time interval taken by a vehicle to travel a specific distance. These types of devices usually consist of two sensors which are located along the length of the roadway.

The speed of a vehicle is determined by measuring the time taken from detection at the first sensor to detection at the second sensor, a fixed distance away. Such devices can detect the presence of a vehicle via changes in light intensity or pressure. Although such devices can be fitted to some form of photographic unit (Fitzpatrick, 1991), and used in an automated enforcement mode, no evaluations have been made of this method.

Schnerring (1985) has reported on the use of the pressure detection device. He indicates that benefits of such devices are that they are highly accurate, may be used in light and heavy traffic streams, are relatively inexpensive, and are generally free from interference unless another vehicle crosses the cable at the same time. The problems associated with such devices are the long initial set up time and the fact that the cables call be seen by alert drivers which may allow them to reduce their speed. The use of the light reflection device has been described by Lock (1993). This device is relatively simple and quick to install and has the added advantage that it cannot be easily detected by motorists.

One modification of the time/ distance speed measurement principle has been recently used to develop an on-board speed monitoring device for use in unmarked police vehicles.

Traditional methods of detection rely on the use of radar, or, the following of an offending vehicle until the speed has been accurately determined. The problem with these methods is that the sight of the radar unit or the fact that they are being followed may alert the speeding motorist to the presence of the police. This new computerised on-board monitoring device, based upon before and after time measurements, allows the average speed of a motorist to be determined without the need for the police vehicle to closely follow behind the offending driver or for the use of radar (Oei, 1993).

Radar based devices

Radar is the most commonly used form of speed measurement device. Radar devices emit a continuous microwave beam at known frequency and when a vehicle is detected the change in the frequency of the reflected beam allows the speed of the vehicle to be determined with a high level of accuracy. There are two different types of radar devices: down-the-road radar and across-the-road radar.

Down-the-road radar emits a microwave beam along the roadway, usually into oncoming traffic, and is easy to set up, can be used in both stationary and mobile mode, and is also relatively inexpensive. This type of enforcement radar unit is the most commonly used speed measurement device in operation in police vehicles around the world (Fitzpatrick, 1991). It has proved effective in mobile operations and is generally well liked by police operators due to its simplicity and overall reliability.

Down-the-road radar does, however, have a number of disadvantages including the fact that any metallic object can provide a 'reading' so care must be taken to ensure that the detected vehicle is in fact the cause of the speed 'reading'. In addition, although this type of radar can determine speeds at long range (500 to 1500 meters), it is not able to discriminate between vehicles and is therefore not suited for use in high volume traffic flows (Fitzpatrick, 1991). One further disadvantage of this device is that the moderately high power beam emitted can be detected by drivers with radar detectors.

Across-the-road radar emits a very narrow, low-powered beam directed at an angle of approximately 20ø across the flow of traffic. The advantages of this type of radar unit include the ability to ensure positive identification of speeding vehicles, to detect nearly all speeding vehicles (even in high volume traffic flows), it is relatively free from effects of electrical and other interferences (when positioned correctly), it is effective even against vehicles with radar detectors. This type of radar is best suited to fixed-site operations and can be employed from a stationary vehicle. There is however, no documented evidence of this type of radar being used for mobile enforcement operations.

Across-the-road radar, when used in conjunction with a photographic processing unit, is the most commonly employed type of automated speed enforcement system. It is ideally suited to speed camera operations because the 20° radar beam angle is specifically designed to detect speeding vehicles close to where radar unit is located (20 to 50 meters). This close range detection capability is an essential requirement in order to obtain accurate vehicle identification information.

The use of this device for speed camera operations does, however, result in some technical problems. In poor or high intensity lighting conditions the optimal photograph angle would ideally be either directly in front or directly behind the offending vehicle. The fixed 20ø camera angle does not allow this and can, therefore, make vehicle identification extremely difficult or in many cases impossible. In Victoria, Australia, less than 50% of those drivers detected travelling over the predetermined speed threshold actually received a speed infringement notice. Although this low infringement notification rate is not due entirely to poor vehicle identification information it is still the main factor (Bodinnar, 1993).

Laser based devices

In recent years the use of laser based speed measuring devices has become increasingly popular. These devices emit a narrow high frequency band of infra-red light pulses which can accurately determine speed due to the change in the frequency of laser pulses. The

benefit of these devices is that they are easy to use and can allow the speed of individual vehicles within the traffic stream to be detected with a high rate of accuracy, even over longer distances (Lock, 1993). In addition, these devices are not affected by electrical and other interferences because they do not rely on the reflected signal from a metallic object. They can also be used in both stationary and mobile enforcement modes and because the laser frequency is higher than that of radar, the signal cannot be picked up by radar detectors (Teed & Lund, 1993).

In a study undertaken in the American State of South Carolina, Teed and Lund (1993) compared the use of conventional police radar and a new laser device. They reported that under the laser enforcement condition police were able to issue 14% more speed infringement notices. Although it was found that the increase in detection rates was due mainly to the apprehension of motorists with radar detection units fitted in their vehicles it was also found that a small increase was due to increased efficiency and an improved detection capability.

In recent years laser based devices have been increasingly used in automated enforcement modes. This type of automated system has a number of advantages over radar based systems. When used in conjunction with high quality photographic or digital imaging equipment these laser devices can provide accurate vehicle identification information from distances in excess of 120 meters. This significantly reduces the vehicle detection angle and would therefore result in much higher vehicle identification rates in poor or difficult lighting conditions. Lock (1993) has described the use of one such laser/digital imaging enforcement system developed in Australia. He stated that the digital image produced is significantly clearer than existing photographic images and can result in a 95% vehicle identification rate, almost twice that of existing systems. The cost of the laser based system is also comparable to that of existing radar based systems and, taking into consideration the potential increase in detection effectiveness, would represent good value for increasingly limited enforcement budget allocations.

Lock (1993) indicated that one further advantage of the use of this laser based enforcement system is that the digital imaging technology does not rely on the use of photographic film. The digital images can be stored on site or can be sent directly to a central processing location almost immediately after an offence has been detected. This significantly increases the efficiency of processing operations due to reductions in film collection and processing times and would allow speed infringement notices to be sent out to offenders in less than half the time of existing radar based systems. Lock (1994) has also indicated that the system can be used in high volume multiple lane traffic situations via the use of several laser detection devices linked to the one digital imaging unit.

Video based detection systems

A number of fully automated, video based detection systems have been developed and trialed in Australia. These systems, based on digital imaging technology, have the capacity to operate remotely on a continual basis and automatically produce a speed infringement notice without the need for a human operator (Tziotis, 1990). The system is able to transmit the image generated by an infringing motorist directly to a central processing site where, the vehicle identification is automatically determined and verified and an infringement notice issued.

One such system being trialed in Australia is Safe-T-Cam (Safety Camera). This digital imaging system which incorporates target classification, scene analysis and Optical

Recognition software has the ability to automatically recognise vehicle registration number plates and can be linked to vehicle registration databases to allow for the automated issuing of speed infringement notices (Roads and Traffic Authority of New South Wales, 1992). This system is presently designed to target heavy vehicles but can be used to detect any category of speeding vehicle.

The Safe-T-Cam system consists of two digital cameras, an infra-red flash unit and a range of associated computer software and processing equipment. The first camera, described as the 'classification' unit, is equipped with software to detect any difference in the current image from the 'normal' traffic free background (Roads and Traffic Authority of New South Wales, 1992). When the system detects a target, it calculates:

- the size of the object (to decide if the vehicle detected is an appropriate target to be imaged - such as a truck, car or motorbike), and

- the speed of the vehicle (to trigger the flash and the second camera when the vehicle is at an appropriate point).

The second, 'acquisition' camera takes an extremely detailed high resolution image (1024 x 1024 pixels) of the front of the vehicle. The image is processed by scene-analysis software and the vehicle registration number plate is located. The acquired vehicle registration number plate is then scanned by Optical Character Recognition software and the number plate deciphered.

4.5.2 Vehicle Based Enforcement

The detection of speeding motorists has traditionally been undertaken by the use of some form of vehicle based speed measurement device. Typically, radar based systems are used but computerised time/distance measurement systems, for use in mobile enforcement mode, are becoming increasingly popular. Vehicle based radar systems have a number of advantages, including the fact that they are usually small and portable and well liked by police operators due to their simplicity of use (Fitzpatrick, 1991). The main advantage of these devices is the fact they can be used in both mobile and stationary enforcement modes. This increases the level of deterrence because motorists know that any police vehicle has a potential speed enforcement capability (Armour, 1984).

The main disadvantage of vehicle based enforcement systems is the fact that they are not well equipped for high detection rate operations and are rarely used in a mobile automated enforcement mode (Sherrod, et al., 1991). When a speeding motorist is detected the normal procedure is to stop the motorist and issue a speed infringement notice. Where stopping the motorist is not possible, due to traffic congestion or unsuitable roadside locations, the vehicle registration details are recorded and an infringement notice mailed to the owner. This reduced enforcement capability limits the number of speeding motorists apprehended and results in low levels of deterrence because motorists perceive the risk of detection as being small (Teed & Lund, 1993).

4.5.3 Fixed Site Enforcement

Fixed site enforcement operations are typically associated with the use of automated enforcement systems. When used for this purpose, fixed site operations can take one of two forms (Blackburn et al., 1989). The first type of operation involves sites where enforcement devices are permanently fixed, and usually not manned by police personnel.

The second type of operations involve sites where automated speed enforcement devices are temporarily set up for a certain length of time, and are usually, but not necessarily, manned by police personnel.

Permanent fixed-site operations can deter speeding behaviour at the enforcement site and can be effective in reducing speeding behaviour at identified high accident areas (Nilsson, 1992). However, because such sites are visible to motorists, and permanently fixed, their effect on speeding behaviour is usually only confined to the enforcement area. Rotating an automated detection device among a series of fixed housing installations, which are strategically positioned along a roadway, may be one possible solution to the problem of site specific deterrence. Motorists have no way of knowing which site or sites have a device fitted and hence modify their speeding behaviour over the entire length of the treated roadway (Blackburn et al., 1989).

Temporary fixed site operations can result in area wide deterrence because motorists have no way of knowing where enforcement sites are located and hence modify their speeding behaviour to avoid possible detection. This type of automated enforcement is best suited to urban traffic situations where specific or area wide speed deterrence are the primary objectives. Bourne and Cooke (1991) have also suggested that in order to be an effective deterrent, such speed enforcement operations should be highly intensive and well publicised.

There is increasing debate regarding whether or not temporary fixed-site enforcement locations should be highlighted with temporarily erected warning signs. Bodinnar (1993) has suggested that warning signs may have merit if the intention of enforcement operations is to deter speeding behaviour at selected high accident locations, as well as to deter potential speeders by highlighting the fact that enforcement is active. However, if the objective of speed enforcement operations is to create an area-wide deterrent effect, by apprehending a large number of motorists, then signs warning motorists that they are approaching an enforcement site may compromise this deterrence objective because motorists may only modify their behaviour at marked enforcement sites.

Fixed-site enforcement operations can also be manned or unmanned by police personnel. In some jurisdictions there is a requirement that the detection equipment is continually monitored by a police officer, and that all recorded speeding offences are visually verified. Automated enforcement devices are designed to increase police efficiency and Blackburn et al., (1989) have suggested that manned enforcement operations may be unnecessarily resource intensive, especially given the proven reliability of such devices and the fact that captured images are already verified at a Later stage during the offence notification process.

However, one of the main problems with unmanned enforcement operations is that the detection equipment may become the target of some form of public vandalism. Incidents of vandalism have been documented in many countries and the resulting cost in replacing damaged or destroyed equipment can be quite high (Fitzpatrick, 1991). The type of vandalism incidents reported include spray painting of the camera lens, pouring of flammable liquids into the camera housing, shooting incidents and even one reported case in Sweden involving high explosives (Nilsson, 1993).

4.5.4 Aerial Enforcement

Aerial speed enforcement is one further means of detecting speeding motorists. This type of enforcement has several advantages over traditional approaches relating mainly to the fact that speeding behaviour can be detected from much further away and over a far longer distance. It is also unpredictable and difficult to detect because the attention of the driver is usually focused on the immediate road environment and not what is happening above them (Saunders, 1978).

Aerial speed surveillance involves a police aircraft (fixed wing or rotary) flying over a series of fixed distance grid lines (usually between 500 and 1000 meters) marked on the road surface. An operator in the aircraft determines vehicle speeds on the basis of the time taken for the vehicle to travel between-two marked grid lines. When a speeding vehicle is detected the operator provides a ground unit with relevant vehicle identification features who then proceed to apprehend the offending driver (Kearns & Webster, 1988).

In a study examining the halo effects of various speed enforcement techniques, Nilsson and Sjorgen, (1982) reported that the longest enforcement time-halo effect was generated by helicopter surveillance. When compared to other enforcement techniques including radar and marked and unmarked vehicles, they reported that the helicopter surveillance resulted in a 17 day time-halo effect as compared to a 10 day effect due to radar based and marked vehicle enforcement and no effect for an unmarked vehicle.

Several studies have been undertaken in Australia which have specifically examined the effect of aerial enforcement on speeding behaviour. Saunders (1978) reported on aerial enforcement operations undertaken in Western Australia. The most interesting finding was that the enforcement zone itself had a significant effect on speeding behaviour. Average vehicle speeds were reported as having dropped by an average of 9 km/h in the marked zone even though there had been no enforcement activity at the enforcement site for the preceding two months.

Several studies (Norrish, 1986; Cairney; 1988; Kearns & Webster, 1988) have been undertaken in relation to aerial enforcement operations in the Australian State of New South Wales. Norrish (1986) examined eight aerial enforcement sites and reported that mean vehicle speeds had been reduced from between 1.8 km/h and 8.5 km/h. Cairney (1988) in a similar study often aerial enforcement sites and five control sites also reported a reduction in mean speeds ranging from 1 km/h to 4.7 km/h.

The most extensive study relating to the effects of the New South Wales aerial enforcement program was undertaken by Kearns & Webster (1988). They examined road accident data for an 11 month period for 14 experimental and 14 control sites. They reported a 23% reduction in accidents at the experimental sites during daylight hours and a 21% reduction at other times, when compared to accident data from the control sites. They also estimated the cost effectiveness of the program based upon estimated injury savings and speeding fine revenue and the costs associated with the policing operations and associated publicity. They concluded that the benefit cost ratio for the program was approximately 12 to 1.

4.6 INCREASING ENFORCEMENT EFFICIENCY

Automated enforcement is generally regarded as one of the most effective means of deterring speeding motorists. However, there are a number of other possible approaches

which have been used as a means of increasing the overall efficiency and effectiveness of policing operations. Underlying the majority of these approaches is the need to increase the level of speed enforcement deterrence whilst, at the same time, ensuring that the associated activities remain effective in terms of both human resources and actual cost. The use of selective enforcement strategies and more specifically targeted enforcement related publicity are two such approaches which have been found to achieve both deterrence and efficiency objectives.

4.6.1 Better Spatial Deployment of Resources

The manner in which policing resources are deployed within the road traffic network has been identified as an important factor in the attempt to increase the effectiveness of speed enforcement operations. Using traditional enforcement methods to effectively police the entire road traffic network is considered to be an impossible task. A number of researchers have suggested that the strategic deployment of available resources at key locations within the traffic network is one method of maximising the effectiveness and deterrent potential of speed enforcement operations.

Armour (1984) suggested that police deployment should be such that drivers have maximum uncertainty as to where police vehicles will be located, and that a large proportion of drivers see policing operations as often as possible. She stated that these requirements seem to suggest the need for some type of random allocation of policing resources with enforcement activities targeted at those locations where speeding behaviour was know to be a causal factor in road traffic accidents.

A number of early studies (Bankhead & Herms, 1970; Rutherford, 1971) used accident records as a guide to the deployment of traffic policing resources. Locations were selected on the basis of accident history and whether or not speed was considered to be a major factor contributing to the high number of accidents. These locations were then targeted by the police using highly visible enforcement operations. The results of both of these studies were encouraging, showing reductions in both the number of speeding drivers and the actual number of traffic accidents.

The reported success of these types of enforcement programs studies have led to the development of what are collectively known as selective enforcement strategies. The underlying principle of these types of enforcement strategies is that available policing resources are systematically and randomly allocated to various locations within the traffic network on the basis of where enforcement is most required to bring about a reduction in the number of accidents and level of risk taking behaviour.

Selective enforcement appears to modify road user behaviour in two ways. Firstly, the presence of police at high risk accident locations at different high risk times reduces the level of deviant behaviour and hence the potential for an accident situation to occur (Roope & Brackett, 1981). Secondly, the random deployment of police, over a long period of time, at particular locations and on certain stretches of road, can create a level of expectancy among road users that enforcement may be present (Leggett, 1990). This may also lead to an increase in vigilance and the level of awareness of drivers resulting in more responsible and law abiding behaviour.

Selective enforcement strategies are typically designed to create a high level of deterrence at particular high risk accident locations within the traffic network. Leggett (1990) has described the use of a different type of randomised selective enforcement strategy designed

to create a larger area wide deterrence effect. He documented the use of a long term, low intensity police enforcement strategy in Tasmania, Australia. The aim was to use random deployment scheduling methods to enable low levels of police enforcement to achieve an area wide reduction in the level of speeding behaviour as well as a reduction in general offence and accident rates.

This strategy involved the visible deployment of single stationary police vehicles on each of three contiguous stretches (between 16 km and 20 km) of rural highway, selected on the basis of high accident rates. Each stretch of highway was divided up into smaller, one kilometre sections with the nominated police vehicle (one vehicle for each stretch of highway) being randomly allocated to one of these smaller sections for a two hour period during high accident times of the day (between 3 pm and 11 pm). The actual program deployment schedule involved three site visits per week over a two year period, on each of the three stretches of rural highway.

The selective enforcement strategy was reported as having resulted in a significant reduction in the level of speeding behaviour and a significant 3.6 km/h reduction in overall mean travel speeds. However, the most impressive finding was a large, significant reduction of 58% in serious casualty accidents (fatal and hospital admission accidents).

Based upon reported accident reduction benefits and the costs associated with program administrative and vehicle deployment, it was estimated that the two year selective enforcement program had resulted in a benefit-cost ratio of four to one.

Rothengatter et al. (1985) have also reported on the use of a targeted selective enforcement strategy. They described the combined use of three types of enforcement techniques, intermittently deployed over a two week period, on two roads in The Netherlands. The three enforcement techniques adopted included:

- the use of two mobile police vehicles, the first an unmarked vehicle used to make radar speed checks of offending drivers, and the second, visible vehicle, located several hundred meters further along in the traffic stream being used to apprehend identified speeding drivers;

- the use of a visible stationary police vehicle on the side of the road; and

- the use of two visible police motorcycles who alternately stop and wait until the other has passed thus creating the impression of high enforcement activity.

Rothengatter et al. (1985) reported a 10% area wide reduction in the proportion of motorists exceeding the posted speed limit. However, the short duration of the study period made it impossible to determine any accident reduction effects that might have resulted from the selective enforcement program.

Optimisation Strategies of Policing Resources

Police resources for enforcement tasks can be limited and the development of a special strategies to maximise available policing resources on the basis of the enforcement tasks required may have considerable potential. One use of such a strategy has been documented in the Netherlands by De Waard et al. (1992). In a three month experiment a special optimisation strategy was used for enforcement of speeding on highways. During the experiment police speed enforcement was undertaken on four work-days per week between

10.00 am and 3 am. Unobtrusive radar checks (speed cameras) were combined with obtrusively holding up offenders (actually stopping offending motorists).

The optimisation strategy required that the intensity of stopping of speed violators was systematically related to the percentage of offenders. It was agreed that the police should take care that the percentage of offenders (defined as those who drover over 130 km/h on highways with an 120 km/h limit) did not exceed a 6% tolerance level. The actual stopping of offenders was varied in a number of steps: stopping every sixth, tenth or twenty fifth offender or no stopping at all (sending home mailed warrants only). If the percentage of offenders in a particular week was below 6%, the intensity of enforcement was lowered one step the next week. When the intensity of offending returned above the 6% level, the frequency of holding up offenders was taken up one step again.

In the first week of the experiment every sixth offender was stopped. In the second week, the stopping of every 10th offender was sufficient to prevent the number of drivers exceeding the 6% tolerance level. In the last five weeks of the experiments a limited effort - stopping every 25th offender - was sufficient to return the percentage of offenders to a level below the tolerance limit. Equally important was the fact that resources were indeed spared. In the first three weeks of the experiment, teams of 8, 6 or 4 police officers had to be present at the enforcement location. In the other 9 weeks 1 to 3 police officers were mostly enough.

4.6.2 The Use of Publicity

The use of publicity to support speed enforcement operations is generally considered to be a proven method of increasing the effectiveness of such activities. The main benefit of using publicity it that it increases the perceived risk of apprehension and the level of general deterrence by highlighting and raising community expectation that additional enforcement activities will be encountered. Homel (1988) stated that this increase in the deterrent effect of enforcement is further reinforced when road users actually observe the publicised changes in policing practices such as noticeable increases in traffic policing activity.

However, Ross (1982) cautions that if drivers do not observe the publicised changes then any potential benefits may be compromised because drivers soon learn that the reported increase in the risk of apprehension does not necessarily mean an increase in the actual risk of apprehension. This proposition is supported by Havard (1990) who stated that if publicised enforcement is not encountered after a certain length of time then driver behaviour soon begins to revert back to pre-publicity driving behaviour. The majority of evidence suggests that whilst publicity can increase awareness and change attitudes towards speeding behaviour it has only a minimal effect on actual speeding behaviour (Elliott, 1993). Fildes and Lee (1993), in a review of the evidence, concluded that publicity should not be used as the sole medium for eliciting a reduction in driving speeds, but rather as a supportive environment for other activities.

The combined effectiveness of publicity and speed enforcement has been well documented. Riedel et al. (1988) examined the impact of publicity on a selective enforcement speed program in The Netherlands. They found that publicity alone resulted in a 27% reduction in the number of speeding motorists as compared to the pre-study speeds. When speed enforcement operations and publicity were combined the number of speeding drivers was reduced even further to 35% as compared to the pre-study speeds. Although these results indicate that publicity alone was more effective than enforcement it

is important to note that the publicity alone period lasted for only one week and it was therefore likely that the initial high level of driver expectation, that enforcement would be present, was the cause of the large reported change in speeding behaviour.

Harrison (1987) examined the impact of site specific publicity relating to the use of speed cameras at two locations in Victoria, Australia. At one enforcement site speed camera operations were highly publicised whilst at the other site there was no associated publicity.

The results indicated that at the publicised site there was an average 32% reduction in the number of speeding drivers. Although it was expected that drivers would reduce their speed once they were informed about the exact location of a speed camera site, the size and duration of the speed reductions was seen as strong evidence to support the combined use of publicity and speed enforcement at known high accident locations.

Cameron et al. (1992) provided details of a comprehensive evaluation of an automated enforcement program in Victoria, Australia. They examined the effect of automated enforcement on accident frequency and injury severity. The results of this evaluation indicated that when high levels of general media publicity about the speed camera program began, there was an initial significant reduction in the frequency of casualty accidents (and a smaller non-significant reduction in the injury severity of casualty accidents), which was independent of an actual increase in the level of speed camera enforcement.

However, the greatest reductions in accident frequency and injury severity occurred during periods which included the combined use of high levels of enforcement and high levels of publicity. These results suggest that media publicity can be an effective means of initially raising and then maintaining community awareness of speed camera enforcement operations but that the greatest speed reduction benefits result from the enforcement operations themselves.

One further benefit associated with the use of publicity is that it can increase community awareness and support of the need to use traffic law enforcement. Elliott (1993) stated that community acceptance of enforcement plays an important role in the process of moderating road user behaviour and suggested that media publicity can be used to create a desirable supportive climate of opinion in which new enforcement measures can be introduced. This proposition is supported by Freedman et al. (1990) who found that media publicity was a factor in creating high awareness and community support for the use of speed cameras.

The type of medium used to convey publicity material has also been identified as an important factor in determining its effectiveness. Rooijers (1988) found that behaviourally orientated publicity messages, rather than those that stressed attitudinal change, resulted in the largest reduction in speed behaviour intentions. In a study undertaken by Leidekerken and van der Colk (1990) television was shown to be the most effective medium for eliciting change, compared to other mediums such as roadside billboards. The use of local media has also been shown to play an important role in the process of behavioural change as it allows the public to identify more closely with the publicity and associated enforcement activities being conducted.

The Combined use of Publicity and Other Measures

In the Netherlands a series of field experiments has been undertaken to investigate the effects of police enforcement, alone or in combination with other measures, on speeding in

built-up areas where a speed limit of 50 km/h is in effect (Rooijers, 1990, 1991). Three experiments were undertaken in the city of Rotterdam, two in the city of Amsterdam. In each experiment, the measures were tested on one specific road, whereas another road served as control location. The police enforcement in both cities consisted of three or four periods of radar checks per week, each of 4-hour duration, with offenders obtrusively stopped by the road side and issued with an infringement notice. In Rotterdam the sequence of measures that was adopted included:

a. introduction police enforcement;

b. introduction of publicity; and c. police enforcement together with publicity.

c. police enforcement together with publicity

In Amsterdam the sequence of measures employed was as follows:

a. introduction of collective feedback (publicly reporting the percentage of car drivers who did not drive over the limit - in fact the percentage of drivers who didn't drive faster than 60 km/h on roads with a50 km/h limit was reported);

b. combination of collective feedback and rumble strips across the roads; and

c. a combination of feedback, rumble strips and police enforcement.

Before, during and after the experiment, the driving speeds of motorists on the 'testing' road and on the 'control' road were continuously registered by means of an induction loop-detector.

The authors themselves note some limitations of their research. In the experiments, the measures adopted were only in use for a period of four of five weeks. A longer continuous use, or repeated use of these measures on the same locations might show different effects on speeding behaviour. Furthermore, the introduction of various measures in successive stages may result in the risk of sequence effects. Keeping these reservations in mind, the following conclusions can be drawn from the results of these experiments:

1. The speed-reducing effects of police enforcement alone were relatively small and short-lived. Publicity alone was more effective in reducing speeds then enforcement alone. Police enforcement together with publicity can bring about reductions in mean speeds of about 4 to 6 km/h. Of course, during the actual police-controls there was a considerable reduction in mean speeds. However, the travel speed of motorists soon reverted back to pre-test levels shortly after the end of the controls. A level of enforcement of three or four 4-hour controls every week is apparently not enough to bring about a meaningful level of general deterrence.

2. When the effects of the diverse measures (publicity, enforcement, rumble strips, collective feedback), are considered in isolation, the rumble strips brought about the largest reduction of speeds (about 7 km/h reduction in mean speeds).

3. As additional measures to rumble strips, police enforcement and collective feedback can bring about an extra reduction of speeds.

In their discussion of the results the authors warn against the thoughtless use of various measures to control speeds. If a large majority of car drivers do not accept the existing

speed limit and perceive a discrepancy between the limit and their experience of the road environment, then the introduction of police enforcement or other measures will probably have small or even adverse effects. They concluded that questionnaires should be undertaken in advance of any speed control measures in order to examine drivers' perceptions and experiences regarding certain road stretches.

4.6.3 Tolerance Levels on Speed Limits

In many jurisdictions the enforced speed level is somewhat higher than the posted speed limit and as a result of these speed tolerance levels, many drivers who are marginally exceeding the posted speed limit are not apprehended. Tolerance levels differ from one jurisdiction to the next depending upon factors such as legal requirements or equipment used. In Australia, speed tolerance levels of 10% plus 3 km/h above the posted speed limits or a fixed margin of 10 km/h are common policing practice.

Fildes and Lee (1993) provided a number of reasons why tolerance levels were introduced. Firstly, the measurement of speed for prosecution is controversial among the courts. Secondly, police compensate for likely challenges to offences by allowing a tolerance for speedometer error and inaccuracies in the speed measurement equipment. Finally, as well as maximising the likelihood that police evidence will stand up in court, this practice also promotes good will among motorists because enforcement efforts target high-risk speed offenders.

Nilsson (1990) has argued that the existence of tolerance levels undermines the credibility of speed limits because they become artificially inflated as the general public becomes aware of the tolerance level adopted. He added that lowering tolerance levels may actually increase the level of deterrence by conveying the message to drivers that no form of speeding behaviour is acceptable. He concluded that drivers simply add the tolerance level to the posted speed limit to arrive at their desired travel speed, and further, that this accepted limit is often regarded as a guide to minimum speed.

Andersson (1989) has evaluated the effect of a 3 km/h to 5 km/h reduction in tolerance levels on speeding behaviour in two test areas in Sweden in 1987. He compared the reduction in mean travel speed between the t\VO study areas and a number of unchanged control areas. He reported a small 0.8 km/h to 1.2 km/h reduction in mean travel speed in the test areas as compared to a 0.5 km/h increase in the control areas. In a follow-up roadside survey he found that between 20% and 30% of drivers knew about the new tolerance limit. One further interesting finding was that 70% to 80% of all drivers interviewed thought that the police tolerance levels for speed should be lower.

Fildes and Lee (1993) indicate that there is no simple solution to the problem of tolerance levels and the need to maximise deterrence. 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 in the courts by motorists and their legal representatives seeking to have charges dismissed on technical grounds. They concluded that the only realistic solution, for this problem, seems to be the adoption of minimal tolerance levels in conjunction with rationalised speed limits based on appropriate and acceptable travel speeds.

4.7 NON- ENFORCEMENT BASED APPROACHES

In addition to the range of enforcement based countermeasures available to authorities, there are also a range of non-enforcement based options which have been identified in the research literature as possible alternatives, or supplementary means of modifying speeding behaviour. These options are based on the principle of rewarding drivers for appropriate behaviour rather than punishing speeding behaviour. They can involve the use of intrinsic rewarding strategies or the introduction of incentive programs which offer recipients the opportunity to obtain some form of reward for appropriate driving behaviour.

4.7.1 Public Posting of Speed Information

The public posting of speed information to provide road users with feedback regarding the level of speeding behaviour, at particular locations within the traffic stream, has also been shown to have some success in reducing excessive travel speeds. These speed information signs typically provide an indication of the proportion of drivers exceeding or adhering to the posted speed limit for a certain time period (usually that day or that week). Bower (1992) suggests that the aims of such signs are to provide drivers with feedback about recent group compliance, set appropriate driving standards, provide a common behavioural reference point and to prompt lawful drivers to reward themselves by noting that they are contributing to the group welfare. Additional benefits include a visual reminder to motorists to think about the speed at which they are driving and to remind them about the possibility of police enforcement in the area (Batini & Maisey, 1990).

Van-Houten and Nau (1983) examined the effect of a speed information sign on speeding behaviour in Canada. The sign (DRIVERS NOT SPEEDING YESTERDAY --%. BEST RECORD -%) was found to be more effective than traditional enforcement methods at reducing speeding behaviour and its level of effectiveness was still evident six months after it had been installed. Maroney and Dewar (1987) undertook a similar evaluation of the same information sign. They found that the number of drivers exceeding the speed limit by at least 16 km/h decreased from 25.2% to 15%. One interesting result was that the higher the rate of change in the displayed percentage values on the information sign (either direction) the lower the proportion of drivers who exceeded the speed limit. This infers that drivers were, in fact, modifying their speeding behaviour in direct response to feedback obtained from the information sign.

Several studies examining the effectiveness of speed information signs have also been undertaken in Australia. Batini & Maisey (1990) examined the impact of one such sign (DRIVERS SPEEDING LAST WEEK --%) in the city of Perth, Western Australia. They reported that the proportion of motorists exceeding a 60 km/h speed limit by 20 km/h or more fell from 11% to 4% and remained significantly lower for the 6 month study period. They also reported a 50% reduction in speed related accidents but stated that the small number of accidents made meaningful statistical evaluations difficult. They concluded that the speed information sign, when used in conjunction with normal enforcement activities, was a cost effective means of reducing speeding behaviour.

Rogerson (1991) evaluated the effect of a number of speed information signs (DRIVERS NOT SPEEDING LAST WEEK --%) in Victoria, Australia, on a particular section of road where over 90% of drivers were exceeding the legal 60 km/h speed limit. They found that the proportion of drivers who were exceeding the posted speed limit by 15 km/h or less fell by 1 %; the proportion of drivers exceeding the posted speed limit by 30 km/h or less fell by 5%; and finally the proportion of drivers exceeding the posted speed limit by over 30

km/h fell by 26%. She reported however, that the speed reduction effects quickly dissipated and therefore questioned the cost effectiveness of using such speed information signs.

Fildes and Lee (1993) have suggested that speed information signs may be more effective if targeted at individual speeding behaviour. They indicated that the large majority of motorists do not perceive themselves to be 'average drivers' and therefore population information may have little effect on their subsequent behaviour. They suggest that dynamic roadside displays showing local instances of excessive speeding, immediately after it has occurred, may act to embarrass those individuals into modifying their speeding behaviour. The aim of such an approach being to focus attention on the inappropriate behaviour of individual motorists.

One such system based upon the principle of targeting individual speeding drivers has been described by Fitzpatrick (1991). This system, operating in the American State of Texas, incorporates the use of a portable billboard speed display to show drivers what their speed is in relation to the posted speed limit. The system was reported to reduce the speed of over 90% of all motorists who were exceeding the speed limit and when a police patrol was located a short distance beyond the billboard the issuing of a speed infringement notice was better accepted by the speeding motorist. One further reported benefit was that the use of the billboard display resulted in positive community and police reactions.

4.7.2 Rewarding Strategies

Speed enforcement strategies are based upon the principle of negative reinforcement.

Drivers know that if they are detected speeding they will receive some form of punishment. The use of rewarding strategies based upon the principles of positive reinforcement have been identified (Wilde & Murdoch, 1982; Wilde, 1988; Cairney & Townsend, 1991) as a possible alternative approach to punishment based enforcement strategies. Cairney & Townsend (1991) have stated that positive reinforcement can be a very effective way of establishing and maintaining appropriate speeding behaviour. They suggest that low probabilities of reinforcement, including situations where a driver is rewarded on only a few occasions, have been shown to be particularly effective in resulting in behavioural change.

There is an impressive array of psychological literature that indicates that positive reinforcement is a more effective means of modifying human behaviour than negative reinforcement. In the area of road safety research, incentive programs for promoting seat belt wearing have been shown to be extremely effective (Cope et al. 1986; Geller et al., 1987; Hagenzieker, 1991). Given that the primary objective of all speed control strategies is to reduce the level of speeding behaviour it is, therefore, extremely surprising that there is no documented evidence of rewarding strategies being used for this purpose.

Hagenzieker (1993), in a research proposal to the Dutch Government to undertake a speed incentive study, has questioned why no attempts have been made to examine the effect of incentive programs on speeding behaviour. She stated that the documented evidence relating to the benefits of incentive programs and their relative low cost in relation to existing enforcement based strategies as well as their overall ease of implementation make them a potentially promising area of future speed related research.

Wilde (1990) has also questioned the reasons why incentive based road safety programs have not been more actively encouraged. He suggests that Governments are often reluctant to try new approaches to social problems especially when such approaches are contrary to existing political views and opinions. They may also be reluctant to reward drivers for what authorities already consider to be appropriate road user behaviour. However, Wilde (1990) suggested that when the proportion of speeding motorists far outnumbers the proportion of those drivers who do not speed it may be better to reward the few, rather than trying to 'punish the majority.

Although there have been no evaluations of incentive programs relating to speed control, there are a number of studies which have demonstrated their effect on road safety. Wilde and Murdoch (1982) have shown that, under a variety of conditions, rewarding safe driving behaviour can result in significant improvements in driver accident records. Rewarding strategies, based upon some form of financial incentive, were found to reduce the number of traffic offences committed (between 20% and 50%) by an experimental group of drivers when compared to a matched control group. Drivers indicated that they were better able to relate their driving behaviour to some form of positive incentive rather than to existing sanctions for inappropriate driving behaviour.

The potential benefits and use of insurance related incentives for safe driving have also been identified by a number of researchers (Wilde & Murdoch, 1982, OECD, 1990; Vaaje, 1990). Reductions in insurance premiums for accident free driving are now a common practice among many insurance companies. Wilde (1990) has stated that well publicised and more meaningful insurance incentive programs can play an important role in modifying driving behaviour. Vaaje (1990) described one innovative insurance based incentive program presently operating in Norway. He reported a significant 35% reduction in accident rates among a group of drivers aged between 18 and 22 years when they were offered a total refund on the extra premiums, paid by young drivers, after a period of accident free driving.

Elliott (1992) has also proposed the use of financial incentive strategies to reward drivers who have a long driving history with no speeding offences. He suggested that drivers, who have incurred no penalties after 10 years, could receive either some reward such as a substantially reduced insurance premium or a discount on the cost of licence renewal. A number of other researchers (Arnold, 1989; Fuller, 1990) have also advocated the use of rewards for appropriate driving behaviour and suggested that publicity relating to such incentive schemes, including the naming of reward recipients, may also improve the effectiveness of incentive based strategies.

Rewarding strategies, based upon the provision of financial incentives have led some researchers to question the cost effectiveness of such programs. Wilde (1990) stated that incentive programs do result in financial benefits and suggested that the increasing use of such programs by industry was clear evidence of this fact. He stated that the introduction, by many large corporations, of reward based incentive programs, to encourage safer driving in the workplace, was a strong indicator of potential cost savings. Wilde & Murdoch (1982) reported on one such industry based incentive program, concluding that the ratios between benefits (savings on accidents prevented) and program costs were greater than two to one.

4.8 LEGISLATIVE CONTROL OF SPEEDING BEHAVIOUR

There is little doubt that police enforcement activities targeted at the speeding driver are an important element in the process of controlling the level of speeding behaviour. This is clearly demonstrated by evidence from Finland (Summala, 1980) showing that the number of serious speeding offences, committed by drivers in Finland, increased by between 50% and 100% during a two week police strike in which almost no traffic enforcement took place.

The legislative controls related to speeding can also play an important role in the process of deterring and modifying driver behaviour. Legislation can be used to support and improve the effectiveness of enforcement activities but it can also, in its own right, be an effective means of deterring speeding behaviour. Legislative control of speeding behaviour can take one of several forms, including; specifying the type of penalty incurred, defining appropriate speed limits and regulating the social and physical environment in which speeding behaviour takes place.

4.8.1 Legal Sanctions

The threat of punishment is a central component of deterrence based policies which are aimed at reducing the level of speeding behaviour. The type of sanctions administered to the speeding driver are considered to be an important determinate in the process of behavioural and attitudinal change (Mäkinen, 1988). However, in many Western countries speeding offences are considered to be only minor misdemeanours and sanctions are generally quite small. Legal sanctions can take one of several forms including warning letters, fines, loss of demerit points and licence suspension actions. More severe sanctions, such as imprisonment, are rarely considered by legislators which may, in part, reflect the concessionary attitude towards speeding drivers in Western society (Hillman & Plowden, 1986).

Warning Letters

The use of warning letters for more minor speeding offences has been advocated by a number of researchers (Roulston, 1973; Armour, 1984; Wilden et al, 1989; Southgate & Mirrlees-Black, 1991). These researchers have identified a number of potential benefits associated with the use of warning letters including the fairness of enforcement, the need to educate drivers as opposed to punishing them and the potential increase in police efficiency due to the amount of offence processing time saved.

Wilden et al (1989) suggested that a large proportion of drivers may actually be unaware that they have committed a speeding offence due to a lack of local knowledge, insufficient speed limit posting or poor attention to the road environment. They argued that there may be greater merit and fairness of punishment in issuing a warning letter to this type of speed offender, and by issuing more severe penalties only to those road users who blatantly exceed the posted speed limit. They concluded that police discretion in the issuing of speed infringement notices was a common practice and that in most roadside situations police officers are able to determine whether or not speeding behaviour is intentional or just a matter of poor judgement.

Southgate and Mirrlees-Black (1991) stated that traffic policing is slowly moving away from a punishment based approach and is now starting to focus on strategies aimed at education of drivers and the promotion of more appropriate road user behaviour. They

suggest that the use of warning letters for less serious offences can be an effective educational tool that leads to a more sustained modification in speeding behaviour than traditional punishment based strategies. They argue that issuing fines for minor speeding offences only causes resentment among drivers and that sending offenders a strong warning letter, explaining the type of offence detected, the location it was committed and the reasons why such behaviour is considered to be unsafe, can create more positive community attitudes towards traffic enforcement activities.

When automated speed enforcement devices were introduced in New South Wales, Australia a one month 'public education' period was initially declared. During this period, motorists who were detected committing a speeding offence were sent a warning letter but were not subject to prosecution (Croft, 1993). The aim of this initial non-offence period was to educate drivers about the way in which the speed camera operations would be undertaken and to convey the message to drivers that enforcement operations would be responsibly and fairly administered. Attitudinal surveys (Roads and Traffic Authority, 1992) indicated that this enforcement approach was generally well received and that there was a strong level of community support for the speed camera program.

The effect of warning letters on speeding behaviour has been examined by Makinen and Joki (as cited by Makinen, 1988). In a study comparing the use of different types of speeding sanctions they found that warning letters were just as effective as fines in bringing about a change in speeding behaviour. They reported an average 10 km/h reduction in speed due to the receipt of either a warning letter or fine. Speed reductions of approximately 7 km/h were still observed three months after the sanctions had been received.

Fines

Fines are the most common form of sanctions administered to drivers who are detected committing a speeding offence. In societies where speeding behaviour is commonplace, such sanctions are generally considered to be the most efficient way of dealing with speed offenders (Road Traffic Authority, 1987). However, efficient sanctions are not necessarily effective sanctions and a number of researchers have questioned the use of fixed amount fines as the punitive means of deterring and modifying speeding behaviour. Indeed, the large proportion of drivers who continue to speed after receiving a fine is strong evidence of the ineffectiveness of such sanctions (Leivesley, 1987).

Increasing the severity of speeding fines has been shown in a number of Swedish studies (Aberg et al., 1989; Andersson, 1989) to have a minimal impact on speeding behaviour. In 1982, speeding fines in Sweden were doubled and Aberg et al. (1989) examined the effect of the fine changes, on driver behaviour, using before and after speed measurements and roadside interviews with drivers. He reported that there was no detectable change in speeding behaviour even though over one third of drivers knew about the publicised fine increases. In 1987, speeding fines in Sweden were once again increased and, in a similar methodological study to that previously conducted, Andersson (1989) again reported no significant change in speeding behaviour .

Bjornskau and Elvik (1990), commented on these Swedish studies and suggested that the findings do not imply that all speeding fines should be removed, just that their severity is less important to their deterrent effect than their existence. This proposition is supported by Ross (1988) who stated that unless road users perceive the risk of apprehension and

punishment to be sufficiently high then there may be only minimal deterrence benefits to be gained by introducing more severe penalties.

Fildes and Lee (1993) have suggested that if the risk of detection is high it would be logical to assume that continual increases in speeding fines would eventually increase the perceived disadvantages of speeding so that increasingly fewer drivers would decide to speed. However, speeding fines are normally set in relation to fines for other criminal acts and substantial increases in speeding fines, for what are often viewed as relatively minor misdemeanours, may undermine other aspects of the criminal justice system (Evans, 1991). The problem with relatively low fines is the type of message conveyed to speeding drivers (Hillman & Plowden, 1986). These drivers know that their speeding behaviour is illegal, but still continue to drive in such a manner because the receipt of a fine is often regarded as little more than an inconvenience rather than a deterrent and strong message to modify their behaviour.

Point Demerit Schemes

The use of point demerit schemes has become an increasingly popular means of deterring repeat offender speeding behaviour. The majority of speeding offences do not involve high excessive speed (double the posted speed limit) and, as a result, offenders usually only receive some type of fixed amount fine. More serious sanctions are not imposed because any one of these speeding offences is regarded as a minor misdemeanour and in many countries the fine amount stays fixed regardless of the number of actual offences committed. Point demerit schemes provide a means of imposing more harsh sanctions on those drivers who frequently commit these minor fixed fine offences.

Point demerit schemes involve the allocation of a certain number of points every time a speeding offence is committed. When a driver has accumulated, within a specified time limit (usually three years), more points than the maximum number permitted then some type of additional sanctions, such as licence suspension, are imposed. Williams et al. (1992) stated that these types of schemes allows drivers to make a certain number of errors before more serious penalties result and have been introduced as a means of differentiating between different types of offending drivers and as a way of providing a regulated deterrent threat to those drivers who consistently violate traffic laws.

Dingle (1985) has identified several ways in which a point demerit scheme can effect speeding behaviour. Firstly, for those drivers who rarely speed the existence of such a scheme provides positive feedback and may be an influencing factor in maintaining a good driving record. Secondly, for those drivers who occasionally commit some form of minor speeding offence the existence of such a scheme may provide them with the necessary incentive to modify their driving behaviour in order to avoid obtaining further points and risking the chance of receiving a more severe penalty. Finally, the point demerit scheme has the greatest effect on the behaviour of those drivers who consistently speed. Drivers in this category quickly approach, and in many cases exceed, the maximum number of points allowable. They modify their speeding behaviour only when they have accumulated a sufficient number of points that the likelihood of more severe punishment becomes a meaningful and real possibility. Experience has shown (Duncan et al., 1990) that such drivers can exceed the maximum allowable number of points several times before more lasting behavioural changes occur.

It is the experience with this last group of drivers who consistently speed that has raised some questions as to the benefits of point demerit schemes. A common problem, which has

been identified, is that such schemes only appear to have a deterrent effect when a driver 'has accumulated a sufficient number of points that the possibility of licence suspension becomes a real threat. Williams et al (1992) argued that point demerit systems can actually reinforce deviant road user behaviour by conveying the message to road users that a certain number of traffic offences may be committed before a more serious penalty will result. He further added that some road users may in fact use the point demerit system as a guide to the type and number offences that they can commit before they must modify their driving behaviour to avoid more serious punishment.

However, the effectiveness of a point demerit scheme in deterring traffic offences has been clearly demonstrated by Haque (1987) in an evaluation undertaken in Victoria, Australia. The empirical results of this evaluation showed that the time interval between the commission of a second and third offence was statistically longer than that between the first and second offence. Haque (1987) concluded that the demerit points system was responsible for almost all of the deterrent effect reflected in the increased mean time before the commission of a third offence subsequent to the commission of a first and second offence. These results indicate that road users who commit a number of traffic offences, and approach the maximum allowable number of points, do in fact modify their behaviour to avoid further more severe penalties.

Licence suspension

Licence suspensions are generally regarded as the most effective form of legal sanction for repeat speed offenders and those drivers who commit more serious speeding violations. The linking of sanctions to the offending driver's vehicle is regarded (Simpson, 1990) as having both a deterrent and road safety benefit. Firstly, it provides a meaningful form of punishment and acts as a strong deterrent because it deprives the offender of a cherished privilege, namely the right to drive a vehicle. It is generally regarded that the resultant change in lifestyle, level of social embarrassment caused and the threat of more harsh sanctions, may act as a strong deterrent to modify speeding behaviour once driving privileges are reinstated.

Licence sanctions can also lead to road safety benefits because suspended high risk drivers are no longer present in the traffic stream. Although there is a large amount of evidence (Ross & Gonzales, 1988) showing that suspended drivers continue to drive during the licence disqualification period there is equally compelling evidence (Duncan et al., 1990; Mann et al, 1991) that shows that their violation rates are substantially reduced either because they drive less, or more cautiously or under conditions of lower risk. Duncan et al. (1990), in a comprehensive survey of suspended drivers, reported that although 34% of drivers knowingly drove whilst suspended, 80% indicated that they drove less, 60% indicated that they drove more cautiously and 50% indicated that they drove more slowly.

Berland et al. (1989) reported on the effectiveness of licence sanctions as a means of deterring speeding behaviour. They examined licensing and police records over a three year period to determine the reduction in the incidence of repeat speeding offences for a group of drivers who had received a period of licence disqualification. They reported a 38% reduction in the number of speeding offences committed by the licence disqualification group when compared to a control group who had received some type of fixed fine. In a series of follow-up surveys they found that a large proportion (65%) of disqualified drivers reported that they had modified their speeding behaviour in some way as a result of what they felt were strict licensing sanctions. In the fine imposed control group only 24% reported that they had made a conscious effort to change their speeding

habits and almost all indicated that the fine was not a very effective means of deterring speeding behaviour.

Duncan et al. (1990) undertook an extensive examination of the licence suspension procedures operating in Ontario, Canada. They reported that drivers suspended for committing a series of minor traffic offences (such as speeding) had lower recidivism rates but were more likely to re-offend than drivers who were suspended for more serious offences such as drink driving, dangerous driving or criminal negligence. They suggest that the length of the suspension period (average of 2.2 months for minor offences and 13.7 for more serious offences) can have a major impact upon the likelihood of a repeat offence. They found that a large proportion of drivers (58%) who had received shorter licence suspension periods indicated that they did not take them seriously. They concluded that longer licence suspension periods were taken more seriously due mainly to the threat of even more serious sanctions.

Haque (1987) reported that the actual threat of possible licence disqualification can also have a significant impact on driving behaviour. In an examination of the point demerit scheme in Victoria, Australia, he found that as motorists approached the maximum allowable number of points, before licence disqualification occurs, they committed fewer traffic offences. Similar results have been reported by Robinson and Smiley (1989) in a review of driver licence disqualifications. They indicated that the threat of licence suspensions can, in some circumstances, have a greater impact on driver behaviour than the actual imposition of the suspension itself. They concluded that licence suspensions were not only an effective sanction for dealing with convicted traffic offenders but also acted as a strong deterrent to potential traffic offenders.

4.8.2 Speed Limit Legislation

Speed limits remain the primary legislative means of imposing some control over the speeds at which motorists travel. However, speed limits are not always respected by drivers and, in such situations, enforcement is relied upon to ensure some level of compliance. The problem is that some motorists may exceed the posted speed limit because they do not understand the reason why such a limit has been set or they may feel that such a limit is inappropriate for the existing road environment conditions. This situation can occur because there are often many variables which effect the decision to impose a particular speed limit and this may lead to a large number of inconsistencies between speed limits in different areas.

The problem of inconsistent speed limits has led authorities to develop a range of innovative speed zoning and speed management practices to ensure that speed limits are perceived by drivers as being both credible and appropriate to the driving environment (Jarvis & Hoban, 1988). The development of expert speed zoning programs and the implementation of variable speed limit systems are two approaches which have generated an increasing amount of interest in recent years. These speed management approaches may provide legislators with a means of increasing the overall acceptance of speed limits, which may, in turn, result in a reduction in the level of speed related accidents and injuries.

Expert speed limit systems

The use of expert systems for determining speed limit zones has been identified as a possible means of improving the consistency of speed limits (Jarvis & Hoban, 1988). Expert systems are designed to solve complex problems in a given domain of knowledge

based upon the collective information and experiences of human experts. Jarvis and Hoban (1988) stated that such systems were ideal for the complex problem of speed zone determination because they have the capability to consider many more factors than their human counterparts, which is important, considering the large number of factors that may influence speed limit determination.

Expert speed zoning systems have been developed for use in several Australian States. The first such system called 'VLIMITS' was developed for use in Victoria. VLIMITS is an advisory tool and its use is currently not mandatory. It is widely used by authorities and has been found to be a reliable and helpful tool because it provides an objective assessment of a road environment situation and can remove a large amount of the guess work previously involved in speed limit determination. In Australia, each State has control of its own speed limits and similar expert systems to VLIMITS have now been developed for use in New South Wales (NLIMITS) and Queensland (QLIMITS).

Variable speed limit systems

One problem identified with regard to existing speed limit systems is that they are usually fixed regardless of changing driving or environmental conditions (Social Development Committee, 1991). Fildes and Lee (1993) have suggested that as the relationship between speed and safety varies with driving conditions, so too should the speed which will result in the desired balance between safety and mobility. Variable speed limits have been proposed as one possible means of addressing the problems associated with fixed speed limits and the need to modify speeding behaviour in relation to changing road environment conditions.

Poor driving conditions at night and during inclement weather are types of changing road environment situations where reduced speed limits may result in additional safety benefits.

Reduced visibility and less vehicle control are two common reasons given for lowering speed limits in adverse weather conditions. Weather related variable speed limit systems do exist in several jurisdictions but are often regarded as difficult to enforce and their main benefit may be to remind drivers to take care rather than ensuring that they reduce their speed (Stollop, as cited in Emmerson & Linfield, 1985).

Traffic congestion is one further type of changing road environment condition. Fildes and Lee (1993) have suggested that a speed limit system that varies from lower limits to normal limits consistent with optimal driving conditions could potentially reduce not only mean travel times, but also the incidence of accidents under favourable driving conditions. In The Netherlands one such dynamic speed limit system is in operation in high volume traffic areas on several major motorways. The system is primarily designed to reduce traffic congestion and improve traffic flows but is also regarded as having road safety benefits. The system incorporates the use of in-road induction sensors, to measure vehicle flow, and over the road variable speed display boards located everyone to two kilometres. The system is completely interactive and displays different speed limits at different locations within the control area so as to maximise vehicle flow.

A similar system called COMPASS, has been operating for a number of years on several freeways in Ontario, Canada. This real-time freeway traffic management system was designed specifically to improve traffic safety and congestion and is based upon principle incident detection and response. Video cameras and sensors embedded in the road surface monitor the traffic situation and relay the information to a central facility. This facility

notifies the appropriate personnel of incidents and transmits information to motorists about traffic conditions via the use of changeable overhead message signs. (Shuman, 1993).

Variable speed limit zones can also be adopted at locations within the road network where the volume of traffic and level of safety varies at different times during the day or week. School locations are one such example where lower speed limits during school hours may reduce the potential conflict between inexperienced pedestrian and vehicles. These type of variable speed limit zones have been introduced in several Australian States and have been reported as resulting in improved safety (Pak-Poy and Kneebone, 1988). Other locations that could be considered include shopping centres and central business districts, however, no evidence relating to the use of variable speed limits in these environments has been reported.

4.8.3 Advertising

Legislation targeted at regulating the content of automobile advertisements may also have the potential to change attitudes towards speeding behaviour. Pfafferott (1990) stated that in many ways automobile advertising can be in direct conflict with the objectives of road safety. The aim of the vehicle manufacturers is to increase sales and this is often done by emphasising the performance characteristics of their vehicles. He indicated that not all forms of advertising are in conflict with road safety objectives but identified those areas where there is some concern, including messages which:

- establish an attitude towards the vehicle which overemphasises its performance and dynamics of movement;
- employ self-assertion and an impulse to dominate as sales arguments; and
- extol the safety features of a vehicle, especially equipment for active safety, as a type of 'safety guarantee'.

Huguenin et al. (as cited in Pfafferott, 1990), in an extensive media analysis, concluded that automobile advertising contained far more information which is in conflict with road safety aims than information which helped to promote it. They identified the following conflicting messages: sporty driving, superior performance dynamics, thrill and risk taking behaviour, and enjoyment of driving. They added that the audience most likely to be negatively influenced by such messages was young male drivers and, considering that this group of drivers were already in the high risk bracket, advertising which promotes more high risk behaviour could only have detrimental impacts on road safety.

Pfafferott (1990) indicated that there are positive signs that vehicle manufacturers are becoming more responsible for the advertising messages. He stated that in an increasing number of European countries, Governments and, in some instances, manufacturers themselves are initiating review procedures and codes of conduct to control the content of advertising. He described measures ranging from specific Government legislation to broadcasting reviews to industry based award programs. He concluded by stating that, although no evaluations of the effectiveness of such measures have been undertaken, a more responsible and accountable motor vehicle industry must lead indirectly to improved road safety benefits.

4.9 MODIFYING THE PHYSICAL ENVIRONMENT

The primary objective of speed enforcement countermeasures is to modify speeding behaviour. In the long term, it is hoped that high levels of enforcement, in combination with other preventative strategies, will result in a change in societal attitudes towards speeding, similar to the change in public attitudes, now being observed, towards drinking and driving (Elliott, 1992). However, changing community attitudes towards speeding is recognised as a difficult and challenging task because many motorists do not perceive speeding as being a particularly deviant form of driving behaviour (Fuller, 1990).

Motorists are aware that speeding is an illegal act, due to the existence of speed limits, the enforcement activities of the police, and messages telling them speeding is an unsafe form of driving behaviour. However, their own driving experiences as well as societal values encouraging a fast and active life-style only serve to reinforce speeding behaviour which, in turn, makes it difficult for motorists to understand the reasons why speeding is a problem and the ways in which it can lead to negative road safety consequences.

The difficulty in trying to change community attitudes towards speeding together with the limited success of enforcement based countermeasures, has led a number of researchers to advocate strategies which target the 'agents' of speeding, namely the vehicle and road side environment (Hillman & Plowden, 1986; Maroney & Dewar, 1987; Cairney & Townsend, 1991). The idea behind these strategies is to reduce the level of speeding behaviour by modifying the physical environment and/or vehicle, so that it becomes impossible for a driver to speed, or by modifying the environment so that the driver perceptions of safety is reduced when travelling at higher speeds. The most common strategies for achieving this include the fitting of devices limiting the maximum speeds of vehicles, physical speed reduction road treatments and perceptual based road treatments.

4.9.1 Speed Limiting Devices

One of the major factors hindering attempts to develop effective speed management strategies is that manufacturers continue to build vehicles that can travel at speeds far in excess of the maximum posted speed limits. A number of researchers (Maroney & Dewar, 1987; Bower, 1990; Elliott, 1992) have questioned this practice, stating that if speeding behaviour is to be discouraged then more pressure should be put on vehicle manufacturers to build slower and less powerful vehicles.

The installation of a device, which artificially controls the maximum speed of a vehicle, seems to be the most promising solution to this problem. At present, a number of countries, including Britain, France and Australia, have introduced some form of legislation which requires speed limiters to be fitted to all heavy vehicles and buses. These devices limit the maximum speed achievable by controlling the supply of fuel to the engine. It would be feasible to incorporate some form of sophisticated electronic engine management system into all vehicles which limit maximum speed but allow brief periods of acceleration over the maximum speed limit for overtaking manoeuvres and avoiding potential accident situations (Fildes & Lee, 1993). Although such devices would only be of benefit in maximum speed limit zones it is generally regarded that this is where many of the speeding problems exist.

Fildes and Lee (1993) have also indicated that limiting the maximum speed of a vehicle would effectively eliminate rural speeding, and significantly reduce the need for

enforcement in these areas therefore allowing policing efforts to be focused on the all important urban speeding situation.

Sculman (1985) has described the use of a different type of speed limiting device called the deaccelerator. This device is attached to the accelerator pedal and provides very high resistance when a driver tries to depress the pedal beyond a pre-set speed limit. However, in the case of an emergency, when additional speed is required, the driver can overcome the pedal resistance by pressing with great force, therefore allowing the vehicle to increase speed. Bower (1990) has reported that this device has been successfully field-tested in a fleet of university owned vehicles driven by employees. The device was found to be operationally sound and was generally well accepted by drivers. The conclusions of the field tests were that the pedal resistance was sufficient to remind drivers of the speed limit, and the extra effort required to go faster was sufficient to deter them from speeding.

Hillman and Plowden (1986) have detailed a range of potential benefits associated with the use of speed alerting devices. They described the use of a system which incorporates a series of flashing lights inside and out-side the vehicle. The driver selects the specified speed zone and when vehicle speed exceeds that limit a visual flashing light and audible buzzer activate inside the vehicle and lights fitted at the front and rear of the vehicle also flash to warn other road users and police that the vehicle is exceeding the posted speed limit. They suggested that the greater exposure of traffic offenders by this means would be likely to generate far more observance of speed limits as drivers would not wish to be caught 'red-handed', especially if it entailed a high fine and the risk of losing their licence.

Elliott (1992) has indicated that Governments can play an important role by introducing legislation discouraging the sale of high powered vehicles. He suggested that economic penalties could be introduced in the form of an additional safety tax on the cost of all vehicles capable of speeds in excess of a certain speed threshold above the highest posted speed limit. He indicated that this tax could be in the order of $1000 for every one kilometre, in top vehicle speed, over the nominated speed threshold. This would result in manufacturers building less powerful vehicles or fitting some form of speed limiter to avoid payment of this tax and additional costs to consumers. An alternative solution, for Governments, may simply be to mandate the use of speed limiters on all vehicles.

However, the question remains whether or not drivers will be prepared to relinquish control over speed choice. Governments may also be reluctant to face the strong resistance from vehicle manufacturers and oil companies who have a vested interest in ensuring that speeding behaviour remains an option for drivers (Evans, 1991). As indicated by Plowden and Hillman (1984), powerful influences have combined to prevent the implementation of any serious measures to combat the speed problem. Governments need to ask: how serious is the problem of speed, how much speeding behaviour is tolerable and whether or not they should do everything in their power to solve the problem or just make a token effort at trying to control the situation.

4.9.2 The Road Side Environment

In recent years there have been increasing efforts to examine ways in which the road environment can be changed to reduce the speed at which drivers travel. There are two ways in which this can be achieved. Firstly, the road environment can be physically changed with the use of speed control devices such as speed humps, roundabouts and other forms of road treatments. Secondly, the road environment can be changed to manipulate the driver’s perception of travel speed, which can, in turn, result in a lower travel speed.

This second approach is based upon research (Triggs, 1986; Bower, 1990) showing that driver's speed choice is often related to their perception of speed and not the vehicle speedometer.

Physical speed control devices

The notion of controlling vehicle speeds via the use of some form of engineering modification of the road environment was first initiated in The Netherlands during the 1960's (Fildes and Lee (1993). The objectives of these schemes were to reduce the conflict between pedestrians and traffic and accommodate the needs of local residents. These early Dutch traffic management schemes, based upon the 'Woonerf design', involved the development of local resident traffic areas where pedestrians and vehicles had equal priority. The objective was to reduce vehicle speeds, through the use of various road engineering treatments such as raised pavements, speed humps, staggerings and narrowings, and to improve local amenity through the use of benches, tables, gardens and different coloured pavement surfaces.

Engineering treatments based upon the original 'Woonerf' concept are now commonly used in many Western countries. The collective term usually applied to such schemes is 'traffic calming', however, other terms often used include local area traffic management (LATM) and environmental adaptation (FORS, 1993). The primary objective of traffic calming measures is to reduce the impact of vehicles on the local environment by incorporating engineering treatments which restrain vehicle speeds and improve both traffic safety and local amenity.

Although 'traffic calming' treatments are used primarily for local traffic situations they can also be used on more major roads and incorporated in such a way as to create a larger area wide effect. In such situations careful consideration must be given to overall traffic impact and issues such as vehicle flow, network capacity and level of service need to be assessed (Brindle, 1992). Westerman (1990) indicated that the effects of speed engineering measures need to be viewed in terms of the total transportation system. While these speed management devices have the potential to stem the speed and 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. Cairney and Townsend (1991) also suggested that the overall effectiveness of traffic calming measures is, to a large degree, dependent upon good design and strategic placement of devices to reduce known accident problems.

There are numerous engineering treatments which can be incorporated to manage speed in a number of different situations. Armstrong et al. (1992) listed some 46 devices that have been used in various locations throughout Australia and still many more devices may be used in other countries. A description of each of these devices and their potential effect on speed is not possible in the context of this review. However, a brief overview of two of the most common treatments, speed humps and roundabouts, may serve to demonstrate how such devices can be used to manage vehicle speed.

Speed humps and raised road pavement sections are common measures adopted in many countries and have been reported (Engel, 1990) to have brought about the greatest change in speed behaviour, as compared to other speed control devices. Speed reductions in the order of 10 km/h to 45 km/h (dependent upon the pre-installation speeds) at such devices, and from 5 km/h to 25 km/h between such devices, have been reported (Stephans, 1986). Roundabouts are one additional speed control measure which can be used to break up

lengths of road that might otherwise encourage speeding behaviour (Fildes & Lee, 1993). Engel and Thompson (1992) reported speed reductions in the order of 30% to 65% at treated sites with the size of the reduction dependent upon the type of manoeuvre required to negotiate the roundabout.

The use of speed management devices to produce an area wide traffic calming effect have been shown to have major road safety and cost benefits. Ho and Fisher (1988) estimated the cost effectiveness of various traffic calming measures, reporting benefit cost ratios ranging from 1.5 to 1 for less speed restricting devices to as high as 6.8 to 1 for more severe speed treatments. Fisher and Van den Dool (1989), in an evaluation of over 65 treatment sites, reported that traffic calming devices were able to reduce traffic speeds, volume and accidents. They concluded that such devices were cost effective (benefit cost ratios above two to one) and resulted in accident and amenity reductions of approximately 50%. Similar results were reported by Chua and Fisher (1991) in an evaluation of an area-wide traffic calming scheme in Sydney, Australia. They reported significant reductions in accidents (50%), through traffic (35%) and speeding (25%). In the United Kingdom, Mackie et al. (1990) undertook an evaluation of the effects of area wide traffic calming treatments in five residential suburbs. They reported a 10% to 15% reduction in injury accidents and associated costs when compared to several matched comparison areas.

Perceptual speed control measures

Fildes and Lee (1993) have identified the use of perceptual countermeasures as a means of reducing the level of speeding behaviour. They suggested that environmental manipulations can effect a driver's perception of speed without requiring deliberate decisions to comply (such as manipulations that influence the pre-conscious perception of speed). Fildes et al. (1989) have argued that such speed control measures are likely to have long-term benefits because of the unobtrusive nature in which they influence a driver's perception of speed (they operate without the driver's awareness or need for action). Additional advantages are their low cost of application and the fact that they do not require the introduction of additional physical hazards on the road surface.

The most common of these perceptual treatments is the use of transverse lines marked on the roadway at the approach to roundabouts and intersections. Fildes and Lee (1993) stated that these treatments have been shown to have desirable long-term speed reduction benefits in both the United Kingdom and Australia. Maroney and Dewar (1987) reported on the use of a transverse line treatment across an exit ramp of a freeway in the city of Calgary, Canada. Over a three week period they reported a 2 km/h reduction in mean speed which was consistent across each hour of the day and each day of the week. The most impressive finding was a 25.5% reduction in drivers exceeding a pre-set 80 km/h speed reference point. They explained this significant increase in terms of increased attentiveness of drivers approaching the exit ramp intersection.

A range of other possible perceptual countermeasures that have been identified by Fildes et al. (1989) and include:

- lane width reductions - evidence suggests that reduced lane widths on particular types of roads can lead to speed and accident reductions.

- centre-line and edge-line treatments - the use of both centre-line and edge-line treatments (including transverse striping on the edges and shoulder region of the road) on the road may result in reduced speeds.

- curvature enhancement - in situations where curvature is tight and there is insufficient sight distance through the curve, the use of measures (such as chevron markers and novel guide-post arrangements) to enhance the curvature may lead to speed reductions.

- intensive road treatments - restricting the number and size of travel lanes using wide white gravel medians with highlighted edge-line marking have been shown to reduce travel speed in some locations.

4.9.3 Vehicle Safety Features

Improving vehicle safety features may be an additional solution in reducing the number of speed related injuries and fatalities. When used in conjunction with other forms of speed control measures, the installation of a range of vehicle safety features, which can reduce the likelihood of an accident event (active safety features) and the level of injuries sustained once an accident event has occurred (passive safety features), may also provide a partial engineering solution to the problem of speeding.

Active safety features are designed primarily to prevent an accident situation from occurring. Safety features that may fall in to this category include; improved braking systems (such as anti-lock brakes), improved vehicle steering and handling systems (such as 4 wheel steering and improved independent suspension systems) and anti-collision warning systems. Although such devices are becoming increasingly popular, it is difficult to determine their accident reduction benefits due to the problem of determining if, indeed, an accident was avoided due to the installation of such devices. The main benefit of such safety features may be that they increase the drivers perception of safety, however, this sense of security might lead to increased risk taking behaviour because drivers feel that they are better able to deal with potential accident situations.

Passive safety features are designed to reduce the level of injury sustained once an accident situation has occurred. Safety features that fall into this category, include: seat belts, airbags, energy absorbing steering wheels, better designed instrument panels and knee bolsters. These safety features may also lead to an increased sense of security but because they are not related to the performance characteristics of the vehicle (as are active safety features), this effect may only be minimal.

The road safety benefits resulting from the use of passive vehicle safety features have been extensively documented in a report prepared by the Monash University Accident Research Centre (FORS, 1992). This report formed part of an extensive occupant protection, crash testing and standards development program, undertaken by the Australian Government, to examine ways of improving the safety of vehicles and thus reducing the severity of injuries of vehicle occupants. As a result of this program, all new imported and locally built vehicles must meet a set performance criteria for vehicle occupant protection by mid 1995.

The results from the MUARC study identified a number of cost effective safety features and their estimated potential to reduce accidents in the event of a frontal impact accident. On the basis of these estimates they developed a preferred countermeasure package which included the following safety features: full-size driver airbag (U .S), energy absorbing steering wheel, seat belt pretensioners, seat belt webbing clamps, improved seat belt geometry and seat design, and knee bolsters. The potential reduction in vehicle trauma was estimated at 25%; the likely benefit cost ratios ranged from 1.4:1 to 1.6:1; and the cost to the consumer was estimated to be between $800 and $1000. A follow up study of consumer willingness to pay indicated that a large proportion (82%) of new car buyers

were prepared to pay the best estimated retail Price or more for the preferred package of vehicle safety features.

4.10 SUMMARY

Excessive speeding behaviour is a significant problem in many Western countries. It has been estimated that well over 90% of all motorists will, at some stage during their driving career, exceed the recommended or posted speed limit. The problem is that it is often difficult for road users to recognise the causal relationship between speeding behaviour and accident occurrence. In addition, society tends to encourage a fast and active lifestyle and speeding is generally not considered to be a particularly dangerous nor illegal form of driving behaviour.

The role of speed in accident causation has long been established. The higher the speed, the greater the injury potential in an accident situation, as suggested by the laws of physics. Speed has also been shown to lead to accident causation with estimates indicating that excessive speed may be a contributing factor in up to 30% of all fatal accidents. The magnitude of the speeding problem has led to the development of numerous preventative strategies aimed at reducing the level of speeding behaviour. It is generally accepted that the speeding problem requires a coordinated approach, combining educational, engineering and enforcement elements. However, the large proportion of offending motorists has meant that reliance is typically placed on legislation and enforcement to deter speeding behaviour. The primary means of imposing some control over the speeds at which motorists travel is through the use of speed limits. Speed limits are designed to take into account the safety and mobility needs of society. In order to be effective speed limits must be perceived by road users as being credible and appropriate for the existing road environment conditions. Improper speed limits may actually lead to excessive speeding because some drivers do not believe speed limits provide an accurate indication of unsafe driving behaviour. Regardless of speed limit credibility there are a number of drivers who travel at speeds far greater than that nominated. In such situations the use of enforcement may be the most effective means of reducing this type of behaviour.

To be effective, speed enforcement operations must be designed to pose a real and significant threat to speeding motorists. Increasing the perceived risk of detection has been shown to be the most effective means of achieving this objective and deterring speeding behaviour. The supporting use of strict legal sanctions and ensuring that punishment is administered quickly and efficiently can facilitate the deterrence process.

Traditional enforcement methods have focused on the visibility and mobility of enforcement operations as the primary means of increasing perceived apprehension risk. Highly visible operations deter speeding behaviour by creating the impression that enforcement is highly active. Less visible, mobile enforcement operations deter speeding behaviour by increasing the unpredictability of where and how enforcement will be encountered.

The main problem with traditional enforcement operations is that speeding behaviour is too widespread and the limited policing resources are only able to cover a small proportion of the traffic network at anyone time. This results in enforcement having only a temporary effect on behaviour which is usually limited to the enforcement site. Drivers modify their speeding behaviour only when they encounter enforcement or in situations where experience has taught them that the risk of apprehension may be somewhat higher.

The most effective means of increasing perceived apprehension risk is by implementing enforcement strategies designed specifically to increase the actual risk of apprehension. Strategies based around the use of automated speed enforcement devices are regarded as the most effective means of increasing apprehension rates and deterring speeding behaviour. The use of these automated devices, commonly referred to as speed cameras, has been shown to significantly reduce the level of speeding behaviour and lead to associated reductions in the number of speed related accidents and the level of injury severity.

The main benefit of speed cameras is their ability to significantly increase detection and apprehension rates (in theory the detection probability can be equal to one). The use of these devices can also have a number of other benefits, including, the simplification of offence notification and prosecution procedures as well as an increase in the overall effectiveness (in terms of cost and human resources) and efficiency of speed enforcement operations.

The main disadvantage of speed cameras is that they do not provide immediate on-site recognition and punishment of a speeding offence. However, it has been found that the receipt of a speed camera infringement notice, several weeks after an offence has been detected, can still result in significant reductions in speeding behaviour and reduce speed related accidents. The use of an information display board, located several hundred meters after a speed camera site, may also provide an effective means of informing road users that a speeding offence has been detected.

One further problem with the use of speed cameras in that apprehension rates can be low (50%) in comparison to the actual number of motorists detected. This problem results due to equipment failure and difficulty in identifying vehicle registration details in poor lighting conditions. The use of new digital imaging systems, which produce more high resolution vehicle identification information, provides a means of significantly increasing apprehension rates (95%) and hence, the effectiveness of speed camera operations.

The intensive use of speed cameras can also result in negative social and political reactions. Improving the community acceptance of speed cameras is important to ensure continued political support for speed camera operations. This can be achieved by using speed cameras only at accident locations where speed is known to be a causal factor, and ensuring that there is adequate community consultation regarding the selection of enforcement sites.

Speed cameras can be used in either permanently fixed locations (unmanned) or in numerous temporary location (manned). Permanent site operations are less resource intensive than temporary site operations but are also more visible to motorists (thus creating only site specific deterrence) and can be the target of public vandalism. The rotation of a small number of speed cameras among a series of fixed housing installations, strategically positioned along a roadway, may be one possible solution to the problem of site specific deterrence.

Aerial speed enforcement is one further means of detecting speeding motorists which may have a potential application on urban freeway and rural highways. This type of enforcement option has several advantages over traditional approaches, due mainly to the fact that speeding behaviour can be detected from further away and for a much longer distance. It is also unpredictable and difficult to detect because the driver's attention is

usually focused on the immediate road environment and not what is happening above them.

Strategies designed to enable better spatial deployment of available policing resources may be an effective means of increasing the effectiveness and efficiency of speed enforcement operations. The randomised targeting of speeding behaviour at traffic locations with a high accident risk potential, or where enforcement visibility can be maximised, has been shown to significantly reduce the level of speeding behaviour and number of speed related accidents.

The use of publicity to support speed enforcement operations can be an effective means of initially raising and them maintaining community awareness of policing activities. Many studies have shown that the combined use of publicity and speed enforcement can result in greater behavioural and accident reduction effects than can enforcement alone. The use of publicity as a stand alone speed reduction countermeasure has been found to be relatively ineffective at producing long-term changes in speeding behaviour.

It is common practice, in many jurisdictions, to introduce enforcement tolerance levels on speed limits. The result is that the enforced speed limit is often higher (approximately 10%) than the posted speed limit. This practice may undermine the credibility of speed limits because they become artificially inflated as drivers become aware that marginal speeding behaviour, above the posted limit, will not result in apprehension. Adopting lower tolerance levels has been shown to reduce the level of speeding behaviour and may lead to greater public acceptance and credibility of posted speed limits.

There are a number of non-enforcement based strategies which may be used to increase the effectiveness of speed enforcement operations. The public posting of speed information has been found to one method which can reduce the level of speeding behaviour. These speed information signs provide road users with feedback regarding the overall level of speeding behaviour and allow drivers to relate their individual actions to that of recent group norms.

The use of rewarding strategies based upon the principles of positive reinforcement have been identified as a possible alternative or supplementary approach to punishment based enforcement strategies. Positive reinforcement has been shown to be a more effective means of modifying human behaviour than negative reinforcement and it is somewhat surprising that there appears to be no documented evidence of the use of rewarding strategies targeted specifically at speeding behaviour. Road safety incentive programs have been shown to be an effective means of modifying road user behaviour in a number of situations and the use of such programs as a speed control measure may warrant further consideration.

There are a range of legal sanctions which can be administered to the speeding driver. These sanctions range in severity from an official warning letter, to fines, to more severe licence actions such as suspension and revocation. The use of warning letters for minor speeding offences may reduce the level of resource intensive offence processing tasks and increase the perceived fairness and educational component of enforcement operations.

Fines are the most common form of speeding sanction and are considered to be the most efficient means of dealing with such offenders. However, the use of fines as a stand alone countermeasure has been shown to be a relatively ineffective means of deterring speeding

behaviour. Drivers must perceive that the risk of apprehension is high before fines can significantly increase the deterrence potential of speed enforcement operations.

The most effective legal sanction for speeding drivers is the use of licence suspension or revocation procedures. Licence actions provide a means of relating sanctions to an offenders lifestyle by depriving them of the privilege to operate a motor vehicle. The use of these sanctions has been found to be an effective means of reducing recidivism rates of convicted speeding offenders. Longer suspension periods (over 6 months) appear to be much more effective than shorter suspension periods (less than 3 months).

The use of point demerit schemes can be an effective means of relating the level of speeding behaviour to more severe penalty outcomes. The benefit of this type of scheme is that consistent, less serious speeding behaviour can still result in severe sanctions if a certain number of speeding offences are committed within a specified time period. This provides a strong deterrent for repeat offenders who soon learn that only a certain number of traffic offences need to be committed before more severe penalties are imposed. Research has shown that once a road user has accumulated a sufficient number of points the threat of licence suspension can result in significantly less speeding driving behaviour.

Increasing the credibility of speed limits may also result in greater acceptance and adherence by road users to the nominated speed zones. The use of expert speed zoning systems has the potential to ensure that speed limits are consistent across the entire road traffic network. The use of variable speed limits can also ensure that speeds remain consistent in relation to changing environmental and driving conditions.

Enforcement should not be relied upon as the sole means of reducing the level of speeding behaviour. Preventative strategies which target the 'agents' of speeding, namely the vehicle and roadside environment provide an alternative or supplementary means of reducing the level of speeding behaviour. The fitment of in-vehicle devices, which artificially control the maximum speed at which a vehicle can travel, is a promising speed countermeasure. These speed limiting devices may effectively eliminate the need for enforcement on maximum speed limit road stretches.

Modifying the physical roadside environment is one further means of reducing the speed at which drivers travel. Engineering treatments such as roundabouts, and speed humps have been shown to be extremely effective speed control devices. The use of perceptual speed countermeasures may offer a low cost means of reducing the level of speeding behaviour. The environmental manipulation of the road side environment, using treatments such as transverse lines, lane width reductions and enhanced centre and edge line markings, have been shown to influence a drivers' perception of speed and result in reduced travel speeds.

Improving the accident avoidance capability of vehicles, as well as the level of protection provided to vehicle occupants, can potentially reduce the injury severity consequences of speeding behaviour. Active safety features such as anti-lock brakes and improved steering systems can reduce the likelihood of an accident occurring. Passive safety features, such as airbags and seat belts, can reduce the severity of injuries once an accident has occurred.

5. ENFORCEMENT OF SEAT BELT WEARING

5.1 INTRODUCTION

Occupant protection, as a fundamental design parameter for motor vehicles, has achieved major recognition only within the last 20 years (Mackay, 1992). The underlying objective of occupant protection design measures is to ensure that vehicle occupants are provided with the maximum level of protection in an accident situation. Occupant restraint systems, more commonly referred to as seat belts, are an integral component of accident protection design and are commonly regarded as being one of the most cost-effective ways of reducing the severity of traffic injuries (Campbell, 1992). Mackay (1991) stated that, if used correctly, seat belts offer the single most powerful protective measure in the event of an accident.

International research and experience have shown that the use of seat belts significantly reduces the risk and severity of injury and the number of deaths resulting from vehicle accidents. Based upon the results of real-world studies, Mackay (1985) concluded that if seat belt usage increased from zero to 100% there would be a reduction of between 47% and 60% in vehicle occupant deaths, and a similar reduction in the percentage of hospital admission cases. Hedlund (1985), in an international review of the relationship between seat belt usage and casualty reductions, concluded that vehicle occupants who use seat belts are 40% to 50% less likely to sustain serious or fatal injuries in the event of an accident. These values were supported by Evans (1988) who, in a comprehensive analysis, estimated that seat belts reduce the risk of injury in accident situations by 40%. The reduction in injuries associated with the use of seat belts can also result in significant public sector health savings and Derby (1991) has estimated that the annual savings resulting from seat belt usage in the United States of America are over $8.5 billion.

Seat belts have been shown to reduce road accident trauma in several ways (Campbell, 1992). Firstly they prevent occupants from hitting the steering wheel or windscreen in all but the most severe accidents. Secondly, they prevent ejection from the vehicle in an accident situation, an event that increases the risk of death by between 200% and 400% (Hedlund, 1985). Thirdly, during an accident event severe forces are inevitably brought to bear on vehicle occupants and seat belts are effective in spreading these accident forces onto the strongest parts of the body. Finally, seat belts reduce the peak deceleration level endured by the occupant in an accident situation by allowing the stopping process to begin earlier in the accident sequence.

Although the injury reduction benefits of seat belts are generally well accepted, and their fitment and use in motor vehicles is compulsory in most Western countries, there are still a large number of vehicle occupants who do not use these safety devices. There are numerous reasons why this non-seat belt wearing situation may occur. Makinen et al. (1991) have listed, 12 possible motives, reported in the road safety literature, as to why vehicle occupants may not use a seat belt. These included:

- indifference ; forgetfulness;
- fear of being trapped or drowned in an accident;
- fending off measures reckoning with a possible accident;
- disbelief in the accident risk;
- disbelief in the injury-reducing effects of seat belts;

- discomfort;
- diminished driving pleasure;
- social norms;
- acceptance of risk;
- freedom of choice; and
- low subjective risk of detection for non-use.

Zeilstra et al. (as cited by Makinen et al., 1991) reported on a survey undertaken in The Netherlands, which indicated that the main reasons for non seat belt use were usually situational factors such as forgetfulness, inconvenience and the length of trip. Evans (1985) suggested that the jurisdictional variation in seat belt usage is a strong indication that factors such as lifestyle values, social norms, legislation and level of enforcement playa crucial role in the seat belt wearing decision. This proposition is supported by Svenson et al. (1985) who found that usage was related to the perceived popularity of seat belts. In addition, they reported a positive relationship between convenience and seat belt use, and suggested that discomfort may also be an important influencing factor.

A number of studies have also tried to differentiate between drivers who wear seat belts and those that do not. Hunter et al. (1988) found that non-seat belt users were likely to have higher accident involvement rates and more traffic violations than seat belt users. Similar results, showing higher traffic violation rates among non-seat belt users were also reported by Evans (1987) and Fockler & Cooper (1990). The results from these studies indicate that although there are certain types of road users that are more likely not to use seat belts, the identification of clearly defined non-user groups is difficult. Fockler and Cooper, (1990) have stated that the large differences in the results obtained from seat belt usage surveys suggest, that the concept of a typical 'wearer' and 'non-wearer' may not be a very useful one.

Given the large variety of factors affecting seat belt usage, it is not surprising that in many Western countries the overall usage rate is still well below 100%. However, it has been well established that seat belts can significantly reduce the level of road trauma and this has led many authorities to develop a range of strategies designed to increase overall seat belt usage rates. The majority of these measures focus around the use of legislation and enforcement, however, in many countries the actual enforcement of seat belt laws is not actively pursued and reliance is typically placed on the individual road user to adopt appropriate seat belt wearing behaviour. This has resulted in the development and implementation of non-enforcement based strategies which aim to increase seat belt usage rates by informing, educating, encouraging and rewarding road users.

The primary focus of this review will be on the legislative and enforcement measures used to increase seat belt usage rates. However, the important role of non-enforcement based measures has also been identified in the research literature (Makinen & Hagenzieker, 1991; Dussault; 1991; Mufti & El-Nour, 1992; Mackay, 1992). These researchers have suggested that such measures, when used in combination with legislation and enforcement, may provide the optimal solution for modifying road user behaviour and increasing seat belt usage rates. In order to provide an understanding of how such an integrated approach can be adopted, the range of non-enforcement options available to legislators will also be briefly examined in this review. However, before reviewing the range of strategies that can be employed to increase seat belt usage, a brief overview of the deterrence principles as they relate to seat belt wearing behaviour will be provided.

5.1.1 The Deterrence Mechanism

The primary objective of enforcement of seat belt usage is to deter non-seat belt wearing behaviour. As with other forms of enforcement, the deterrence mechanism which operates can be either specific or general. Specific deterrence, as it relates to seat belt usage, is based upon the assumption that road users who are charged with a non-seat belt wearing offence will be discouraged from committing further such offences. General deterrence is based upon the assumption that road users who become aware of the risk of apprehension and punishment adopt appropriate seat belt wearing behaviour to avoid the consequences of enforcement.

The number of motorists apprehended for seat belt violations is extremely low, and usually less than 1% (Campbell, 1986), and this would suggest that general deterrence may be the primary enforcement mechanism which effects seat belt using behaviour. General deterrence is achieved by increasing the perceived risk of apprehension through an increase in the level of enforcement activity and associated publicity. This suggests that an increase in the actual risk of apprehension will lead to an increase in the perceived risk of apprehension which will, in turn, result in a reduction in non-seat belt wearing behaviour.

However, the actual risk of being caught for a commission of a seat belt violation is quite low and this raises the question as to why, in many countries, seat belt usage rates are not much lower. There are several possible reasons why this may occur. Firstly, the public may grossly overestimate the probability of apprehension or the resulting consequences, through the use of infrequent yet highly publicised enforcement activities. Secondly, educational and promotional programs relating to seat belt usage may lead individuals to adopt appropriate seat belt wearing behaviour, primarily on the basis of increasing personal safety and to a lesser degree on the perceived risk of apprehension. Finally, a range of factors, including legislation, education, publicity and enforcement can lead to habitation of seat belt wearing which, in turn, means that less enforcement effort is required to ensure that road users adopt appropriate seat belt wearing behaviour.

Makinen and Hagenzieker (1991) stated that habitation was a very important mediating factor for seat belt use. They suggested that once the habit of wearing a seat belt is formed, it is relatively easy to maintain usage rates at high levels. However, the initial increase in seat belt usage rates, in order to create the wearing habit, requires appropriate legislation and a high level of publicity, education and enforcement. Once habitation and usage rates are at a sufficiently high level the primary role of enforcement, for the majority of road users, may be to act as a reminder of the importance of seat belt usage rather than to deter them from non-usage via the threat of apprehension and punishment.

5.2 SEAT BELT LEGISLATION

Legislative measures have been shown in numerous studies to be an effective means of increasing seat belt usage rates (Loeb, 1993). There are two distinct types of seat belt legislation which impact on the road user in a number of different ways. The first type of legislation relates solely to the vehicle, making the installation of seatbelts mandatory. These laws are targeted at vehicle manufacturers and have no direct impact on road users other than providing them with the option to use the occupant restraint device fitted. The second type of legislation relates specifically to the road user, making it compulsory for all occupants in a moving vehicle to use the seat belts provided. These laws classify the decision not to use a seat belt as illegal driving behaviour which can be subject to a range of legal sanctions. As a result, these laws often rely on a range of enforcement based

countermeasures to promote seat belt usage and to ensure that road user compliance is maintained at a relatively high level.

Landry (1991) has identified four distinct types of drivers in relation to seat belt usage and the effect that legislation and enforcement has on their seat belt wearing behaviour. The first group of drivers (10% to 30%) are those who wear seat belts solely on the basis of improved safety. Laws requiring the installation of seat belts in vehicles are all that is required for these drivers to wear seat belts. The second group of drivers (20% to 30%) are those who adopt appropriate seat belt wearing behaviour in response to the compulsory legislative requirement. They are typically law abiding road users who modify their behaviour due to legal requirement and not as a result of the possible risk of apprehension. The third group of drivers (30% to 40%) adopt appropriate seat belt wearing behaviour only in response to the knowledge that enforcement is present and failure to wear a seat belt, when detected, will result in some form of penalty. The last group of drivers (10% to 20%) are those who do not wear seat belts regardless of the legislative requirement or the existence of enforcement. It is this road user group that provide authorities with the greatest challenge because considerable effort is usually required to modify their attitudes and behaviour.

5.2.1 Mandatory Installation Legislation

The introduction of laws requiring the mandatory installation of seat belts in vehicles is the first step in the legislative process to encourage seat belt use among road users. The laws relating to the compulsory use of seat belts are usually initiated at some later stage in this process to allow road users to become accustomed to the use of such devices. As a result, it has been possible to determine the initial effectiveness of seat belt installation legislation in non-enforcement situations where usage is solely dependent upon the disposition of the individual road user.

Dassualt (1991) indicates that the experience of many countries shows that mandatory installation legislation results in usage rates somewhere between 10% and 25%. Even when combined with extensive educational and promotional efforts these type of laws only appear to result in usage rates of between 30% and 40% (Murray, 1991; El-Nour & Mufti, 1992). Hunter et al. (1993) have suggested that the type of road users who wear seat belts in response to the mandatory installation legislation are typically low risk taking road users. As a result, the accident reduction potential of such laws is usually lower than would be expected given the demonstrated injury reduction benefits of these safety devices.

El-Nour & Mufti (1992) suggest that the main benefit of such legislation, when combined with educational efforts, is to create a receptive social and political environment in which to introduce more effective compulsory use legislation. This proposition is supported by Mackay (1987) who suggested that one of the main reasons for the introduction of compulsory use legislation in Britain, in 1983, was the high level of favourable public opinion regarding the use of seat belts. He added that this high level of public support only occurred due to the intense media publicity associated with the new legislation and the fact that the use of seat belts was generally well accepted because they had been fitted in all vehicles (by law) for over 15 years.

5.2.2 Compulsory Usage Legislation

The second step in the process of encouraging seat belt usage is to introduce legislation which makes it compulsory for all occupants to wear seat belts in a moving vehicle. This type of legislation, which has now been introduced in approximately 40 countries, is regarded as a necessary prerequisite to increase seat belt usage rates to a level exceeding 50% (Makinen & Hagenzieker, 1991). In the majority of Western countries compulsory use legislation also involves the provision of increased policing powers to ensure that road users comply with the new law. This makes it difficult to determine the sole impact of the new legislation on seat belt wearing rates.

Legislation without enforcement

However, in several countries, including Finland, Norway and West Germany, compulsory use legislation was passed in such a manner that failure to use seat belts was not a punishable offence. In Finland, in 1975, the introduction of this type of legislation resulted in an increase in seat belt usage rates from approximately 20% to 60% (Valtonen, 1991). In the absence of enforcement this rate slowly dropped to about 40% by 1985, however, the new usage rate was still almost double the rate recorded before the legislation was passed. In Norway, seat belt usage rates also increased by over 15 percentage points as a result of the introduction of compulsory use legislation in 1975 (Hedlund, 1985).

In Germany, a similar situation was reported (Heinrich, 1991) with seat belt wearing rates increasing dramatically (20% to 45% on urban roads, 40% to 70% on rural roads and 65% to 75% on motorways) with the introduction of the compulsory use legislation and then declining in the absence of enforcement. The observed decline in usage rates was most pronounced in the first 12 months after the new legislation was introduced, however, soon after this period the usage rates stabilised and actually began to slowly increase over a nine year period, even though enforcement was not present. The average seat belt usage rates during this nine year period were approximately 40% on urban roads, 60% on rural roads and 80% on motorways.

Legislation with enforcement

The most effective type of compulsory use legislation is that which includes some type of enforcement component. This type of legislation has the potential to increase seat belt wearing rates to a level above 80% (Campbell, 1986). The success of this type of legislation is, to a large degree, dependent upon the level of enforcement and associated publicity which accompanies the legislative changes (Miikinen & Hagenzieker, 1991). In those countries where seat belt wearing is actively promoted and enforced, usage rates which exceed 90% have been reported (Campbell, 1987).

In Finland and Germany the use of enforcement and legal sanctions to increase usage levels occurred a number of years after the compulsory legislation was introduced. This allowed researchers to measure the direct effect of enforcement on seat belt wearing rates. In 1982, seven years after the introduction of the compulsory use legislation in Finland, neglecting to use a seat belt became a punishable offence. The effect of enforcement on seat belt wearing behaviour was dramatic and usage rates increased from 40% to 90% within a 12 month period (Valtonen, 1991).

In Germany, seat belt usage rates also increased dramatically when a fine of DM 40 was introduced in 1984. This followed a nine year period during which seat belt use had been

compulsory but not subject to enforcement or legal sanctions. Seat belt usage rates increased from 40% on urban roads, 60% on rural roads and 80% on motorways to over 90% on all three road types (Heinrich, 1991). These results indicate that the best seat belt usage level results are not achieved merely by changing the law. It is equally important to show drivers that compliance with the law is an important aspect of safety-oriented road user behaviour, by making non-usage punishable (Makinen et al., 1991).

The effect of legislation on injury reduction

In many countries the effect of compulsory seat belt legislation on road accident injury levels has been well documented. The State of Victoria, Australia, was the first to enact a law, in 1970, requiring the compulsory use of seat belts in vehicles. By 1972, all other Australian State and Territories had adopted similar legislation. The results from a number of evaluations (Foldvary & Lane; 1974; Andreassend, 1976; Joubert, 1979; Fisher, 1980) indicated that the new seat belt legislation resulted in a nationwide reduction in fatalities of between 11% and 21 %.

Similar reductions in fatalities have been reported in a number of Scandinavian countries including 14% in Sweden, 21% in Norway, 13% in Denmark and 18% in Finland (McCarthy et al., 1984; Hedlund, 1985; Valtonen, 1991). Slightly higher fatality reduction rates have been recorded in a number of other European countries including 25% in West Germany (Hedlund, 1985), 21% in France (Chodkiewicz & Dunbarry, 1977) and 25% in England (Mackay, 1984). The highest fatality reduction rates have been reported in several Canadian provinces including 26% in Ontario, 30% in British Columbia and 37% in Saskatchewan (Jonah & Lawson, 1984).

One additional benefit of the reduction in road trauma, associated with increased seat belt usage, is the reduced burden, in terms of cost and resources, placed upon the public health sector. In Victoria, Australia, five years after compulsory seat belt usage legislation was introduced, hospital data indicated that there had been an 87% reduction in major eye injuries in road accident victims, a 50% reduction in facial and major chest injuries, a 40% reduction in kneecap and hip injuries and a 27% reduction in the incidence of spinal cord injuries (Key, 1991). Similar reductions in hospitalisation injuries, in the United Kingdom, were reported one year after the new seat belt legislation was introduced (Rutherford, 1984).

The overwhelming majority of evidence has clearly shown that the introduction of compulsory use legislation has been responsible for significant reductions in road fatality and injury rates. Although the methodology used to determine fatality reductions often differs from one study to the next, it is generally accepted that the laws requiring vehicle occupants to wear seat belts have resulted in a 15% to 20% reduction in all road accident injuries and fatalities, and led to substantial cost savings (Wagenaar et al., 1988).

5.2.3 Issues Associated with Seat Belt Legislation

The introduction of compulsory seat belt legislation has inevitably resulted in a question regarding the reported accident reduction benefits of these safety devices. The two main issues that have been raised include, the possibility that the use of seat belts may actually encourage more risk taking behaviour because they make drivers feel more safe, and the possibility that seat belts may result in particular types of injuries that might not have occurred if the occupant was unrestrained.

Risk compensation

A number of researchers (Garbacz, 1991; Evans & Graham, 1991) have suggested that seat belt usage may actually lead to some type of risk compensation or offset driving behaviour which may result in an increase in accident rates. They argue that seat belts may fall into the same category as vehicle safety features such as antilock brakes, sport suspensions, traction control and four-wheel drive, which can increase the ability to drive more safely at higher speeds. They have suggested that if using a seat belt makes a driver feel more safe, they may, in fact, compensate for this by driving faster or in a more reckless manner, thus negating the safety benefits of seat belts.

Garbacz (1991) used fatality rates in New Zealand from 1960 to 1985 to examine accident trends involving seat belt wearing occupants and other road users (motorcyclists, bicyclists and pedestrians). He concluded that the positive safety benefits of seat belts for vehicle occupants were substantially offset by negative consequences to other road users. Similar results were reported by Evans and Graham (1991) who undertook an examination of 12 years of accident data from 50 America States during the period from 1975 to 1987. They found that seat belt usage laws generated an increased number of collisions as measured by pedestrian, motorcyclist, and bicyclist fatality counts.

However, Rock (1993) has questioned the results of these studies. He suggested that the statistical techniques applied were inappropriate for use with time series data and that this may have resulted in a number of variables appearing significant when in fact they were not. Using a more stringent and appropriate statistical technique (ARIMA), he undertook a similar methodological study to those previously reported, examining fatality data relating to occupant and non-occupant accident rates in the American State of Illinois. He found no evidence of an increase in the number of non-occupant accidents and concluded that risk compensation did not appear to be a negative consequence associated with the increased use of seat belts.

Seat belt injuries

One further argument against the introduction of seat belt legislation is that the use of a seat belt may actually cause injuries or be dangerous for certain occupants (such as children and pregnant women). Seat belts are designed to confine occupants inside the vehicle during an accident situation and this may lead to certain types of injuries that may not occur if the occupants were unrestrained or thrown from the vehicle. Estimates relating to the potential danger that the seat belt itself can cause injuries range from 0.02% to 0.6%, depending upon the seriousness of the injuries examined (Andreasson, 1992). Mackay (1991) stated that these injuries are, however, minimal in comparison to what they would have been if the belt had not been used. Andreasson (1992) indicated that seat belt induced injuries are generally limited to bruises, abrasions or chest pressure which usually heal quickly. He indicated that this was in direct contrast to injuries resulting from non-seat belt usage which often leave disabilities that can last a life time.

In a review of the effectiveness of seat belt legislation, Hedlund (1985) reported that injuries resulting from the use of seatbelts were an extremely uncommon event. He further stated that when serious seat belt injuries did occur it was usually the result of a high speed accident event where non-seat belt usage would more than likely have resulted in more serious injuries or even death. He also argued that the suggestion that occupants were less likely to sustain severe injuries if thrown from the vehicle was not supported, with evidence showing that this event increases the risk of death by a factor of between 2 and 4.

Andreasson (1992) indicates that chance of survival after being thrown from a vehicle is in fact one in ten. He stated that for occupants who remain belted in a vehicle the survival rate is estimated to be five to thirty times as great as that for occupants who are thrown from the vehicle. He also suggests that pregnant women have less tolerance against mechanical violence and as a result it is especially important for them to use seat belts, to avoid being thrown out of a vehicle in a collision. He reported on a study which examined accidents involving 180 pregnant women. The results showed that 33% of these women who were not wearing a seat belt died when they were thrown from a vehicle, whereas the fatality rate was only 5% for those who were using a seat belt. Of those thrown from of the vehicle, 72% received serious injuries as compared with 15% for those who remained in the vehicle due to the use of a seat belt. The foetus was lost in 47% of cases where the woman was thrown from the vehicle, as compared to 11% of those who were using seat belts.

5.2.4 Legislation Relating to Rear Seat Belts

Legislation requiring seat belt usage has traditionally targeted the front seating positions in vehicles. The reasons for less attention being focused on seat belt usage in the rear seating positions of vehicles are varied. Historically, seat belts were designed as a device for use by adult occupants. Exposure data showing that adults were far more likely to use front seating positions (over 95%) and that occupancy rates for rear seating positions were low (less than 15%), may have lead many authorities to believe that seat belt usage legislation relating to rear seating positions was not required (Mackay, 1991). In addition, there may also have been a widespread public perception that rear seating positions were safer in an accident situation than front seating positions. .

The perception of the safety, of rear seating positions, may have developed due to the belief that rear seat occupants are usually located further away from the accident impact point and have the additional protection of the front seat. However, these perceptions of safety are not supported by research evidence which has shown that 75% of all rear seat fatalities could be prevented by the use of seat belts. A further 6% of all front seat fatalities, caused by the excessive loading effect of rear seat occupants being thrown into the front seat, could also be prevented if seat belts are used in the rear seating positions (Griffiths et al., 1976).

Seat belt usage by children

Probably one of the main reasons for the reluctance to introduce rear seat belt legislation relates to use of restraint devices by children who often occupy rear seating positions. A number of researchers (Kahane, 1986, Lowne et al., 1987) have questioned the use of seat belts, designed specifically for use by adults, as a means of restraining children. The two main areas of concern relate to potential head and abdomen injuries. Firstly, a child's head mass in relation to the body is much greater than that of an adult and a highly positioned shoulder belt may lead to excessive loads being placed on a child's neck. Secondly, the wide band width of a seat belt may also result in excessive abdominal loads because even if the belt is placed correctly across the top of the child's thighs it still overlaps onto the abdomen.

The problem is that seat belts are commonly designed to accommodate only those vehicle occupants who are over 140 cms in length. On the basis of standard population charts and vehicle occupancy rates, Mackay (1991) has estimated that approximately 34% of all rear seat occupants are under 139 cms in length. However, as the safety benefits of rear seat

belts have become more widely recognised there have been increasing moves in many countries to introduce compulsory use legislation which applies to all vehicle seating positions. This type of legislation must therefore be designed to take into account the problem associated with seat belt usage by children. The result has been that many countries have introduced special legislation which provides exemptions for children under a certain age (usually 12 or 15 years) from the mandatory requirement to wear seat belts. Several countries have even specified that children are not allowed to travel in a moving vehicle whilst located in a front seating position (Mackay, 1991).

However, this type of legislation does not address the problem of ensuring that children are also restrained in a moving vehicle. One possible solution may be to legislate or encourage the use of after-market child restraint equipment, such as baby capsules, child harnesses and seat belt boosters. These restraint devices have been shown to significantly reduce the level of child fatalities. In the United Kingdom the use of child restraints, for children aged between 1 and 4 years, has been shown to reduce the incidence of fatal injury by approximately 75% (Transport and Road Research Laboratory, 1987). It was reported that between 1972 and 1984 there were 404 child fatalities of which only 30 involved children using child restraints and the remaining 374 involved children who were not restrained. A similar evaluation undertaken in the United States of America by the National Highway Traffic Safety Administration (1986) concluded that the correct use of child restraints, for children aged between 0 and 4 years, reduced fatalities by 71% and serious injury by 67%.

The effect of rear seat belt legislation

The effect of introducing compulsory use legislation for rear seating positions is, in many ways, similar to that for front seats. Makinen et al. (1991) reported that when rear seat belt usage is not mandatory, user rates have rarely exceeded 20%. The effect of rear seat belt legislation has also been shown to significantly increase usage rates. Makinen et al. (1991) reviewed a number of studies relating to the effect of rear seat belt legislation in several Scandinavian countries. They reported that in Finland, seat belt usage increased from 27%, one month before legislation was introduced in 1988, to 66% one month after the legislation was introduced. In Sweden, rear seat belt usage rates increased from 8% in 1983 to 54% immediately after legislation was introduced in 1986. A smaller increase was reported in Norway where usage rates increased from 20% to 46% one year after legislation had been introduced.

Enforcement and associated publicity have also been shown to have an impact on the effectiveness of rear seat belt legislation. In Victoria, Australia, legislation relating to seat belt usage in both front and rear seating positions was introduced in 1970. However, in 1982, road side surveys indicated that usage rates were 85% for front seat occupants and yet only 19% for rear seat occupants. It appeared that attention had been focused solely on increasing front seat usage rates and many motorists, and even some police, were unaware of the legislation relating to rear seating positions (Road Traffic Authority, 1988). In order to improve this situation a combined enforcement and publicity program was implemented.

This program had a dramatic impact upon wearing rates and within 12 months, roadside surveys indicated that seat belt usage in rear seating positions had increased to 82%.

5.3 SEAT BELT ENFORCEMENT

Enforcement is generally regarded as the final step in the process of ensuring that vehicle occupants use seat belts. Legislation and promotional measures have been shown to

increase usage rates to moderate levels (40% to 60%) but reliance is typically placed on the law enforcement system to significantly increase usage rates and ensure that they remain at high levels (over 80%). However, in many countries seat belt enforcement is a low priority activity and this has meant that, in these countries, usage rates are relatively low and the true injury reduction potential of seat belts has not as yet been realised.

5.3.1 Detecting Non-Seat Belt Wearers

Detection of non-seat belt wearers is generally regarded as one of the most difficult aspects of seat belt enforcement. Police surveys have indicated that the difficulties associated with the detection of seat belt violations may be the one of the main problems hindering the effective enforcement of seat belt laws (Yann et al., 1993). It is the inconspicuous nature of the offence which makes detection difficult. The problem is that seat belt violations do not occur at particular times or locations and are not associated with a certain type of driving behaviour. Although, the police maintain that their 'eyes' have been well trained to observe seat belt violations, there are no overt signs such as speed or poor or dangerous driving.

Yann et al, (1993) have identified a number of factors which contribute to the difficulty in detection of seat belt violations.

- Seat belt wearing is one of a number of offences that require police observation on the road, and the police are not able to check everything, all of the time, while still maintaining concentration on their own safety while driving;

- The speed at which vehicles travel, particularly on highways, makes detection difficult and the problem is heightened by occupants wearing dark clothing or being located in the rear seating positions, and by vehicles with tinted windows and travelling at night;

- Detecting non-compliance of occupants of vehicles travelling in the opposite direction to the police vehicle is also very difficult, not to mention the difficulty and danger involved in turning around and pursuing the offender.

- The police usually have to be close to a vehicle to see whether the occupant is wearing a seat belt or not and this allows the road user to quickly put the seat belt on, when they see a police vehicle, well before a police officer can visually detect an offence.

- In situations where the majority of road users comply with the law, detection is difficult because the chance of detecting a non-seat belt wearer is quite low, and the police may therefore devote less time to what they perceive as a low probability detection event.

Detection of seat belt offences is dependent upon the police being able to clearly observe occupants in a vehicle. This requires the police to be located sufficiently close to a vehicle to be absolutely certain that a seat belt violation is being committed. A number of factors including the speed of the vehicle, traffic density, the location of the vehicle in the traffic stream and the location of the actual police unit can make detection very difficult. These factors have a number of implications for the type of policing operations that can be used to detect offending motorists.

Stationary enforcement

Stationary policing operations are often employed as a means of enforcing seat belt laws (Australian Automobile Association, 1986). The only problem with this type of enforcement technique is that it usually requires the police to be located sufficiently close to a vehicle that seat belt wearing behaviour can be observed. This requirement may lead to difficulties in high volume, high speed traffic situations because when an offence is detected the driver has to be notified and given time to stop by the side of the roadway.

There are two possible solutions to this problem. Firstly, enforcement operations can be undertaken at traffic slow points such as at intersections and roadway entry locations. This approach has the benefit that such enforcement operations are highly visible and it encourages road users to adopt appropriate seat belt wearing behaviour (Leivesley, 1987). However, the disadvantage is that road users usually have enough time to put on their seat belt and as a result apprehension rates are quite low.

The second, most often used approach is to employ two police units, along a stretch of roadway, a short distance apart from one another (Australian Automobile Association, 1986). The first police unit is assigned the task of detecting offenders and then conveying the information to the second police unit which is responsible for stopping offenders and issuing an infringement notice. The main problem with this approach is that it can be extremely resource intensive and only a small number of offenders can be processed at any one time.

Mobile enforcement

Mobile policing operations to enforce seat belt usage are usually undertaken in association with routine policing patrols. If the police, during the course of general traffic enforcement operations, observe a vehicle occupant not wearing a seat belt then the vehicle is stopped and an infringement notice issued (Leivesley, 1987). The benefit of mobile enforcement operations is that the occupant has less time to put on the seat belt and the added manoeuvrability of the police vehicle makes detection and apprehension easier.

The use of police motorcycles has been identified (Yann et al., 1993) as a particular form of mobile enforcement that can increase the overall effectiveness of seat belt surveillance operations. Motorcycles are more manoeuvrable than other types of police vehicles and are not only able to turn and chase an offender more quickly but can also be positioned so as to provide a better view into vehicles. The only problem associated with this type of seat belt enforcement strategy is that there are only limited numbers of motorbikes available to the police.

Automated seat belt enforcement

The difficulties associated with traditional methods of detection of seat belt violations have led a number of researchers to discuss the possible use of automated detection devices. Lock (1993) has suggested that the images obtained during automated speed enforcement operations could also be used as a means of detecting seat belt violations. He indicated that high quality digital images can, in many cases, clearly show whether or not occupants are wearing seat belts. He further added that, in most countries, images are already manually processed and asking operators to include a check for seat belt violations would not place a significant additional burden on policing resources.

The use of automated detection devices as a means of enforcing seat belt laws has a number of benefits. Firstly, it negates the requirement to undertake specific seat belt enforcement operations and increases the resources available to the police for other activities. Secondly, the knowledge that seat belt usage was being enforced using automated detection devices would increase the perceived risk of detection and may result in higher usage rates. This type of enforcement technique would be most effective in countries where seat belt laws are not actively enforced due to limited policing resources and doubts exist about the effectiveness and necessity of undertaking traditional seat belt enforcement operations.

The use of information, gathered as a result of a speed offence, to prosecute non-seat belt wearers may be perceived as being a questionable enforcement practice because it targets only one particular type of road user. However, linking seat belt usage to speeding behaviour may have a number of benefits. Firstly, it has been shown that drivers who do not to use seat belts are more likely to have commit other traffic offences, such as speeding (Hunter et al., 1988; Fockler & Cooper, 1988), and targeting this group of drivers may therefore result in the greatest injury reduction potential. Secondly, seat belt effectiveness is directly related to speeding behaviour because the higher the accident speed the greater the reliance placed on occupant restraint devices to reduce injury severity.

5.3.2 The Effect of Enforcement on Seat Belt usage

Legislation relating to the enforcement of seat belt laws can take one of two forms and the approach adopted may also reflect the low priority given to such violations (Campbell, 1988). The first type of legislation is based upon a policy of 'secondary' enforcement where a seat belt law violation may be addressed only if the police officer has stopped the motorist for some other type of violation. The second type of legislation is based upon a policy of 'primary' enforcement which allows a police officer to stop a motorist solely on the basis of a seat belt law violation.

Primary enforcement policies have been shown to have the greatest impact on seat belt wearing behaviour. This makes intuitive sense because when using this enforcement approach the risk of apprehension is higher because motorists know that they can be stopped at any time for not using a seat belt. Campbell (1988), in a study undertaken in North America, examined the effect of enforcement in 20 States, of which 8 had primary enforcement laws and 12 had secondary enforcement laws. He found that for a given level of enforcement, seat belt usage rates in primary enforcement States were 17 percentage points higher than those in secondary enforcement States (49% and 32% respectively).

Campbell (1988) also reported on the relationship between the level of enforcement activity and seat belt usage rates. He found that, in both primary and secondary enforcement States, seat belt usage was higher in the presence of higher levels of enforcement. He indicated that if the number of motorists apprehended for seat belt violations was less than 0.2% then seat belt usage rates were also likely to be low. If, on the other hand, apprehension rates were higher than 0.5% then corresponding seat belt usage rates were also likely to be higher.

Campbell (1988) also looked at enforcement levels in several countries with high reported seat belt usage rates. In Australia, where seat belt usage rates were 90%, apprehension rates of 1.3% had been reported. In Sweden, where seat belt usage was reported at 85%, apprehension rates ranged between 0.65% and 1.3%. On the basis of these results he concluded that if seat belt laws are vigorously enforced then compliance will increase.

However, he added that enforcement should not be the sole means of increasing seat belt usage rates, stating that it should be supported by appropriate public information campaigns which address the enforcement policies.

One of the best examples of the effect of enforcement on seat belt usage relates to the experience in the Canadian Province of Alberta (Grant, 1991). Seat belt laws were introduced and enforced in Alberta from the beginning of 1987. Usage rates increased from 28% in 1986 to 74% in 1987 and 83% in 1988. In 1989, as a result of a court decision, the seat belt law was no longer enforced and seat belt usage rates dropped to 45% (a drop of 38 percentage points). When the extremely low seat belt usage rates were publicly announced, at the beginning of 1990, the court reversed its decision and enforcement activities were reinstated. By the end of 1990 seat belt usage rates had increased to 88% (an increase of 43 percentage points) which is a clear indication of the effectiveness of enforcement.

5.3.3 Problems with Enforcing Seat Belt Laws

The majority of countries which have introduced compulsory seat belt usage laws have also adopted primary enforcement policies. However, what is stipulated by the legislation is not necessarily what occurs in practice and in many countries seat belt usage laws are not actively enforced. This low level of police enforcement activity usually results in extremely low apprehension rates (less than 0.25%) which, in turn, leads to seat belt usage rates which are well below 100% (Reinfurt et al., 1990). One of the main reasons why this situation occurs relates to the attitudes, beliefs and general concerns of police in regard to the enforcement of seat belt laws. Hunter et al., (1993) has listed a number of reasons why police authorities may be inclined not to enforce seat belt laws, including:

- a perception of little cooperation from the legal system;
- the feeling that detection and enforcement are difficult;
- beliefs that adults should have the right to choose to wear (or not wear) seat belts;
- scepticism about the reported effectiveness of seat belts;
- a view that there are more important laws to enforce; and
- community attitudes regarding the enforcement of seat belt laws.

The combination of all of these factors can often make it difficult for policing authorities to understand why they should allocate resources to target non-seat belt wearing behaviour.

In addition, the tangible benefits of seat belt enforcement are not always obvious because although, seat belt usage may reduce the level of road trauma, it does not actually lead to a reduction in the number of road traffic accidents (Reinfurt et al, 1990). The attitude often adopted by the police is that if road users are aware of the risks associated with non-seat belt usage, and still make the decision not to wear a seat belt, then they are only putting themselves at risk and not affecting the safety of other road users. A brief overview of the specific issues relating to why the police are often reluctant to actively enforce seat belt laws, may help to explain why usage rates in many countries are still unexceptionably low.

The legal system

A number of policing authorities have suggested that the concessionary attitude towards seat belt non-wearers, taken by legislators and magistrates alike, provides them with little encouragement to actively enforce seat belt laws (Hunter et al., 1993). The fines are usually very low and the administrative tasks associated with processing seat belts violations are often viewed as being more time consuming than the nature of the offence warrants. Dussault, (1991) has also stated that the existence of special seat belt wearing exemptions, for certain types of road users, does little to promote the safety benefits of seat belts and can make enforcement more difficult.

When road users decide to dispute the receipt of a seat belt infringement notice, in a court of law, magistrates are often lenient and sympathetic to the reasons as to why seat belts are not used (Nelson & Moffit, 1988). This may also reflect the attitudes of magistrates towards non seat belt wearing violations and the perceived severity of such an offence (Yann et al., 1993). In addition, the legal system in many countries is barely able to handle existing prosecution requirements and is often hesitant to encourage enforcement efforts which have the potential to further increase the prosecution burden.

Freedom of choice

The issue of freedom of choice has been used as an argument against the introduction of enforced seat belt laws (Mackay, 1992). Opponents have stated that non-seat belt wearing does not directly cause road accidents and argue that vehicle occupants should therefore be allowed to make their own decision regarding whether or not to use a seat belt. Hunter et al. (1993) suggested that some police may be reluctant to enforce seat belt laws because they believe that vehicle occupants (adults) should have the right to decide whether or not they want to use a seat belt. If vehicle occupants are aware of the increased injury risk, and still make the decision not to wear a seat belt, then they are only putting themselves at risk and not affecting the safety of other road users.

Effectiveness of seat belts

Exposure to numerous road traffic accidents may also lead police to question the reported effectiveness of seat belts which may, in turn, influence their resolve to enforce seat belt laws (Hunter et al., 1993). This may occur because they attend many road accidents where deaths and serious injuries have resulted regardless of whether or not the vehicle occupants were wearing a seat belt. In some accident situations the police may even form an opinion that seat belts may have facilitated certain types of injuries which may lead them to further question the benefits of such safety devices.

The perceived importance of seat belt enforcement

The limited resources available to policing authorities may also result in less enforcement effort being placed on what is perceived as being a relatively minor traffic offence. Hunter et al. (1993) have suggested that police believe that the enforcement of more serious traffic offences such as drink driving and speeding behaviour is far more important, and a better utilisation of their resources than are enforcement efforts targeted at non-seat belt wearers. The enforcement of these more serious traffic offences is perceived by the police as having a greater level of road safety benefit because speeding and drink driving have the potential to cause road traffic accidents and therefore result in death and injury to innocent road users (Yann et al., 1993).

Community attitudes

Community attitudes towards the enforcement of seat belt laws may also have an impact on police enforcement priorities. The police may be somewhat reluctant to enforce a law that is perceived by the community as being relatively minor in comparison to other more serious offences such as drink driving and speeding. Hunter et al. (1993) indicate that this may be particularly evident in smaller communities where the police are well acquainted with many of the local residents. When seat belt enforcement operations do take place, the resulting policing activities may lead to community resentment because road users may feel that enforcement is unwarranted and unfair, especially in situations where 'forgetfulness' is the primary reason for non-seat belt usage (Evans, 1987).

5.4 IMPROVING THE EFFICIENCY OF SEAT BELT ENFORCEMENT

The problems associated with the detection of seat belt offences and the need to increase the overall seat belt usage rate have led to the development of strategies aimed at increasing the overall effectiveness and efficiency of policing operations. Underlying these strategies is the need to educate and inform the public about the benefits of seat belt usage as well as the need to deter habitual non-seat belt wearers by implementing strategies which increase the perceived risk of apprehension. Educating the police as to the benefits of, and need for, seat belt enforcement, the use of targeted enforcement operations and increased enforcement related publicity have been common approaches adopted to increase enforcement efficiency.

5.4.1 Police Education Programs.

It is generally regarded that educating and motivating the police to more actively enforce seat belt laws can lead to substantial increases in usage rates (Mackay, 1991). If the public becomes aware of an increase in seat belt enforcement activities then the associated increase in the perceived risk of apprehension as well as the additional focus on seat belts invariably leads to an increase in usage rates. In countries where seat belt enforcement is actively pursued, usage rates above 90% have been recorded (Key, 1991). Educational programs designed specifically for policing authorities usually focus on three aspects of seat belt usage, namely, safety benefits, cost benefits and effective ways to enforce seat belt laws.

Safety Benefits

The police are often unaware of the true potential of seat belts to reduce injuries and fatalities, believing that other traffic enforcement activities which focus on drink driving and speeding behaviour can lead to far greater road safety benefits (Hunter et al., 1993). The police typically target road user behaviour which has the potential to reduce the actual number of road accidents. Seat belt wearing behaviour does not fall into this category because it does not lead to a reduction in the number of accidents but only reduces the likelihood of injury once an accident event has occurred.

However, if the primary objective of traffic enforcement is to reduce the total level of road trauma, and not only road accidents, then the enforcement of seat belt laws is an extremely effective way of achieving this objective. Dussault (1991) stated that the use of a seat belt is, to date, the most effective road safety countermeasure available. It is effective, not only in terms of safety but also cost, and has the potential to result in far greater reductions in the level of road trauma, than any other existing enforcement based countermeasure. He

further added that the tremendous advantage of seat belts is that they provide protection to occupants regardless of the cause of the accident.

Derby (1991) stressed the importance of educating the police about the potential benefits of seat belt usage. She stated that unless the police are made aware of how their enforcement activities can lead to improved road safety it is often difficult for them to understand the need for enforcing particular types of traffic laws. She added that this is extremely important with seat belt enforcement because there is often no real tangible evidence, such as less road accidents, that their enforcement efforts are having a beneficial impact on road safety.

Dassualt (1991) also stressed the importance of involving the police in active seat belt enforcement activities. He indicated, that in order to achieve this, there are a number of steps which should be undertaken. Firstly, the police must be educated as to the benefits of seat belt usage and provided with training relating to the best way of undertaking an effective seat belt enforcement program. Secondly, the police must be supported publicly and therefore the community should be educated about the need to enforce seat belt laws so that the police do not feel as if they are undertaking activities which are contrary to community expectations. Finally, pre-survey and post-survey data should be collected so that the police can be provided with feedback regarding the effectiveness of their enforcement activities.

Key (1991) has indicated that, in Australia, special efforts have been made to educate police authorities about the necessity and importance of continuing to enforce seat belt legislation. Road safety authority and police liaison committees ensure that the police are involved in the development of seat belt enforcement campaigns from their inception. This process ensures commitment from police authorities once the enforcement campaigns are initiated. In addition, seat belt enforcement activities are well supported by media publicity campaigns, community education programs and legislation in the form of legal sanctions (fines in the order of $130 U.S. and loss of licence demerit points).

Cost Benefits

Cost considerations can play an important role in the decision to enforce seat belt laws because, as with other road safety activities, promoting seat belt usage requires both human and financial resources. Police authorities often allocate their limited resources to those enforcement activities which they perceive as providing the maximum returns. Seat belt enforcement must therefore compete with more high profile enforcement activities and the result is usually in favour of the latter. Landry (1991) has suggested that if police authorities can be made aware of the cost benefits associated with seat belt enforcement then more resources may be allocated to such activities.

Mackay (1991) reported on the potential cost and resource savings to the police, in the United Kingdom, associated with an increase in seat belt wearing rates due to more effective legislation and enforcement. An economic analysis showed that an actively enforced seat belt law would result in a specific saving in police resources which could be diverted to other enforcement activities. The cost savings were due primarily to the man-hours saved by police not having to attend inquests and in not having to prepare all the necessary documentation associated with a road accident fatality.

A number of police authorities believe that because non-seat belt usage only affects the non-wearer, it is not necessary to actively enforce seat belt laws (Hunter et al., 1993).

However, in most Western countries, road traffic accidents result in significant costs to society which are paid for in the form of taxation. The road trauma associated with non-seat belt usage adds to these accident costs and therefore has an impact on all members of society, not just on those individuals who are involved in an accident. Estimates of the cost to society for a single road accident fatality differ between countries, depending on the costing methodology used, but generally range from between $0.5 to 2.2 million (U .S.).

Reducing the level of road trauma can lead to significant cost savings which are absorbed by other sectors in the economy, including law enforcement, thus providing benefits to society as a whole. The use of seat belts is recognised as one of the most successful road trauma countermeasures (Dassualt, 19991) and increasing seat belt wearing rates through the use of enforcement has significant cost saving implications. Derby (1991) has estimated that the annual cost savings resulting from seat belt usage in the United States of America, in 1990, were over $8 billion. Based upon this estimate, a one percent increase in seat belt wearing rates, due to increased enforcement, would result in an annual cost saving, in the United States of America, of approximately $165 million. Laundry (1991) has also estimated that, in Canada, a one percent increase in seat belt usage rates would result in 18 fewer road fatalities and 500 fewer injuries each year. These estimates clearly demonstrate the potential cost savings which could result from an increase in the level of seat belt enforcement activity.

5.4.2 Seat Belt Enforcement Programs

The underlying objective of seat belt wearing enforcement operations is to increase seat belt usage rates whilst ensuring that the associated increase in policing activity remains efficient in terms of both cost and human resources (Dassualt, 1991). Two approaches commonly adopted to increase the effectiveness and efficiency of seat belt enforcement operations include the use of 'integrated' enforcement strategies and the use of enforcement 'blitzes'.

These two enforcement approaches have a number of benefits and can affect seat belt wearing rates in different ways. The optimal solution to the problem of increasing seat belt usage rates may in fact be to incorporate both of these approaches into one coordinated enforcement strategy.

Integrated enforcement programs

The simplest and most cost effective approach to increasing seat belt usage rates is to integrate seat belt enforcement operations with other policing activities. This approach, when accompanied by supportive efforts to increase public awareness, has been shown to be an effective means of obtaining long term gains in seat belt usage rates (National Highway Traffic Safety Administration, 1991). Demonstration projects, conducted in a number of cities in the American State of Illinois, have shown that the use of an integrated enforcement approach can increase seat belt usage rates from between 10 and 18 percentage points (with a base seat belt usage rate of approximately 30%).

The main benefits of this type of enforcement approach are that such a program is easy to administer and does not require the allocation of additional policing resources. Seat belt infringement notices are issued as part of ongoing policing activities and, as a result, this type of enforcement approach does not require an increase in the level of policing man-hours. These activities have also been shown to be effective even in situations where policing resources have already been diminished (National Highway Traffic Safety

Administration, 1991). Furthermore, when combined with enforcement activities which incorporate some form of random roadside stopping procedures, this integrated enforcement approach can significantly increase the actual and perceived probability of apprehension.

Selective enforcement programs

Increasing the perceived risk of apprehension associated with non-seat belt wearing is, to a large extent, dependent upon road users actually observing and becoming aware of an increase in the level of seat belt enforcement activity. The best way of achieving this is through the use of intensive, highly visible, and well publicised seat belt enforcement operations (Dussualt, 1991). Several jurisdictions have developed seat belt programs based upon this type of enforcement 'blitz' approach. These enforcement programs have been shown to be extremely effective at bringing about 'sharp' increases in seat belt wearing rates (Dussault, 1991; Grant, 1991; Derby, 1991).

These seat belt enforcement 'blitzes' usually only last for one to four weeks and are undertaken several times per year (Grant, 1991). This use of periodic, high intensity enforcement activities minimises the resources required whilst ensuring that road users are continually reminded of the need to use seat belts and the possible risk of apprehension. In addition, this type of enforcement approach can actually facilitate the habitation of seat belt usage (Derby, 1991). Road users form the habit of seat belt wearing during the enforcement phase and maintain this habit for a certain period during the non-active enforcement phase. At the stage when the wearing habit may be beginning to be broken another enforcement phase is initiated, thus reinforcing the wearing habit and repeating the process.

The most documented use of this type of enforcement approach relates to the Canadian 'Selective Traffic Enforcement Programs' referred to as 'STEP'. Grant (1991) stated that this specifically designed seat belt enforcement program has three major components, education, enforcement and evaluation. The education component is designed to inform road users about the benefits of seat belts and encourage a high level of voluntary use, before applying enforcement. The education component also includes the training of police officers to ensure that they are aware of the need to enforce seat belt laws and the benefits associated with high levels of road user compliance.

The enforcement component of the STEP program incorporates the use of intensive, highly visible policing activities. Roadside checkpoints are set up at random locations within the traffic network and are designed to stop and check the seat belt usage by occupants of a large proportion of vehicles. Those vehicles that are not stopped are aware that the policing operations are targeted at seat belt usage because of the high level of associated media publicity. Grant (1991) has suggested that the high visibility checks may allow some vehicle occupants to buckle their seat belts prior to being checked. However, he indicated that this is acceptable because the goal of the enforcement program is to ensure that road users are aware that the law was being enforced and to encourage the use of seat belts.

The evaluation component of the STEP program is designed to determine the effectiveness of the program and provide feedback to the community and the police. This feedback is seen as an essential part of the STEP program for several reasons (Grant, 1991). Firstly, if the police are aware that their activities have been successful then they are more likely to participate in future programs. Secondly, providing the community with feedback about the success of the program is also likely to increase support and ensure high seat belt

wearing rates. Finally, the data collected indicates that single STEP programs generally do not maintain wearing rates and program organisers, therefore, need evaluation information to be able to solicit support for future programs.

Evaluations of the Canadian STEP programs indicated that they had resulted in significant increases in seat belt usage rates. In a series of three STEP programs, undertaken in the province of Ontario, seat belt usage rates increased from 58.3% to 76.5% after the first STEP, from 66% to 84% after the second STEP and from 79% to 87% after the last STEP (Grant, 1991). In a number of other Canadian provinces, increases in seat belt wearing rates from 58% to 73% (British Columbia) and from 68% to 86% (Quebec) have been reported (Dassualt, 1991).

A number of seat belt enforcement programs, similar in structure to the Canadian STEP programs, have also been undertaken in the American States of New York and Texas. Williams et al. (1987) reported on a three week enforcement and publicity campaign, in the State of New York, which was found to have increased seat belt wearing rates from 49% to 77%. In a series of similar enforcement programs, undertaken in several cities in the State of Texas, the average reported increase in seat belt wearing rates was over 20 percentage points (National Highway Traffic Safety Administration, 1991). It is important to note that those cities with the lowest baseline usage rate level reported the largest increase in post enforcement usage rates.

5.4.3 Publicity

The use of publicity has been shown, in numerous studies, to be a proven means of increasing the effectiveness of seat belt enforcement activities (Makinen et al., 1991). It is generally regarded that publicity has two primary objectives (Key, 1991). Firstly, it can be used to increase community awareness of the benefits associated with the use of seat belts. Secondly, and most importantly, it can be used to enhance the effectiveness of legislative and enforcement measures by promoting the perceived risk of apprehension and punishment.

The use of publicity as a stand alone countermeasure has been shown to initially result in significant increases in seat belt usage rates, however, these effects are usually only temporary and seat belt wearing behaviour soon reverts back to pre-publicity levels (Fricker & Larsen, 1989). The majority of evidence indicates (Elliott, 1993) that publicity is effective in increasing awareness of the need to use seat belts but that its ability to actually change and maintain appropriate seat belt wearing behaviour is limited. It appears that once road users become aware that enforcement is not active then any publicity related increase in seat belt wearing behaviour soon diminishes.

Makinen and Hagenzieker (1991) have stated that publicity seems to have been effective, in isolation, only when it has preceded legislative changes to 'prepare' public opinion for the new behaviour. This proposition is supported by a number of researchers (Campbell, 1987; Mackay, 1991; Derby, 1991) who have found that the use of media publicity prior to the introduction of seat belt legislation has led to greater community acceptance of the new measures adopted. Grant (1991) has also found that publicity preceding the implementation of enforcement campaigns can lead to less public criticism of enforcement operations because road users feel that they have been given a 'fair chance' to modify their behaviour.

Determining the actual effectiveness of publicity is often difficult due to its combined use with other measures. Makinen et al. (1991) have stated that the experience in countries

with high seat belt usage rates (over 90%) indicates that these rates cannot be explained solely in terms of legislation and enforcement. This implies that publicity must also play an important role in the process of modifying road user behaviour. They concluded that the specific combination of the various measures (legislation, enforcement and publicity) seems to be responsible for the high seat belt wearing rates in these countries.

It is generally regarded that the main benefits of publicity are realised when it is used in combination with enforcement (Campbell, 1987; Dussualt; 1991). Williams and Lund (1987) reported on a combined enforcement and publicity campaign in the American State of New York. They found that seat belt usage rates increased from 49% before the campaign to 77% immediately after the campaign and stabilised, several months later, at a level of 66%. Kim (1990) reported on the effectiveness of enforcement and publicity on seat belt usage in Hawaii which has the highest compliance rate of any State in the United States of America. He suggested that main reasons for the high usage rates include active enforcement, high fines and high level of publicity. He indicated that when enforcement is active the main benefit of publicity is to increase the perceived risk of apprehension. If enforcement is not active, then publicity does little to facilitate the deterrence process. In such situations, an increase in seat belt wearing behaviour relies almost solely on the ability of publicity to create a high level of awareness regarding the benefits of seat belts. This can be a costly exercise and nowhere near as effective as the combination of enforcement and publicity.

Gundy (1988) carried out a well-designed study to evaluate the effects of a combined enforcement and publicity campaign, conducted in the Netherlands province of Friesland in 1984. The enforcement campaign was conducted over a period of two months. The police invested 2800 hours in surveillance, controlled about 40,000 motorists and issued about 1300 tickets. The campaign was extensively covered by local media and included demonstrations of cars dropped from a height of 10 meters and collision simulators. It was also widely supported by local chapters of the Dutch Road Safety Organization. Total costs were estimated to be about 200,000 Dutch guilders (about 120,000 US dollars).

A total of 28,688 observations of driver seat belt use were made cross-sectionally over 5 measurement waves, and divided equally between the 'campaign' area Friesland (about 590,000 residents) and a control area, West-Friesland (about 320,000 residents). All observed drivers were asked a few questions in the field, and half of them were also given a written survey form to fill in at home and return in a pre-stamped envelope.

Interestingly only about 1% of total police surveillance capacity for this two month-period was actually deployed, about 12% of what was actually budgeted and planned. Defective time registration, insufficient process guidance and poor motivation were some of the factors explaining the under-use of planned capacity. Despite the relatively small allocation of police resources, the Frisian campaign resulted, at its conclusion, in an improvement in wearing rates of about 25 percentage points for both inside and outside built-up areas.

The results for the fourth (a half year after the end of the campaign) and fifth (one year after the end of the campaign) waves were somewhat more variable, yet an improvement of 15 percentage point above the base rate was maintained. This improvement clearly contrasted with the small improvement in the control area. An extra sixth measurement wave, not part of the original study, conducted 24 months after the original campaign had ended, showed usage rates at approximately the same level as in April 1984, six months after the campaign had ended.

Publicity played an important role in the success of the campaign. The percent of Frisian respondents who reported being aware of some publicity promoting seat-belt use during the previous month increased from 16% before the campaign to 75% during the campaign.

During the campaign 62% of the respondents were of the opinion that there was more enforcement, and 67% thought that the chance to be checked by the police was higher. The base rate for these questions before the campaign was approximately 5%.

The importance of social communication for the process of general deterrence was also highlighted. About 50% of the respondents reported haven spoken recently about the subject with friends or neighbours, and 36% reported knowing someone who had been recently checked by the police for seat-belt use. The baseline for these two questions were about 20% and 10%. The author concludes that the mass media and word of mouth very likely played an important role in communicating the intent and purposes of the campaign, and that first-hand contact with the police was a less essential element.

A simple benefit cost analysis was undertaken with the results indicating that the combined enforcement and publicity campaign had been very cost effective. It was calculated that a campaign costing three times as much as that for the Frisian campaign, and achieving an improvement of 15 percentage points in seat-belt usage rates for one year, would result in a benefit cost ratio of 1 to 1 (break even point).

5.5 NON-ENFORCEMENT MEASURES TO INCREASE SEAT BELT USAGE

In many countries the enforcement of seat belt laws is not actively pursued and this has led a number of researchers to examine the use of non-enforcement methods as a possible means of increasing seat belt usage rates. The aim is to encourage seat belt usage by informing, educating and rewarding road users as opposed to enforcement which is based upon the principles of punishment. Typical methods include the use of incentives, to reward seat belt usage, and feedback devices to remind occupants to adopt the habit of using a seat belt.

5.5.1 Incentive Programs

There is a large amount of literature relating to area of human psychology which indicates that positive reinforcement is a far more effective means of modifying behaviour than negative reinforcement (Bandurra, as cited in Dussault, 1990). The use of incentives to promote seat belt usage is based upon this principle of positive reinforcement and assumes that behaviour which has favourable consequences is more likely to be repeated and at higher rates than behaviour that does not lead to favourable effects (Makinen et al., 1991).

Incentive programs, which reward road users either collectively or individually, have been shown to be an effective means of increasing seat belt wearing rates (Cope et al., 1986; Hunter et al., 1986; Geller et al., 1989; Hagenzieker, 1991). Although these studies differed in terms of the type and frequency of the incentives used to promote seat belt usage, they all reported significant increases in seat belt usage rates. The magnitude of the increase ranged from 10 to 25 percentage points with the size of the increase partially dependent upon the initial baseline seat belt usage rate.

Hunter et al. (1986) reported on the use of a community-wide incentive program in the American city of Chapel Hill, North Carolina. Incentives, generally ranging in value from $3 to $5 (donated by local businesses), were issued to a high proportion of randomly

selected belted occupants over a six month period. Recipients of these smaller incentives were also entered into a lottery and given the opportunity to win larger cash prizes ($500 or $1000). The results from the study indicated that seat belt usage rates increased from a base level of 24% to a peak value of 41 %.

Hagenzieker (1991) reported on the use of various incentive and enforcement programs conducted at 12 different military bases in the Netherlands during 1988. Incentives were either group-dependent cash prizes ($2,500 U.S.) or individual prizes (money coupons, cameras, cassette or compact disc players) which were drawn from a lottery at certain stages during the study. The results from the study indicated that both enforcement and incentive programs had the same overall effect on seat belt usage rates. Usage rates increased from a baseline level of 67% to 75% for the enforcement programs and from a baseline rate of 62% to 69% for the incentive programs.

A series of follow-up surveys, two months after the programs were completed, indicated that usage rates had not only been maintained but had actually increased even further to levels of 78% (enforcement programs) and 76% (incentive programs). The overall results indicated that the enforcement treatment had resulted in an 11 percentage point increase in seat belt usage rates and the incentive treatment had increased usage rates by approximately 14 percentage points. Hagenzieker (1991) concluded that seat belt incentive programs appeared to have the potential to be equally as effective as enforcement activities. However, the results from the study specifically related to seat belt usage behaviour on military establishments and whether similar results would be obtained among the general driving population may still require further investigation.

Sleet and Geller (1986) provided a range of recommendations and general conclusions regarding the use of incentives or rewarding strategies in seat belt promotion programs. These include:

- rewards are more effective than punishments;
- low-cost incentives result in cost effective increases in seat belt usage;
- intermittent rewards have longer-lasting effects;
- incentives are more effective in combination with education;
- delayed rewards can be as effective as immediate rewards;
- family involvement leads to higher seat belt usage; and
- a combination of individual and group rewards yields the best results.

The combined use of incentives and enforcement

The combined use of incentive programs with enforcement activities has been shown to be a particularly effective means of increasing seat belt usage rates. Dussualt (1990) reported on the use of such an approach during a STEP program undertaken in the Canadian Province of Quebec in 1987. This approach involved the issuing of a ticket to seat belt offenders and the provision of a promotional voucher to all occupants who were using seat belts (total value of about $1 and the chance to win one of eight $3000 prizes). He reported

that the combined enforcement and incentive STEP program increased seat belt usage rates from 67.7% to 85.8% which was the highest usage rate ever achieved in North America.

Dussualt (1990) indicated that there were a number of ways in which the inclusion of incentives had enhanced the STEP program. Firstly, the promotional vouchers allowed police officers to make direct contact with seven times the number of road users (226 830 vouchers versus 32274 tickets). Secondly, voucher distribution was an innovative element of the STEP program and, as a result, received extensive media coverage. Finally, this promotion put the STEP program in a favourable light with the public and the media. The message conveyed was that the program objective was indeed to increase the seat belt usage rate and not to fill government coffers by dealing severely with offenders.

Mortimer et al. (1985) also reported on the combined use of enforcement and incentives. He described the results from a study in the American State of Illinois which compared the effect of three approaches, including incentives alone, enforcement alone and the combined use of incentives and enforcement. They reported that all three conditions were effective in increasing seat belt wearing rates during the course of the study. The sole use of incentives resulted in an increase in seat belt usage rates of between 18% and 26%. The sole use of enforcement resulted in an increase in usage rates of approximately 45%. However, the greatest increase in usage rates (52%) was realised when both incentives and enforcement were combined. One additional finding was that the effect of enforcement alone on usage rates had largely decayed in about six weeks, whereas incentives retained their effect on usage rates for at least three months.

5.5.2 Feedback Mechanisms

The use of feedback devices to remind occupants to use seat belts has been shown to be an effective means of increasing seat belt usage. The philosophy behind this approach is that occupants may often forget to use their seat belts and some form of gentle reminder may be all that is required to get them to adopt appropriate seat belt wearing behaviour. The use of this approach is supported by the findings of a number of road user surveys (Makinen et al., 1991) which have indicated that 'forgetfulness' is one of the main reasons given by occupants for not using a seat belt.

Vehicle reminder systems

A number of vehicle manufacturers have included seat belt warning devices in their vehicles as a means of encouraging occupants to use seat belts. These systems typically consist of a warning light and/or buzzer which indicates that an occupant is not wearing a seat belt.

Geller (1992) has described the use of one such system in America. When the vehicle is started, and an occupant is un-belted, the warning light begins to flash for a six second period. If the occupant is still un-belted after this six second period a warning tone sounds for another six second period. Geller (1992) reported on the effectiveness of seat belt warning systems that used either a vocal reminder (with the message "PLEASE FASTEN YOUR SAFETY BELT") or a buzzer/tone. The vocal reminder was found to increase usage rates by 60% and the buzzer reminder by 29%.

Fildes et al. (1991) has suggested the use of a seat belt interlock device which prevents the vehicle from being started if there are any unrestrained occupants present. The first such interlock system was introduced in 1974 but was not actively promoted because vehicle

occupants could undermine the system by sitting on a buckled seat belt. However, with the improved design and comfort of present seat belt systems, the use of an interlock device may be more widely accepted. Instead of occupants going to the trouble and discomfort of sitting on a fastened belt they may instead decide to adopt appropriate seat belt wearing behaviour.

Dashboard stickers

The use of dashboard stickers is one approach that has been adopted to promote seat belt usage. Thyer and Geller (1987) reported on the effectiveness of such an approach which used a sticker with the message 'Seat belt usage is required in this car'. These stickers were placed in 24 test vehicles where the average baseline usage rate was 34%. They reported that after the stickers were attached to the dashboard, the seat belt usage rate increased to 70%. The stickers were then removed from the vehicle to examine whether or not other factors had affected seat belt usage. Usage rates dropped sharply to 41% and when the stickers were replaced the usage rate once again increased to a level of 78%. Rogers (1984; as cited in Geller, 1992) found that similar dashboard reminder stickers were able to increase seat belt usage from 10% to 34% in a fleet of Government-owned vehicles.

Public posting signs

The effectiveness of public posting signs have also been documented by a number of researchers. Grant et al. (1983) reported on the use of a large sign installed at two high volume intersections which displayed the message "DRIVERS WEARING SEAT BELTS YESTERDAY --%". They observed a 10% increase in seat belt wearing rates at the locations where the signs were being used. Williams et al. (1987) reported on the use of prompting signs, at two parking lot exits, which displayed the message "FASTEN SAFETY BELT". They observed an increase in seat belt wearing rates from 40% to 47% at one location and from 50% to 59% at the second location. They also found that usage rates could be further increased, if someone was standing next to the sign and was able to make vehicle occupants aware of the message displayed.

5.5.3 School Education

Key (1991) has emphasised the important role of school education. She indicated that in Australia, considerable emphasis has been placed on the development of suitable classroom information and teaching resources for children aged between 4 and 16 years. Younger children are taught the value of seat belt and appropriate restraint usage through the use of visual demonstrations. For older students, road safety is taught across the curriculum and students learn about the value of seat belts through physics and geometry as well as in school operated driving courses.

There are a number of advantages associated with the use of education programs which are designed specifically to target children (Key, 1991). Firstly, children learn the about the benefits of seat belt usage and develop the habit of wearing a seat belt at an early age. Secondly, younger children often ask their parents for help to ensure that they are using a seat belt and this, in turn, reminds the adult occupants to also use seat belts. Finally, seat belt usage is promoted as a family activity and develops into a set routine which ensures that all occupants are restrained whilst travelling in a vehicle.

5.6 SUMMARY

Seat belts are an integral component of vehicle based occupant protection design and are commonly regarded as being one of the most effective means of reducing traffic injuries. It has been estimated that vehicle occupants who correctly use seat belts are 40% to 50% less likely to sustain serious or fatal injuries in an accident situation. However, regardless of the widespread knowledge regarding the benefits of seat belts, wearing rates still remain at relatively low levels (50% - 70%) in many Western countries.

Increasing seat belt usage rates requires a coordinated approach involving educational and enforcement measures. The primary objective of such measures is to develop habitation of seat belt wearing. However, in many countries seat belt enforcement is not actively pursued and reliance is typically placed upon legislation, education and publicity to increase usage rates. The aim is to encourage seat belt usage by ensuring that road users are well informed and educated about the safety benefits of using such devices.

Legislation can play an important role in the process of developing appropriate seat belt wearing habits. The introduction of mandatory fitment and compulsory use laws have been shown to have resulted in significant increases in seat belt usage rates. Legislation relating to the use of seat belts in rear seating positions has lagged behind that for front seating positions due primarily to issues relating to the use of restraint systems by children. Seat belts are designed for adult occupants and their use by young vehicle occupants (0 to 5 years) may lead to particular injury problems. The introduction of special legislation relating to the use of child restraint devices, such as harnesses, boosters and baby capsules, has been shown to be an effective means of reducing injuries among child occupants.

The introduction of seat belt laws has also led to a number of questions regarding the benefits of seat belts. The two main issues include, the possibility that the use of seat belts may actually encourage more risk taking behaviour because they make drivers feel more safe, and the possibility that seat belts may actually result in particular types of occupant injuries that might not have occurred if the occupant was unrestrained. These potential negative benefits of seat belts have generally not been supported by the research literature.

The combined use of legislation and active enforcement is regarded as the best means of increasing and maintaining wearing rates at a high level. The experience in countries where seat belt laws are actively enforced, has shown that wearing rates over 90% can be achieved. The effectiveness of enforcement is, to a large degree, dependent upon the type of legislation introduced. Legislation based upon a policy of primary enforcement (any vehicle can be stopped for a seat belt violation) has been found to be far more effective than secondary enforcement policies (a vehicle cannot be stopped only on the basis of a seat belt violation).

However, in many countries seat belt laws are not actively enforced due to a number of reasons including problems associated with detecting offenders and general concessionary attitudes towards enforcement. Police surveys have indicated that the difficulties associated with the detection of seat belt offenders are one of the main problems hindering effective enforcement of seat belt laws. The most common means of detecting seat belt offenders is through the use of traditional vehicle based deployment options which can be resource intensive and relatively ineffective.

The use of information obtained from automated speed enforcement operations may provide an effective means of detecting seat belt offences and significantly increasing the

actual and perceived risk of apprehension. Targeting speed offenders has a number of benefits. Firstly, seat belt offenders tend to be more high risk road users and are likely to have committed other offences such as speeding. Secondly, seat belt effectiveness is directly related to speeding behaviour in that the higher the travel speed the greater the injury potential, and need for some form of protection, in an accident situation.

Police commitment is essential to the success of seat belt enforcement operations. However, police are often reluctant to enforce seat belt laws especially when they believe that there are far more important traffic enforcement priorities. A common attitude adopted by police is that if road users are aware of the risks associated with non-seat belt usage, and still decide not to adopt appropriate seat belt wearing behaviour, then the only road users that they affect in an accident situation are themselves. Police can also be discouraged from enforcing seat belt laws due to the perceived lack of support from the legal system and general community resentment of seat belt enforcement operations.

Police education programs are essential in order to increase overall awareness regarding the benefits of, and need to, enforce seat belt laws. Education programs aimed at developing a greater appreciation of the safety and cost benefits associated with seat belt enforcement have been shown to be an effective means of increasing police motivation levels. These programs are also designed to provide police with guidelines regarding the most effective type of seat belt enforcement methods.

The simplest and most cost effective approach to increasing seat belt usage rates is to integrate seat belt enforcement operations with other policing activities. This approach has been shown to lead to long term gains in seat belt usage rates. The use of periodic, high intensity enforcement activities ('blitzes') has been shown to be an extremely effective means of bringing about 'sharp' increases in seat belt wearing rates. These enforcement activities can be further enhanced when combined with police education programs, publicity, and post enforcement evaluation studies. Evaluation is an important component as it allows police to be provided with feedback regarding the effectiveness of their efforts.

Publicity can be an effective means of increasing community awareness of the benefits of seat belts. When used to support enforcement activities, it can also improve the effectiveness of seat belt operations by increasing the perceived risk of apprehension. As a stand alone countermeasure it has been shown to initially result in significant increases in seat belt usage rates. However, these effects are usually only temporary and seat belt wearing behaviour soon reverts back to pre-publicity levels.

The lower priority placed on seat belt enforcement has led to the development of a range of non-enforcement strategies aimed at increasing seat belt wearing rates. The most reported of these strategies involves the use of incentive programs. These programs, based upon the principle of positive reinforcement, assume that behaviour that has favourable outcomes is more likely to be repeated and at higher rates than behaviour that has negative outcomes.

The use of incentive programs to promote seat belt usage has been shown, in certain situations, to be just as effective as enforcement in increasing the level of appropriate seat belt wearing behaviour. Incentive programs have also been shown to have a greater long term effect on wearing rates than does the use enforcement. The main potential benefit of incentive programs may be their ability to enhance the overall effectiveness of enforcement operations. The combined use of incentive programs with enforcement activities has been shown to be a particularly effective means of increasing seat belt usage rates.

The use of feedback devices to remind occupants to use seat belts has also been found to be an effective means of increasing seat belt usage. The installation of an in-vehicle seat belt warning device, which consists of a warning light and/or buzzer, has been shown to have considerable potential. The use of seat belt interlocks which prevent the operation of a vehicle when an occupant is not wearing a seat belt is a more drastic yet effective approach.

An extremely low cost alternative, which has also been shown to improve wearing rates, is the attachment of a seat belt usage sticker to the dashboard of the vehicle. The use of public posting signs to provide road users with information about group seat belt usage has also been demonstrated to have the potential to increase overall wearing rates.

6. ENFORCEMENT OF SIGNALISED INTERSECTIONS

6.1 INTRODUCTION

Intersections are locations within the road traffic network where two or more traffic flows converge and therefore, by their very nature, provide points of potential conflict. The successful negotiation of intersections is dependent upon careful attention to the road environment which includes the adherence to the road traffic rules which govern the entry into and out of an intersection. The decision to obey these road traffic rules is dependent upon a number of factors which relate to:

- the driver - behavioural and attitudinal aspects as well as knowledge of the particular road environment, and the perceived risk of being detected;
- the vehicle - speed and position within the traffic stream;
- the road environment - congestion, road condition, and time of day etc.; and
- the social environment - including attitudes towards enforcement and road traffic laws.

Given all of these factors, it is not surprising that accidents at intersections continue to pose a significant road safety problem in many Western countries. Road traffic accidents at intersections are one of the most common type of accident events. This fact has led to the development of a range of countermeasures aimed at reducing the potential conflict at intersection locations. It is generally regarded that the problem of intersection accidents requires a coordinated approach which involves education, engineering and enforcement elements. However, engineering solutions can often be expensive and if commonsense does not prevail and road users cannot be educated to obey intersection traffic laws then reliance is typically placed on enforcement to ensure road user compliance.

There are a several ways to reduce conflict at intersections. Straight sign-posting is a common practice on minor roads where vehicle numbers and accident rates are low. One of the main traffic safety issues relating to this type of intersection is the visibility of the sign posting. Drafer (1988) experimented with a range of more visible sign posting methods including on-road sensors which provide night-time illumination of roadside signs when a vehicle approaches an intersection. Drafter (1988) found that intersection approach speeds at treated sites were reduced but was unable to demonstrate any accident reduction benefits.

Engineering treatments such as roundabouts have been used successfully on low to moderate volume roads and have been shown, in certain situations, to be a cost effective solution for reducing accidents (ITE Technical Council Committee, 1992). The added benefit of these devices is that they reduce traffic speeds on through streets, regulate traffic flows and can improve the aesthetic quality of the road environment.

In many other situations where traffic volumes are high and/or complex traffic movements are required the use of straight sign-posting or engineering treatments is not feasible and the most common way of managing these intersections is through the use of traffic signals.

The main focus of this review will be on enforcement methods available to authorities to ensure that road users comply with traffic laws governing the negotiation of intersections.

However, enforcement is usually the last solution to the problem of intersection management and the possible application of engineering solutions should always be examined before enforcement options are considered. The range of engineering options, available to authorities will, therefore, also be briefly examined in this review.

6.2 TRAFFIC SIGNALS

Traffic signal systems are designed to maximise the capacity of junctions whilst maintaining an operating environment which is as safe as possible. One of the main advantages of signal control is that it minimises the conflict points within an intersection by sharing the available time between competing traffic streams. The use of traffic signals may still, however, result in significant road safety problems. In Great Britain it has been estimated (Lawson, 1989) that 8% of the total number of accidents, dis-aggregated by speed limit and accident severity, occur at signalised intersections. South et al (1988) have estimated that, in the city of Melbourne, Australia, approximately 10% of all fatal accidents and 18% of all accidents, resulting in at least one admission to hospital, occur at signalised intersections.

One of the main problems with signalised intersections is that the automated control and hence simplification of the road environment is achieved at the expense of requiring a driver to make a decision whether or not to stop when presented with an amber signal (Baguley, 1988). In some circumstances, such as at the onset of the amber signal, this decision can be difficult, depending on the speed and position of the vehicle. When the amber period is insufficient for the driver to stop comfortably, or to clear the stop-line before the red signal has appeared, the driver is said to be in the 'dilemma zone' (Baguley, 1988). The driver must make a choice in this situation either to pass through the intersection after the red signal has appeared, to accelerate 'to beat the red', or to brake hard. All three of these actions increase the potential for an accident situation to occur with rear end collisions particularly common when the driver accelerates through or brakes hard before the intersection.

The greatest potential for accidents at signalised intersections occurs when drivers, for whatever reason, blatantly disregard the red signal and continue to travel through the intersection. Baguley (1988) reported that more than 20% of drivers who fail to stop at the red signal would have been outside the dilemma zone and should have been able to stop comfortably. The term most often used to describe the action of a driver who, for whatever reason, fails to stop their vehicle when instructed to do so by the red signal and continues their passage over the stop-line, usually travelling into and through the intersection is 'red-light running' (Lawson, 1991).

6.3 RED-LIGHT RUNNING

Red-light running poses a serious problem in that it creates a high potential conflict situation and significantly increases the likelihood of an accident event. A red-light running accident is said to occur when a driver fails to comply with the red signal and, as a direct effect of that action, collides with another vehicle or pedestrian (Lawson, 1991). Croft (1981) estimated that 18% of all reported casualty accidents, and 23% of casualties of accidents occurring at signalised intersections in Australia involve a driver running a red-light.

In Great Britain in 1989 there were 20970 accidents resulting in injuries at 8500 signalised intersections (Department of Transport, 1990). Lawson (1991) estimated that approximately 5,000 (20% - 25%) of those accidents may have involved red-light running. He further estimated that the approximate annual cost of red-light running accidents in Great Britain in 1992 was around œ100 million. Baguley (1988) identified three groups of red-light running drivers:

(a) those who could have entered the intersection before the onset of the red signal but were delayed either by their own indecision or by slower traffic in front;

(b) those in the dilemma zone who could neither stop safely nor cross the stop-line before the onset of the red signal; and

(c) those who could have stopped safely but chose to deliberately run the red signal.

The risk of accidents arising from the first type of red light running can be effectively minimised with good geometric design of the intersection (Frantzeskakis, 1984). Proper design consideration given to the use of right/left priority overlap stages has been identified as an effective means of reducing this type of red light running (Henson et al., 1992).

Drivers who find themselves in this type of situation usually have no choice but to continue through the intersection and, as such, are usually not deemed by authorities to have committed an illegal driving act.

The second type of red light running (those caught in the dilemma zone) can be effectively reduced by careful design consideration of the intergreen timing (Retzko & Boltze, 1987).

Jourdain (1986) indicated that there are two ways to avoid problems associated with a dilemma zone at signals: one is to adjust the amber warning to fit the traffic approach speed, the other is to enforce a speed limit which relates to the amber duration set. Drivers in this situation are also usually treated leniently with the issuing of an infringement notice dependant on the officer's subjective judgement as to whether or not there was sufficient time for the driver to have stopped safely.

It is the third type of red light running offence, committed by those drivers who deliberately run the red light signal, which poses the most serious traffic safety problem. Engineering and design considerations appear to have little effect on this type of red light running activity and surveillance and enforcement techniques appear to be the best way of discouraging this type of red light runner (Chin, 1989). It is these type of drivers who are the primary target of enforcement activities as they pose a significant risk, not only to themselves, but also to other road users.

The are a number of reasons why motorists choose to run red light traffic signals. The Federal Highway Administration (1993) have identified a number of likely contributing factors which include:

- a general disregard for road traffic laws - many individuals may believe that in situations where it is safe to proceed through an intersection they should be allowed to do so, regardless of the red signal;

- lack of effective and continuous enforcement - police have only limited resources and the enforcement of traffic signals is usually a low priority;

- excessively long cycle lengths for signals - driver frustration with traffic congestion may lead to red light running behaviour in situations where they have to wait for long periods at traffic signals;

- driver perception that there is little risk of being caught - drivers are aware that the actual risk of detection for committing a red light offence is extremely low; and

- driver attitudes and conflicting safety and mobility needs - driver attitudes such as "I don't have time to wait for a red light" are quite common, especially in societies which promote a fast and active lifestyle.

These factors highlight the problems facing many authorities in trying to develop effective intersection management strategies. There are many thousands of signalised intersections and the use of engineering solutions and effective enforcement at all such locations is not possible nor feasible. In addition, enforcement resources are usually limited and the fact that violation rates are very low (less than 1 %) often results in only minimal enforcement activities being targeted at red light running behaviour.

6.4 TRADITIONAL ENFORCEMENT METHODS

Visible police presence at signalised intersections has been shown to reduce the incidence of red light running by posing a sufficient threat to deter potential offenders (Thompson et al., 1989). Bankhead and Herms (1970) found that the presence of uniformed police officers or highly visible stationary police vehicles at signalised intersections reduced the incidence of red light violations by up to 80%. Road users modified their behaviour in direct response to the visible police presence and the possibility of apprehension.

The traditional approach to the detection of red light violations involves one police officer stationed at the point where traffic enters the intersection, to judge when an offence has been committed, and a second police officer on the other side of the intersection to apprehend offenders. Police vehicles travelling with the traffic stream can also, as part of their general duties, detect and apprehend intersection violators.

There are a number of operational issues which call into question the effectiveness and efficiency of this traditional approach (South et al, 1988). In urban areas there may be many hundreds of signalised intersections and in order to have a lasting effect on driver behaviour many of these sites would need to be policed over a long period of time. Red light violations are also relatively infrequent events, and the presence of a large number of police may have a significant deterrence effect but the detection and prosecution of offenders could prove to be a labour intensive task and would be undertaken at the expense of other policing activities (Thompson et al, 1989).

One way to overcome these problems is through the use of selective enforcement programs (Leggett, 1992). By strategically targeting high risk intersections at peak volume traffic times the level of general deterrence can be increased with only a moderate impact on police resources. This approach is supported by Lawson (1991) who found that the majority of red light running accidents occurred where traffic volumes were high and a large number of vehicles were crossing the 'stop' line. Sanderson and Cameron (1982) also advocated the use of selective enforcement and suggested that the most effective means of deterring transient offences at signalised intersections is by the use of sporadic but frequent visible patrols at high volume accident locations.

The benefit of on-site police enforcement of intersections is that red light runners are apprehended immediately after the offence has been committed. Immediacy has been pinpointed, in both laboratory and field experiments, as a crucial factor in behavioural change (Rothengatter, 1990). With regard to traffic law enforcement, driver surveys have shown (Corbett & Simon, 1992) that the immediate on-site recognition and punishment of red light offences reduces the level of recidivist behaviour. Another benefit of on-site enforcement is that the police presence may impact on other deviant road user behaviour such as speeding and traffic lane violations.

In general however, the use of on site enforcement of intersection violations is viewed as a relatively costly and labour intensive method of reducing intersection accidents. Slavender (1988) has indicated that costs of using traditional enforcement methods to bring about significant area wide reductions in the level of red light running violations may be up to four times the potential savings in terms of accident reduction benefits.

Another commonly documented problem (Lawson et al, 1989) is that unless the level of enforcement is maintained the incidence of red light running soon reverts back to pre-enforcement levels. In a previously reported study by Bankhead & Herms (1970), it was found that within 30 minutes of police leaving an intersection site the level of red light violations had fallen back to pre-existing levels.

6.5 AUTOMATED ENFORCEMENT METHODS. RED LIGHT CAMERAS

The need to develop permanent on-site surveillance and enforcement of intersections has led to the development of automated enforcement devices. Chin (1989) has reported that the best way to discourage red light running is through the use of an automatic red light camera which captures an image of a vehicle caught in the act of red light running. Chin (1989) further stated that this form of surveillance can lead to a more objective prosecution of the offender and is less labour intensive when compared to surveillance by police officers.

Red light cameras are devices, linked to the signal control system, which automatically photograph vehicles that enter an intersection once the red light signal has been displayed. They are mounted into a housing on a drop pole to allow ease of access and are triggered by a wire induction loop embedded in the intersection about 10 cm below the surface. The devices are used in conjunction with an independent flash unit to ensure accurate exposure in poor lighting conditions.

When an infringing vehicle is detected the camera automatically takes two photographs; one at the moment of detection and the second after an appropriate time lapse depending on the geometry of the intersection. The photographs allow the registration number of the offending vehicle to be recorded and include additional information such as the date, time of day, and the time elapsed since the onset of the red signal.

Red light cameras are designed to modify driver behaviour when approaching a treated signalised intersection. Wray (1985) stated that this effect manifests itself in driver's actions, altering and increasing their preparedness to stop on a red light signal. Red light cameras are also designed to change driver behaviour in response to the amber signal, with fewer drivers passing through intersections on such phases when a red light camera is present (Chin, 1989).

Site selection for a red light camera installation is normally based upon a number of factors including, accident history, traffic volumes and physical site characteristics. On the basis of this information, intersections are ranked according to the number of accidents (usually right angle accidents) as related to traffic volume (Federal Highway Administration, 1993). Camera rotation among selected sites is also a common practice, in order to increase the overall effectiveness and efficiency of the enforcement operations.

6.5.1 Red Light Camera Effectiveness

Red light cameras have been shown to be an effective means of reducing the incidence of red light running. Chin (1989), in a study of the effect of cameras on red light running at 11 'camera sites' and 5 'non-camera' sites, found that the cameras reduced the rate of red light running by about 40% at the camera sites but not at non-camera sites. Red light cameras have also been used in limited numbers in the United Kingdom since 1987. A study conducted by the County Surveyors' Society (1990) of UK authorities, who have installed traffic signal cameras, concluded that red light violation rates at sites where cameras have been installed were reduced by approximately 55%.

Sweden was one of the first countries to introduce red light cameras as a means of deterring and detecting red light violations. In Stockholm, between 1972 and 1978, red light cameras were installed at five major intersections. The use of these devices was found to have only a minimal effect on red light running behaviour. However, these results may be explained by the fact that red light violations were already quite low (0.3% to 0.7%) before the cameras were introduced and enforcement was carried out with any supporting publicity or the use of posted warning signs.

Red light cameras were first introduced in Australia in 1979 and are presently used in Western Australia, South Australia, Queensland, New South Wales and Victoria. Evaluations of red light camera operations have been undertaken in the majority of these Australian States. The general consensus of these evaluations is that red light cameras reduce the incidence of red light running by between 35% and 60%. The study by South et al (1988) of the red light camera program in Victoria, was the first Australian study to examine the effectiveness of the installation of red light cameras as a means of accident reduction. Changes in accident rates for six different types of intersection accidents were analysed and the following results obtained.

Accident Type	Change in Accident Rate
Right angle	- 32.0%
Right angle (turning)	- 25.0 %
Right against	+ 2.0 %
Rear end	- 30.8 %
Rear end (turning)	+ 28.2 %
Other	- 2.2 %

The final analysis indicated that there had been a 6.7% reduction in all intersection accidents and a 10.4 % reduction in the number of casualties at red light camera sites.

A similar evaluation of the accident reduction benefits resulting from the South Australian red light camera program was undertaken by King et al (1990). The results indicated a significant change in both right angle casualty accidents (57%) and right angle property

damage accidents (32%). An examination of other intersection accident types indicated that, overall, there had been a 24% reduction in the total number of casualty accidents at the red light camera sites.

Hillier et al (1993), undertook an evaluation of a red light camera program in New South Wales, Australia and concluded that right angle and right turn against accidents had been reduced by approximately 50%. However, an examination of other accident types found that rear end accidents had increased by 25% to 60% at red light camera sites. They concluded that there was an overall reduction in the number of accidents and casualties, due to the more severe nature of right angle accidents.

The finding that red light cameras increased the number of rear end collisions is consistent with previous research findings (Maisey, 1981; ARUP, 1992). It is generally accepted that increasing compliance with traffic signals will reduce right angle accidents and increase read end collisions (Lawson, 19991). The increase in rear end collisions has been explained (South et al, 1989) in terms of an increase in the stopping behaviour of motorists.

There is evidence to suggest that the number of rear end collisions actually decreases after a certain time period. South et al (1989) found that there had been a relative decrease in rear end collisions one full year after the introduction of the Victorian red light camera program. King et al (1990) reported a non-significant increase in rear end accidents which appeared to have occurred only in the first six months of red light camera operations.

The reduction in the number of rear end accidents, over time, has been explained in terms of slower approach speeds to camera sites if drivers are deterred from running the amber and red signals due to the presence of the red light cameras. By slowing down at the approach to signalised intersections the likelihood of being able to stop when necessary would be increased and the likelihood of rear end accidents would therefore be reduced.

6.5.2 Red Light Cameras - The Deterrence Process

Red light cameras may reduce accidents at intersections in two ways (MacLean, 1985). The first is specific deterrence: drivers who are detected and penalised may be deterred from running red lights in the future. The second is general deterrence: drivers are deterred from running red lights because they believe that if they do, they will be photographed and punished.

It is likely that a large proportion of the accident reductions resulting from red light cameras are due primarily to site specific deterrence effects. Perceived apprehension risk increases as drivers become aware of the increase in the actual risk of apprehension, due to publicity and the visible presence of the red light camera hardware. In the Australian States of Victoria and New South Wales, the site specific effect has been maximised in a number of ways:

(a) by the use of warning signs on all the approaches to a treated intersection, although the camera only operates on one traffic stream;

(b) by making the camera hardware installations (camera housing and flash unit) clearly visible to motorists;

(c) by using a small number of cameras rotated through a large number of sites; and

(d) by using widespread publicity to increase awareness of the red light camera program.

Use of warning signs

One feature of the Victorian, New South Wales and South Australian red light camera sites are that they are clearly signposted with the message "RED LIGHT CAMERAS AHEAD". South et al (1989) stated that "it was clear that the maximum deterrent effect would only occur if the presence of the devices was signalised in some way" and concluded that warning signs, as visible symbols of enforcement, were likely to provide the greatest deterrent effect to red light running behaviour.

This notion was supported by Hillier et al (1993) who found that the presence of the red light camera hardware (signposting and camera housing / flash unit) appeared to be effective at reducing right angle and right turn against accidents, even when seldom used as active red light camera sites. It appears that drivers see the installed hardware and are reminded of the possible risk of detection even when they know that the site is not always actively enforced.

The benefits of using site specific warning signs at the approaches to red light camera intersections has recently been questioned. Bodinnar (1993) has argued that, after a suitable time period, drivers learn that only sign-posted intersections present the possibility of red light camera detection and hence modify their behaviour at those sites but are less cautious and law abiding at other non-camera site intersections. This finding is supported by Chin (1989) who reported a significant reduction in red light running at camera sites but no such reduction at non-camera sites.

Bodinnar (1993) suggested that generalised red light camera sign posting should be used as opposed to site specific sign posting as a possible means of addressing this problem. This sign posting practice would still ensure that driver awareness of red light camera operations was maintained, but by not highlighting the precise location of the camera sites, may actually lead to drivers modifying their behaviour at all signalised intersections. A contrary argument has been put forward by Schnerring (1993). He suggested that, since red light camera sites are selected on the basis of accident history, the use of generalised sign posting may reduce the deterrent effect of site specific sign posting and increase the number of accidents at potentially dangerous intersections.

No research evidence was found relating to the deterrent or crash reduction benefits of generalised as opposed to site specific sign posting. However, an evaluation study may soon be undertaken in New South Wales, Australia (Lane, 1993) to examine the benefits of both of these sign posting approaches. This study will involve the use and evaluation of each particular method in one of two similar regional cities.

Camera rotation at sites

The rotation of a small number of cameras through a large number of sites has also been shown to increase general deterrence by maintaining a high level of perceived detection risk at each possible camera site (South et al, 1989). In order to produce the most cost effective coverage of red light intersections whilst maintaining a high level of general deterrence it is recommended (Lawson, 1991) that the ratio of sites to actual cameras not exceed 6 to 1.

South et al (1989) reported that when red light cameras were first introduced in Victoria, Australia there was no formal strategy for rotating cameras among treatment sites. Initially cameras were left at sites until the offence rate started to decline. Once sufficient data on particular sites had been collected cameras were rotated on the basis of violation rates and the need to maintain the level of general deterrence. In Australia it is common practice to rotate cameras among sites every 7 to 10 days. Exceptions to this rule include high red light violation sites, which may require continuous camera surveillance and low violation sites, which require only minimal surveillance.

Use of publicity

Another reported means of increasing the general deterrence effect of red light cameras is by using the media to raise community awareness of red light running and red light camera operations. MacLean (1985) detailed a study undertaken in Victoria, Australia which highlights the effectiveness of the media in modifying driver behaviour at intersections. In 1981 a red light camera, located at a major intersection, was trialed for a three month period. In an initial period, when drivers were not aware of its presence, there were approximately 300 red light violations detected per week. As a result of an intensive period of media publicity this rate dropped to 20 per week. At the end of the trial period the camera was replaced by a dummy unit and this had the effect of ensuring that offence rates continued to remain at a low level. It appeared that the media attention given to this one particular intersection created a lasting deterrent effect.

Thompson et al (1989), reported on the use of red light cameras by the Nottingham County Council in the United Kingdom, and concluded that the reduction in red light running offences was greatest during the period of extensive publicity just after the cameras were officially switched on. Similar publicity campaigns were launched in conjunction with the introduction of red light camera programs in Australia. It is generally accepted that these campaigns had a significant impact on driver behaviour by increasing driver awareness, and hence the general deterrence, of red light camera operations.

Flash unit operations

One final means of increasing general deterrence has been reported by Wray (1985) and involves the deployment of the red light camera flash unit at non-active camera sites. Red light camera flash units can be activated, when a red light runner is detected, independent of the actual camera units themselves. The general policy in most jurisdictions is not to deploy the flash unit when a camera is not present as it may reinforce red light running behaviour when no traffic infringement notification is received by the offending driver.

Wray (1985) has argued against this proposition. He suggested that the non-deployment of the camera flash unit at non-active sites may also reinforce red light running behaviour and actually reduce the level of general deterrence. This occurs because the red light runner, and all other drivers present at the intersection, realise, due to the non-deployment of the flash unit, that a red light camera is not operating, and hence no infringement will be recorded. Wray (1985) concluded that the deployment of the flash unit can, at a relatively low cost, increase the general deterrence of red light cameras.

The use of non-detectable, infra-red flash units has also been suggested as a means of increasing the general deterrence effect of red light cameras. When drivers do not see the visible flash deployment they assume that an offence has not been recorded. If the public

are informed about the use of non-visible flash units then, the fact that no flash was observed, would not lead offenders to assume that an infringement had not been recorded.

The available evidence indicates that both visible and non-visible flash deployment options have the potential to increase deterrence. However, studies that have examined the visibility of enforcement (Sanderson & Cameron, 1982; Armour, 1984) suggest that a visible flash deployment at a red light camera site may have a greater impact on deterrence due to physical message it conveys than that created with a non-visible infra-red flash deployment.

6.5.3 Red Light Cameras - Cost Effectiveness

The use of red light cameras has been found to be a cost effective countermeasure for reducing and preventing accidents at signalised intersections. South et al (1988) estimated that the red light camera program in Victoria, Australia, resulted in a 13.8% reduction in accident costs at red light camera sites. This equated to savings of $30,253 per site per year, or about $1.4 million per year at 46 sites (1987 dollars). At the same time police estimates indicated that the red light camera program operating costs were approximately $520,000 per year. Based on these figures, South et al (1988) concluded that the benefit-cost ratio of the program, excluding fine revenue, was approximately 2.7 to 1.

King et al (1990) estimated that the South Australian red light camera program (5 cameras rotated through 15 sites) achieved an accident reduction benefit of $1.42 million in the first 12 months, equating to a saving of $95,000 per site per year (1989 dollars). The cost of establishing the program was reported at $1.83 million with operating costs and revenue in 1989 amounting to $285,074 and $271,870 respectively. On the basis of these figures, it was estimated that the benefit-cost ratio of the program, over a five year period, would be 2 to 1.

In an evaluation of the likely benefits of initiating a red light camera program in Birmingham in the United Kingdom, Lawson (1990) estimated that the cameras and on-site hardware (warning signs, camera/flash housing) would pay for themselves within twelve months as a result of the potential projected accident savings. Lawson (1990) based this estimate on an annual accident reduction benefit of approximately £200,000 which equated to an annual per site saving of £6, 700. These potential savings are considerably lower than those reported by South et al (1988) and King et al (1990) and may reflect the conservative accident reduction estimates used by Lawson (1990) in his calculations.

6.5.4 Red Light Cameras - Problems and Limitations

There are a number of problems identified in the research literature which relate specifically to the use of red light cameras. These include low detection rates, the permanency of on-site enforcement treatments and the length of time taken to notify drivers that an offence has been committed. These problems can reduce the effectiveness of red light camera operations and may lead some policing authorities to question the reported benefits and use of these devices.

Relatively low red light offence apprehension rates of between 40% and 60% have been reported (Lane, 1993; Bodinnar, 1993). Low apprehension rates can result due to a number of reasons including; equipment limitations, poor quality images in certain lighting conditions, weather and road conditions and vehicle identification problems in multiple lane and heavy traffic flow situations. Lock (1993) has indicated that most of these

problems relate to the equipment used, and has suggested that as more innovative technology (such as digital imaging systems) is introduced, many of these problems will disappear.

The on-site permanency of red-light cameras has also been identified as a problem which can reduce the potential deterrence effect of these devices. This occurs because only a certain number of treated intersections can be used at anyone time for red light camera operations. Drivers soon become aware, due to the presence of the camera hardware, of which intersections are treated and may modify their behaviour only at those sites where they perceive the risk of detection as being high.

One final problem is that the use of red light cameras can result in significant time delays between offence detection and offence notification. The delays result from the time intensive tasks of collecting, developing and processing the photographic images. The problem with such delays is that the punishment associated with the red light offence is not immediately administered. Immediacy of punishment can be a crucial factor in changing deviant road user behaviour (Rothengatter, 1990).

6.6 NEW AUTOMATED ENFORCEMENT TECHNOLOGY

In recent years, innovations in automated police enforcement technology have led to the development of several new intersection enforcement systems which negate many of the previously mentioned problems associated with existing red light camera systems. The main improvement of this new technology is the ability to significantly increase overall apprehension rates through the use of better image collection methods. The much improved performance capability has the potential to increase the perceived risk of detection, thus leading to more effective and cost efficient enforcement operations.

A new laser and digital imaging detection system, developed in Australia, has been shown to significantly improve the effectiveness and efficiency of red light camera operations. One of the main advantages of this new laser based system is that it is fully portable and requires no physical connection with the traffic signal control system. This significantly increases the mobility and deterrence effect of red light camera operations by enabling any signalised intersection to be automatically monitored.

When an offence is detected, the information is digitally recorded and security coded and can be stored on location or sent direct, via telephone line, to a central location for immediate processing. The high resolution digital image produced is significantly clearer than existing photographic images and has been reported to result in a 95% detection rate, almost twice that of existing systems. The ability to produce an image, at a central processing location, within minutes of a traffic offence being recorded also means that the owner of the offending vehicle can receive notification of an offence in a fraction of the time normally taken.

The new digital imaging system has the added advantage of being able to detect the speed of vehicles travelling through the intersection regardless of whether or not a red-light offence has been committed. This means that both red light runners and speed offenders, including those high risk drivers who speed up through an intersection in order to 'beat the red', may be detected and prosecuted.

The system has a significant deterrence potential due to the increase in detection rates, the reduction in offence notification time and increased driver awareness that any signalised

intersection could be monitored by an automated camera device which detects both red light running and speeding offences. The system is also extremely cost effective with the estimated cost of treating an intersection (including equipment) being approximately half that of existing red light camera systems.

A different type of red light camera and speed detection system also developed in Australia has been successfully trialed with encouraging results. This system incorporates the use of state-of- the-art camera technology, automated vehicle tracking and optical management techniques, and additional speed induction loops to detect intersection offenders.

The main advantage of this system is its ability to detect offending vehicles in multiple lane and high volume intersections. The automated tracking camera can rotate at high speed through a full 30ø and can be programmed to photograph offending vehicles, depending upon their position within the intersection, at different magnifications via the use of an automated variable high speed wide-angle/telephoto lens (35 mm - 105 mm).

The series of induction loop sensors have a dual purpose. They not only detect the presence of an offending vehicle but also provide information about its exact location within the intersection. This information is then used to automatically track the progress of the offending vehicle at the most optimum angle and level of magnification. This automated tracking system has been reported (Jones, 1993) to result in a 90% - 95% detection rate.

The high detection rate and the ability to target both red light and speed offences suggests that this system also has the potential, especially at high volume multiple lane intersections, to increase deterrence. The cost of this system is comparable to that of existing red light camera systems and therefore represents good value for money given the additional enforcement benefits it provides.

6.7 MODIFICATION TO THE PHYSICAL ENVIRONMENT

Reliance on enforcement as the primary means of reducing the level of red light running behaviour is regarded as a costly and counter productive exercise. There are many thousands of signalised intersections and the active enforcement of each of these traffic locations would be extremely cost prohibitive. Red light running is also a relatively infrequent event and the over emphasis on enforcement may lead to negative social and political consequences.

It is generally regarded that red light enforcement operations are best suited to targeting known high accident locations. When used in this manner, enforcement can significantly increase the level of deterrence and can result in the maximum accident reduction potential.

The control of all other intersection locations may be effectively managed through the use of design and engineering treatments. These treatments can offer a low cost means of reducing traffic conflict and minimising the likelihood of an accident event.

6.7.1 Traffic Light Signal Design Considerations

The most cost effective means of reducing conflict at signalised intersections is through the use of traffic light timing sequences. The collection and examination of traffic accident data can allow traffic engineers to determine the most appropriate intergreen timings and traffic movement sequences. The use of intergreen timing considerations and methods to

warn drivers of the termination sequence of the green phase are common practice and recognised as being an effective means of reducing potential vehicular conflict.

Intergreen timing

The intergreen signal phase has two primary function (Jourdain, 1986). Firstly, the amber following a green signal (leaving amber) provides drivers with a warning that the related movement right-of-way is being terminated. Secondly, the all-red part of the intergreen phase provides time for vehicles which enter the intersection on amber to clear the area of conflict before right-of-way is reassigned. Standard practice is to allocate between 2 and 5 seconds for the leaving amber phase and from between 1 to 3 seconds for the all-red phase. Intergreen timings can vary significantly within jurisdictions depending upon the traffic density and vehicle approach speeds.

Jourdain (1986) has stated that amber warning time must be set so that all drivers are provided with a real choice zone on the approach, between having to stop and having to continue because they are too close to the stop-line. She also suggested that the choice zone should be as narrow as possible and there should be no dilemma zone for any reasonable driver and vehicle. She recommended a 3 second amber period for roads with approach speeds from 20 km/h to 60 km/h and a 3.5 second amber period for higher speed roads. She further added that the all-red phase should be set at a minimum of 1 second for low volume roads and at least 2 seconds for higher volume roads.

Green phase warning signals

A number of researchers have also examined methods (other than the amber signal) of warning drivers that the green phase is about to be terminated. These methods are not regarded as part of the intergreen phase. Several devices that have been examined include, a clock-like dial showing the remaining green time; a series of lit lamps that turn off one by one as the green phase closes; and several warning methods that combine flashing amber or green (Mahalel & Zaidel, 1985).

Evaluation of these methods found them to be relatively ineffective. Mahalel and Zaidel, 1985) reported on the use, in Israel, of a 3 second green light flashing phase just prior to the onset of the amber signal. In a three year evaluation study they found that the use of this method increased the length of the indecision zone and consequently resulted in an increase in the probability of rear-end collisions. They also found no reduction in the level of right angle accidents over the three year period.

Design considerations for turning traffic

Special design consideration, given to traffic wishing to turn against the flow of opposing traffic, has also been shown to significantly reduce intersection accidents as well as the overall level of red light running behaviour. At simple two stage traffic signals, vehicles wishing to turn against the opposing flow of traffic do so in traffic gaps or make their turn in the intergreen period at the end of the stage. Both these manoeuvres have a high accident potential as they rely on the judgement of individual motorists to decide when it is safe to turn.

Henson et al. (1992) have identified two principle ways in which this problem can be overcome. Firstly, the turning movement (against the opposing traffic flow) can be given a separate stage. This approach may, however, result in a consequent reduction in the overall

capacity of the traffic junction. The second approach involves the use of turning overlap stages. This allows turns to be made in gaps in the opposing traffic flow, but also provides a stage in the cycle (at the beginning of the intergreen period) when opposing flow is held by the traffic signals to allow an unopposed turn movement.

Advance warning signs

The introduction of signalised intersections on high speed roads (over 80 km/h) creates the potential for a significant increase in traffic accidents. Eck and Sabra (1986) have indicated that two common problems at such locations are the creation of a decision zone and the existence of geometrics such that the signal is not expected or that the display cannot be seen in time. They suggested that the most promising countermeasure for these intersections is the use of active advance warning devices. These traffic control devices, placed at or in advance of problem intersections, provide drivers with necessary information regarding the decision of whether to stop or proceed. These devices have been found to be an effective means of reducing the level of right angle and rear end accidents (Styles, 1982).

There are two principle types of advance warning signs. The first type of signs only flash during the red light phase and are designed to provided drivers with an indication as to whether they should stop or proceed. The second type of devices permanently flash and are designed to draw motorists attention to a traffic light signal in situations in which the signal is unexpected or difficult to see. This second device is generally the most popular with traffic engineers as it has a lower installation cost and appears to be equally as effective at reducing the level of intersection accidents (Eck and Sabra, 1986).

6.7.2 Intersection Design Considerations

Physical modification of the intersection environment has also been shown to be an effective means of reducing the number and severity of intersection accidents. The provision of special lanes for traffic, wishing to turn against the flow of opposing traffic, is one such design consideration which has been shown to be an effective means of reducing the number of intersection accidents as well as the overall level of traffic congestion. Hillier et al. (1993) have indicated that the introduction of special turning lanes, at a number of intersection in New South Wales, Australia, may, in certain situations be more effective than red light cameras; They reported that such treatments resulted in a 50% reduction in right angle and right-turn against accidents as well as a 15% to 25% reduction in rear end accidents.

Roundabouts

The use of roundabouts has been shown to be a particularly effective means of reducing the level and severity of intersection accidents. These devices are able to achieve high accident reductions by significantly reducing traffic approach speeds as well as the actual speed of traffic through the intersection. Engel and Thompson (1992) reported speed reductions in the order of 30% to 65% at roundabout locations. One additional benefit is that such devices provide an effective means of regulating traffic flow and reducing traffic congestion.

In comparison to traditional controlled or uncontrolled intersections, roundabouts may offer a considerable reduction in the overall number of traffic accidents (SWOV, 1993). In an evaluation of over 200 roundabout locations, undertaken in the Netherlands from 1984

to 1991, Schoon and Van Minnen (1993) reported a 47% reduction in the number of traffic accidents and a 71% reduction in the number of fatalities and injuries. They further reported that the greatest level of injury reduction occurred among passenger car occupants and pedestrians: 95% and 89% respectively. The lowest level of injury reduction was reported among cyclists (30%).

The cost of roundabouts can be relatively high in comparison to other types of engineering solutions. However, in a recent benefit cost analysis, undertaken by the Australian Bureau of Transport and Communications Economics (1993), it was reported that roundabouts were cost effective. Over a 20 year period a $300,000 roundabout could pay for itself two times over in terms of accident severity reductions and four times over in terms of reductions in particular intersection accident types.

6.8 SUMMARY

Intersections, by their very nature, provide potential points of conflict within the road traffic network. It has been estimated that traffic accidents which occur at intersections are one of the most common type of road accident events. Efforts to minimise intersection accidents have traditionally focused on education, engineering and enforcement measures. However, if commonsense does not prevail and road users cannot be educated to obey intersection traffic laws then reliance is typically placed on enforcement to ensure road user compliance.

Traffic signals are designed to maximise the capacity of traffic intersections whilst providing a safe operating environment for road users. However, signalised intersections still pose a significant road safety problem and it has been estimated that approximately 10% of all road fatalities and 18% of all accidents occur at these types of traffic locations. The large proportion of these traffic accidents occur when road users, for whatever reason, enter the intersection contrary to the red signal displayed.

This type of problem, termed "red light running" creates a high potential conflict situation which significantly increases the likelihood of an accident event. There are several types of red light runner. A large majority (70% to 80%) of red light running behaviour occurs as a result of road users being delayed or not being able to stop safely before the onset of the red signal. The remaining 20% to 30% of red light running behaviour is the direct result of road users who deliberately run the red light signal. It is this last type of road user behaviour which is the primary target of intersection enforcement activities.

The use of highly visible enforcement activities, at signalised intersection, has been shown to be an effective means of reducing red light running behaviour. The problem with this approach is that it is extremely resource intensive and the large number of signalised intersections makes effective enforcement impossible. Red light violation rates are also extremely low, especially when enforcement activities are highly visible, and police often believe that other traffic enforcement activities are more important and cost effective.

Selective enforcement strategies provide one means of improving the effectiveness and efficiency of policing activities. The targeting of known high accident risk intersections at peak volume traffic times can result in maximum accident reduction benefits. The use of these strategies also increases enforcement visibility, due to the high traffic exposure, and therefore has the potential to significantly increase the overall level of deterrence.

The most effective means of enforcing signalised intersections is through the use of automated detection devices. These automated devices, commonly referred to as red light cameras, have been shown to reduce the level of red light running behaviour by up to 55%.

Significant reductions in the number of accidents (between 10% and 25%) have also been reported at intersections where red light cameras have been installed. Red light cameras have also been shown to be cost effective with derived benefit-cost-ratios in the vicinity of two to one.

The overall effectiveness of red light cameras is directly related to their deterrence potential and ability to increase perceived apprehension risk and maintain it at a high level. There are a number of way of maximising the deterrence potential of red light camera operations. Firstly, red light cameras are usually used at high accident risk locations and the use of clearly posted warning signs can ensure a high accident reduction potential. Secondly, highly visible hardware installations can ensure that motorists are continually aware of red light camera operations. Thirdly, the rotation of a small number of cameras through a large number of treated intersections can increase the area wide deterrent effect. Fourthly, the widespread use of publicity can increase community awareness of enforcement operations and increase the level of perceived apprehension risk. Finally, when cameras are not installed at treated sites, the visible deployment of the flash unit may increase deterrence.

There are a number of problems associated with the use of red light cameras which have been identified in the research literature. These include generally low apprehension rates, the permanency of on-site enforcement treatments and the time taken to notify drivers that an offence has been committed. The use of new digital imaging detection technology may provide a possible means of solving these problems.

Digital imaging systems produce a better quality high resolution image than that of existing film based systems and have been reported as having the capacity to almost double existing apprehension rates (from 50% to 95%). One such digital imaging system has also been adapted for portable use, thus increasing the application and deterrence potential of red light enforcement operations. The portability of the system also reduces the significant costs associated with the installation of induction loop sensors in the intersection. The estimated cost of this system is approximately half that of existing red light camera systems. The last benefit of digital imaging systems is that they can significantly reduce offence notification delays because they do not require the time intensive tasks associated with the collection and development of photographic images. Red light violation information can be sent directly to a central processing unit (via telephone line) within minutes after the offence has been detected.

Enforcement is only one means of ensuring that road users adhere to the traffic laws which govern the use of intersections. Engineering considerations relating to traffic signal phases and the actual physical design of the intersection environment, have also been shown to be effective accident reduction measures. In particular, the use of appropriate intergreen timings and the introduction of special vehicle turning phases (for drivers wishing to turn against the opposing flow of traffic) have been shown to reduce the number of potential conflict situations. The use of active warning signs at high speed and/or low visibility intersections has also been shown to have considerable potential.

The physical design of intersections is one further means of reducing vehicular conflict at intersections. The provision of turning lanes has been shown to have a considerable

accident reduction potential. The use of roundabouts is considered to be one of the most effective means of managing intersection problems. These devices can significantly reduce the number of intersection accidents and have the added benefit of being able to improve vehicle flow, thus reducing traffic congestion.

7. RECOMMENDATIONS AND CONCLUSIONS

7.1 GENERAL REMARKS ON TRAFFIC LAW ENFORCEMENT

Road traffic accidents are a major cause of death and injury and result in significant social and economic costs. The majority of these accidents are the direct result of "driver error" and attempts to reduce the level of road trauma have traditionally focused on means of minimising the level of high risk road user behaviour. The three most commonly adopted approaches include, education, environment/engineering treatments and enforcement.

Traffic law enforcement can be an effective road safety countermeasure but should be regarded as the final solution in the attempt to reduce the level of inappropriate road user behaviour. Authorities should endeavour to develop a coordinated approach in which enforcement is used to support other road safety measures such as education programs, engineering solutions and modification of the social and physical environment. However, if non-punitive measures are unsuccessful at modifying road user behaviour then increased reliance must be placed on enforcement to deter, apprehend and punish traffic offenders.

The success of enforcement is dependent on its ability to create a meaningful deterrent threat to road users. To achieve this, the primary focus should be on increasing surveillance levels to ensure that perceived apprehension risk is high. Once this has been achieved, increasing penalty severity and the quick and efficient administration of punishment can further enhance the deterrent effect. If apprehension risk is low then penalty severity and immediacy of punishment may only have only a limited impact on road user behaviour.

Increasing the level of enforcement activity is the most effective means of increasing the perceived risk of apprehension. The available evidence indicates that existing enforcement levels need to be increased by a factor of at least three, and maintained over a long period of time, in order to bring about sustained increases in the level of perceived apprehension risk. This type of approach can be resource intensive and the use of periodic, short-term intensive enforcement operations (blitzes) should be considered as a more cost effective enforcement option, however, the overall effect on road user behaviour may be reduced.

The use of selective enforcement strategies, designed to target high risk road user behaviour and traffic accident locations, should be considered. These strategies have the potential to improve the effectiveness of enforcement whilst ensuring that associated policing activities remain efficient in terms of cost and human resources. The use of highly visible operations can also create the impression that enforcement is highly active. This, in turn, can increase the perceived risk of apprehension and result in less illegal driving behaviour.

Automated enforcement devices provide the most cost effective means of significantly increasing apprehension risk and should be adopted as a matter of priority. The intensive and publicised use of these devices can not only reduce the level of illegal driving behaviour but also the number of road accident fatalities and injuries. Although these devices do not provide immediate on-site punishment of an offence, the receipt of a penalty, several weeks after an offence has been detected, can still result in significant behavioural changes.

The use of publicity to support enforcement operations should be adopted as a means of increasing enforcement effectiveness. This is achieved by increasing community awareness of enforcement operations and raising the level of perceived apprehension risk. It is

essential that road users actually observe the publicised increase in the level of enforcement activity otherwise behavioural changes are usually only short-term. Publicity as a stand alone measure can increase community awareness of road safety issues, however, its effect on actual road user behaviour is usually only minimal.

7.2 ALCOHOL ENFORCEMENT

Driving whilst under the influence of alcohol is regarded as being the single largest cause of road accident fatalities. It has been estimated that over 30% of all road fatalities and serious injuries are likely to involve at least one driver who is impaired by alcohol. The introduction of strong legislation and highly active enforcement is generally regarded as the most effective means of reducing the level of drink driving behaviour. However, the magnitude of the drink driving problem requires a coordinated approach, involving the implementation of a range of preventative strategies which not only target the drink driver but also the social and physical environment in which alcohol is consumed.

The primary focus of alcohol enforcement activities should be on increasing the overall level of surveillance. The use of severe penalties and strategies to ensure that punishment is administered quickly, have been shown to be relatively ineffective unless potential drink drivers perceive that the risk of apprehension is high. It is therefore essential that legislation is structured so as to allow police to implement high intensity alcohol enforcement strategies. The introduction of per se legislation and provisions which allow police to stop and test any driver, are necessary prerequisites in order to develop effective enforcement strategies.

Consideration should be given to the implementation of enforcement strategies based upon the use of sustained and highly intensive random breath testing (RBT) operations. These operations have been shown to be one of the most effective means of deterring drink driving behaviour. To maximise the benefits of RBT operations it is essential that a large proportion of drivers are stopped and that ALL are tested for alcohol impairment. RBT operations should also be highly visible, accompanied by sustained high levels of publicity, rotated among numerous FIXED locations and undertaken for no longer than a one hour period at each location.

The strategic deployment of random breath testing operations should be considered if a less resource intensive enforcement option is required. However, the deterrence potential of such strategies, may be reduced. Effective countermeasures include the periodic use of highly intensive enforcement "blitzes" and the use of targeted enforcement programs which involve less intensive activities (focusing on enforcement visibility) during low alcohol hours and more intensive activities (focusing on apprehension) during high alcohol hours.

The use of passive alcohol sensors should also be considered as a means of increasing the efficiency of roadside testing operations. These devices minimise the delay to motorists caused by roadside stopping and testing procedures and can increase the capacity of police to screen a greater proportion of drivers.

Police commitment to RBT is essential to ensure its overall success. Problems relating to police morale and professionalism can impact on the effectiveness of RBT operations. Police education programs should be implemented to increase awareness of the need for, and deterrence objectives of, RBT operations. Evaluation studies are also required to provide police with feedback regarding the effectiveness of RBT operations. Consideration should be given to the use of new police graduates to undertake RBT operations. This

practice has been found to increase RBT effectiveness and is a good learning experience for new recruits.

Legal sanctions are an essential element in the process of deterring drink driving behaviour. Imprisonment should only be used in extreme cases as it appears to have only a minimal impact on recidivism rates. Greater emphasis should be placed on the combined use of fines with licence actions, such as suspension and revocation. Consideration should also be given to the use of roadside licence suspensions as a means of increasing the immediacy and certainty of punishment. The particular use of these sanctions for drivers apprehended with relatively low blood alcohol levels, has the potential to reduce the time-consuming tasks associated with arrest procedures as well as the high costs associated with adjudication.

The lowering of legal blood alcohol concentration (BAC) limits for more high risk road users can be an effective means of reducing the level of alcohol related accidents. Young drivers are a particular group of road users that have been shown to have a significantly higher alcohol related accident risk than that of more older drivers. Lower HAC limits for road users who are exposed to higher levels of traffic and have special risks and responsibilities (drivers of public passenger and heavy vehicles) may also warrant further consideration.

The fitment of alcohol ignition interlocks, in the vehicles of recidivist drink drivers, has the potential to be an extremely effective countermeasure. The main benefit of an alcohol interlock device is that it bypasses any decision-making requirement by the drink driver and targets the vehicle as a point of intervention. A less costly alternative is the use of a vehicle monitoring device. These devices provide a means of ensuring that offenders adhere to the driving restrictions imposed by the courts. They have a particular application in situations were offenders are provided with a special licence to use their vehicle during working hours.

Traffic law enforcement should never be relied upon as the sole means of modifying road user behaviour. Publicity campaigns should always be an integral component of enforcement strategies. There are a range of other preventative strategies that can be used in conjunction with enforcement to specifically target the problem of alcohol impaired driving. Preventative strategies which may warrant further consideration include the implementation of alcohol control policies and taxation measures, the development of server intervention programs and the increased availability of public and personal breath testing devices.

7.3 SPEED ENFORCEMENT

The role of speed in accident causation has long been established. Speed has been identified as a causal factor in up to 30% of all fatality and serious injury road accidents. The magnitude of the speeding problem has led to the development of numerous preventative strategies aimed at reducing the level of speeding behaviour. It is generally considered that the problem of excessive speed requires a coordinated approach which combines educational, engineering / environmental and enforcement elements. However, reducing the level of speeding behaviour has proven to be a difficult challenge and reliance has typically been placed on legislation and enforcement to deter the high proportion of offending motorists.

The primary means of imposing some control over the speeds at which motorists travel is through the use of speed limits. Speed limits are designed to take into account both the safety and mobility needs of society. In order to be effective, speed limits must be perceived by road users as being appropriate for the existing road environment conditions. This can be difficult to achieve because safety and mobility requirements are often in conflict. Although appropriate speed limits provide a high degree of control over speeding behaviour, a large proportion of drivers still travel at speeds greater than those nominated. In such situations the use of enforcement may be the most effective means of reducing this type of behaviour.

Effective speed enforcement operations must be designed so as to pose a real and significant threat to actual and potential speeding motorists. To achieve this objective, the primary focus of speed enforcement should be on increasing surveillance levels, and hence the actual and the perceived risk of detection. The supporting use of legal sanctions and ensuring that punishment is administered quickly and efficiently can also facilitate the deterrence process.

Traditional enforcement methods based upon police vehicle deployment options should focus on increasing the visibility and unpredictability of traffic policing operations. Highly visible stationary enforcement operations have the greatest deterrence potential when using police vehicle deployment methods. These activities should also be supported by the use of both marked (visible) and unmarked (non-visible) mobile speed enforcement operations in order to increase the unpredictability of where, how and when enforcement will be encountered.

Primary consideration should be given to the implementation of strategies based around the intensive use of automated speed enforcement devices. These devices, commonly referred to as speed cameras, have been shown to significantly reduce the level of speeding behaviour and can lead to large reductions in the number of speed related accidents and associated injuries. The use of speed cameras has also been shown to significantly improve the overall efficiency (in terms of financial cost and human resources) of speed enforcement operations.

To maximise the benefits and community acceptance of speed camera operations it is important that enforcement is primarily targeted at accident locations where speed is known to be a causal factor. Increasing the apprehension effectiveness of speed camera operations is also important and consideration should be given to the use of new automated digital imaging systems. These systems provide a means doubling existing apprehension rates due to the high resolution vehicle identification information produced. The ability to transmit offence information directly to a central processing office (film collection and development is not required) can, also, significantly reduce offence notification delays.

The combined use of both fixed (unmanned) and temporary site (manned) speed camera operations has a number of benefits. Fixed site operations are less resource intensive and should be used at know accident locations and along rural and high speed motorways. The rotation of a small number of speed cameras among a series of fixed housing installations, which are strategically positioned along a roadway, should be considered as a cost effective means of creating an area wide deterrence effect. Temporary site operations should be used primarily in high density urban traffic environments. The use of an information display board, located several hundred meters after a speed camera site, should also be considered as a means of informing road users that a speeding offence has been detected.

Consideration should be given to the development of strategies designed to ensure better spatial deployment of available policing resources. The randomised targeting of speeding behaviour at traffic locations with a high accident risk potential, or where enforcement visibility can be maximised, is one such option that has considerable potential. The use of publicity to support speed enforcement activities is an essential requirement to raise community awareness and improve the effectiveness of enforcement operations. Reducing the size of enforcement tolerance levels on speed limits should also be considered as a means of reducing the level of speeding behaviour and ensuring greater adherence to posted speed limits.

There are a number of behavioural feedback strategies which may be used to increase the effectiveness of speed enforcement operations. Two methods which have been identified as having the potential to modify speeding behaviour and facilitate the overall effectiveness of enforcement operations include the use of public posting speed information displays and community based incentive programs. Consideration should be given to examining the possible application of these two approaches (especially incentive programs).

Legal sanctions are an important element in the process of deterring speeding behaviour. However, in order for sanctions to be an effective deterrent it is essential to first ensure that the perceived risk of apprehension is high. If road users believe that the likelihood of apprehension is low then the introduction of more severe penalties or new penalty systems, such as a point demerit scheme, may only have a minimal deterrent effect.

The actual type of penalty administered can also impact upon their deterrence effectiveness. Fines are an extremely efficient means of dealing with speeding offenders, however, their use as a stand alone countermeasure has been shown to be a relatively ineffective. Greater emphasis should be placed on the use licence suspension or revocation procedures. These types of sanctions, when related to travel speed over the posted limit, appear to be the most effective means of deterring speeding behaviour. Longer suspension periods (over 6 months) are considerably more effective than shorter suspension periods (less than 3 months).

When examining penalty structures, the development of strategies designed to target and deter repeat offenders should be given a high priority. Consideration should be given to the introduction of point demerit schemes as a means of relating the level of speeding behaviour to more severe penalty outcomes. The benefit of this type of scheme is that consistent, less serious speeding behaviour can still result in more severe sanctions if a certain number of speeding offences are committed within a specified time period.

Emphasis should be placed on increasing the credibility of speed zones so as to ensure greater acceptance and adherence, by road users, to the posted speed limits. Consideration should be given to the use of 'expert' systems for speed zoning classification. These expert systems provide a means of ensuring that speed limits are consistent across the entire road traffic network. The use of variable speed limits also has the potential to ensure that speeds remain consistent in relation to changing environmental and driving conditions.

Enforcement should not be relied upon as the sole means of reducing the level of speeding behaviour. Preventative strategies which target the "agents" of speeding, namely the vehicle and roadside environment should be considered as an alternative or supplementary means of reducing the level of speeding behaviour. The fitment of in-vehicle devices, which artificially control the maximum speed at which a vehicle can travel, has considerable potential. The use of these speed limiting devices could improve policing

efficiency by effectively eliminating the need for enforcement on maximum speed limit road stretches.

Increased emphasis should be placed on the use of measures designed to physically modify the roadside environment. Engineering treatments such as roundabouts and speed humps have been shown to be extremely effective speed control devices. The use of perceptual speed countermeasures may also offer a low cost means of reducing the level of speeding behaviour. Treatments such as transverse lines, lane width reductions and enhanced centre and edge line markings, have been shown to influence a drivers' perception of speed and result in a reduction in their preferred travel speed.

Vehicle design characteristics may also need to be considered. Improving the accident avoidance capability of vehicles, as well as the level of protection provided to vehicle occupants, can potentially reduce the injury consequences of speeding behaviour. Active safety features such as anti-lock brakes and improved steering systems can reduce the likelihood of an accident occurring. Passive safety features such as airbags and seats belts can reduce the severity of injuries once an accident situation has occurred.

7.4 SEAT BELT ENFORCEMENT

Seat belts are regarded as being one of the most effective means of reducing traffic injuries. It has been estimated that vehicle occupants who correctly use seat belts are 40% to 50% less likely to sustain serious or fatal injuries in an accident situation. Increasing the level of seat belt usage requires a coordinated approach involving educational, engineering and enforcement measures. However, in many countries seat belt enforcement is not actively pursued and reliance has typically been placed upon legislation, education and publicity to increase usage rates.

Legislation should be based on the policy of 'primary' enforcement in order to support the increased use of more active enforcement operations. The experience in those countries where seat belt laws are actively enforced has shown that wearing rates over 90% can be achieved. The introduction of compulsory use laws for all seating position should be given immediate priority. Special consideration should be given to mandating the use of child restraint devices, such as harnesses, boosters and baby capsules. These devices have been shown to be an effective means of reducing injuries among child occupants (0 to 5 years).

Consideration should be given to the use of information obtained from automated speed enforcement operations as a means of detecting seat belt offences and significantly increasing the actual and perceived risk of apprehension. Targeting speed offenders has a number of benefits. Firstly, seat belt offenders tend to be more high risk road users and are likely to have committed other offences such as speeding. Secondly, seat belt effectiveness is directly related to speeding behaviour in that the higher the travel speed the greater the injury potential (and need for some form of protection) in an accident situation.

Police commitment is essential to the success of seat belt enforcement operations. Special consideration should be given to the implementation of police education programs. These programs are essential to increase police motivation and raise awareness regarding the benefits of, and need 1;o, enforce seat belt laws. Education programs should be targeted at developing a greater appreciation of the safety and cost benefits associated with increased seat belt wearing rates. These education programs should also be designed to provide police with structured guidelines regarding the development of the most appropriate and effective seat belt enforcement strategies.

The simplest and most cost effective enforcement strategy is one which ensures that seat belt checks are adopted as a standard operational procedure when undertaking other forms traffic policing activities requiring roadside stopping of motorists. However, this type of enforcement strategy is often difficult to implement due to a general reluctance, and poor motivation among police to actively enforce seat belt laws. The use of police education programs, performance incentive schemes and supporting publicity may help to increase police motivation towards seat belt enforcement.

Special consideration should be given to the development and implementation of periodic, high intensity enforcement strategies ('blitzes'). This type of enforcement operation has been shown to be the most effective means of bringing about 'sharp' and sustained increases in seat belt wearing rates. To maximise the benefits of these enforcement operations it is important that they are supported by police education programs, sustained high levels of publicity, and post enforcement evaluation studies.

Enforcement activities should be supported by high levels of publicity. Publicity programs provide an effective means of increasing community awareness of the benefits of seat belt usage and can improve the effectiveness of seat belt enforcement operations by increasing the perceived risk of apprehension. Evaluation programs should be an important consideration in the development of seat belt enforcement strategies. These programs provide police with feedback regarding the effectiveness of their efforts and allow for the development of more effective enforcement strategies.

Consideration should be given to the more widespread implementation of seat belt incentive programs. These programs have been found to be an effective alternative to enforcement operations and may actually have a more sustained long term effect on wearing rates. The combined use of incentive programs with enforcement may warrant special consideration. The use of these type of combined strategies have been shown to be a particularly effective means of increasing seat belt usage rates.

The use of feedback devices, designed specifically to remind occupants to use their seat belts, should be actively promoted. The use of in-vehicle seat belt warning devices and the simple attachment of a seat belt usage sticker on the dashboard of the vehicle have been shown to have considerable potential. A more drastic yet effective countermeasure may be the installation of some form of seat belt interlock device. The use of public posting signs is one further feedback device that has been shown to have the potential to increase seat belt wearing rates.

7.5 SIGNALISED INTERSECTION ENFORCEMENT

Intersections by their very nature provide potential points of conflict within the road traffic network. It has been estimated that traffic accidents which occur at intersections are one of the most common type of road accident events. Efforts to minimise intersection accidents have traditionally focused on education, engineering and enforcement measures. However, if engineering solutions are not effective and road users cannot be educated to obey intersection traffic laws then reliance should be placed on enforcement to ensure a high level of road user compliance.

The primary focus of enforcement activities should be on reducing the level of deliberate red light running behaviour at signalised intersections. This type of road user behaviour creates a potential conflict situation which significantly increases the likelihood of an accident event. Enforcement activities should be designed to maximise both site specific

deterrence, at high risk intersections, and to increase the overall level of general deterrence. Highly visible enforcement operations supported by sustained publicity are essential elements.

The use of selective enforcement strategies should be considered as one possible means of improving the effectiveness and efficiency of traditional enforcement activities. These strategies which target known high accident risk intersections at peak volume traffic times (to increase enforcement visibility) have been shown to be an effective means of increasing the overall level of deterrence and maximising accident reduction benefits.

Primary consideration should be given to the introduction of automated red light cameras at high accident risk intersections. The use of these devices is the most effective (in terms of financial cost and human resources) means of enforcing intersections and can significantly reduce the level of red light running behaviour and the number of associated road traffic accidents. In order to maximise both the deterrence and accident reduction effectiveness of red light cameras consideration should be given to the following deployment options: the use of warning signs at intersection approaches; the use of highly visible hardware installations; the rotation of a small number of cameras through a large number of treated intersections; the use of high levels of supporting publicity; and the visible deployment of the camera flash unit when cameras are not installed at treated sites.

Enforcement authorities should be encouraged to introduce red light cameras based upon the use of new digital imaging systems. These systems have a number of benefits including, significantly higher (almost double) apprehension rates, the ability to be used as a portable enforcement device, the potential to significantly reduce offence notification delays, and an estimated cost of approximately half that of existing red light camera systems.

Greater consideration should be given to intersection design considerations as a means of reducing intersection conflict situations. The use of appropriate intergreen timings, vehicle turning phases (for drivers wishing to turn at a right angle against the opposing flow of traffic) and active intersection warning signs have all been shown to have considerable accident reduction potential.

The more widespread use of roundabouts, as an alternative to signalised intersections, should be given a high priority. These devices have been shown to be one of the most effective means of reducing vehicle conflict and can significantly reduce the number of intersection accidents and improve traffic flow. The provision of turning lanes at intersections should also be given a greater priority as such treatments have also been shown to have a considerable accident reduction potential.

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