



**ADVANCED TECHNOLOGY
AND
ROAD SAFETY**

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Abstract:

Advanced technologies are being applied to many transportation problems. There is an opportunity to tackle some of the seemingly intractable problems in the road safety area by innovative application of emerging technologies. This report reviews the range of technologies being developed which are potential candidates in the road safety field. It concludes that Australian road safety agencies should direct their attention to technologies which show promise to provide:

- . video based vehicle detection particularly for use with existing traffic control systems;
 - . traffic incident detection and driver warning systems;
 - . expert systems to improve the identification of traffic hazards and selection of appropriate countermeasures;
 - . an in-vehicle recorder of pre-crash vehicle characteristics; and
 - . automatic vehicle identification technology for speed detection and other traffic control measures.
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Key Words:
Advanced technologies, machine vision, expert systems, road safety, bar-codes, tachographs, intelligent highways.

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ADVANCED TECHNOLOGY AND ROAD SAFETY

INTRODUCTION

This report has been prepared as an overview of developments in advanced technology applications with a potential to improve road safety. It is intended as a means of stimulating discussion and interest in the use of new technology to increase the range of countermeasures available to traffic authorities and road users.

Advanced technology has often been advocated as a means of significantly reducing the incidence and severity of road crashes. For example, Shefer and Klensch (1973) described a radar alerting and braking system which they claimed "had the potential to prevent or moderate .. one of our most destructive and daily occurrences, the rear-end collision". In recent years there has been a resurgence of interest in the development of high technology crash countermeasures; possibly as a result of the significant advances in miniturisation of electronic equipment and the use of micro-electronics in vehicle ignition, braking and performance monitoring.

Despite significant road safety gains from better designed vehicles, occupant restraint laws, programs to discourage drink driving and improvements to the road/traffic environment, road crashes continue to be a major cause of death, injury and damage to property. In conjunction with increased effort on the application of these proven techniques there is also a need to search for other ways to reduce the severity and incidence of road crashes.

For example, the Commission of the European Communities (CEC) has estimated that their road system is costing ECU¹ 50 billion in economic losses due to road crashes - plus human misery and suffering which cannot be measured in money terms; ECU 500 billion per year in wasted time and fuel due to traffic congestion; and, environmental pollution of between ECU 5 and 10 billion per year. As a result the CEC has initiated a major programme called DRIVE to co-ordinate research toward the goal of automating their highways sometime after the year 2000 (Press release of December 13, 1988). The research programme will involve projects worth a total of ECU 100 million over a 12 to 36 month period. Clearly, the potential to apply advance technology to road problems is a major interest in Europe.

ROAD USER BEHAVIOUR

A major difficulty in assessing the potential for advanced technology to be applied to the road safety problem is the apparent lack of a theory regarding road user behaviour in response to deterrents and enforcement of road rules.

Proposals for high technology solutions to the road safety problem appear to stem from two different conceptual positions; these could be termed the *optimistic* and the *pessimistic* views of road user behaviour:

- the *optimistic* view assumes that road users will improve their behaviour if they are given more and better information. This assumption seems to be the basis for in-vehicle technology designed to give the driver more precise information about the road conditions and vehicle performance. Shefer and Klensch (1973) in discussing their radar system, to measure distances between vehicles and closing speed, suggest that "The forewarned driver could then slow down, change lanes, or ignore the warning if he chose."

¹ One European Currency Unit (ECU) = A\$1.45.

- the *pessimistic* view assumes that road users are inherently poorly behaved and deterrents (penalties) are required to improve their behaviour. This view seems to underlie the push for tachographs and other monitoring equipment as in the comment that "The NRMA believes that tachographs are vital to ensuring responsible behaviour from heavy vehicle drivers and operators." (NRMA 1986).

Experimental or empirical evidence on the effectiveness of both of these approaches is essentially lacking. There is, however, evidence to suggest that drivers will modify their behaviour in the presence of visible police surveillance (Portans, 1988). Surveillance by automatic means, such as by red light cameras, has also been shown to change driver behaviour and achieve road safety gains (South *et al.*, 1988).

For the assessment of new technology, there is a need to develop a consistent theory of road user behaviour to provide a common base for evaluation of proposals. This will require an understanding of the way in which road users respond to information and stimuli; whether for the purpose of improving their ability to select appropriate behaviour or as a threat to discourage the adoption of unsafe behaviour.

Behaviour models may need to be adapted from other fields of human behaviour. There is, however, a considerable body of literature on the subject of driver behaviour (Michon, 1988). The common hypothesis seems to be that drivers acquire skills and abilities to avoid unsafe situations by learning from mistakes or errors. In some cases - crashes - the consequences of their errors are very costly.

PRINCIPLES FOR ASSESSING ADVANCED TECHNOLOGY

A number of principles can be followed in the assessment of advanced technology proposals. These are:

- evidence of a potential to reduce the incidence and severity of road crashes. This requires an understanding of the target class of crashes such as proportion of the total crash problem, causal factors and distribution amongst the road user population;
- high likelihood of community acceptance and support for widespread use the equipment. Questions are likely to arise in relation to the impact of advanced technology on individual rights and personal freedoms; and,
- there should be evidence of technological feasibility and successful testing of prototypes of the equipment involved.

In addition, there are advantages if:

- the equipment involved can be applied to existing vehicle fleets; and,
- success of the proposal depends as little as possible on government intervention or finance for development and operation. Where there are potential savings for current government programs, this principle may have less importance in the evaluation process.

Some of the above principles may appear to be unduly restrictive - considerable investment in research and development would be required to satisfy the third requirement. However, this list provides a common benchmark for comparing proposals and should minimise subjectiveness in the evaluation process.

COMMUNITY ACCEPTANCE

Projects involving new and novel use of advanced technology often raise questions of privacy and individual freedoms. This is particularly the case where the new technology is used to gather information about individuals' behaviour and movements.

Technology in itself is benign, however, in the hands of people wanting to exploit others it can be threatening to the community as a whole. This potential needs to be recognized in the development of new systems for road safety. Research of community acceptance issues needs to be undertaken in parallel with technical development.

A number of the new technology proposals involve some method of determining the location of vehicles in real time automatically and without reference to the driver. The need for location information is not exclusively a safety issue - e.g. what speed limit applies to the section of road being traversed - but arises in the consideration of fleet management systems and road user charging schemes.

Establishing the location of vehicles in a network raises important questions about potential acceptance - or rejection - of new technology by the community. Early systems for locating vehicles for the purpose of road user charging were based on intelligent road side surveillance equipment and passive tags on vehicles. There are cost advantages in this approach in terms of fitting vehicle fleets with necessary equipment. However, the implication in social terms is that the central government agency is collecting very detailed information on the movements of all drivers - there is a perception of centralised and intrusive monitoring of community activities. While there may be some who would want to be able to closely monitor the movement of others, it is an incidental activity to the main purpose of collecting road user charges or detecting drivers who flagrantly disobey road rules.

With the advent of cheaper electronics, a less intrusive approach is now possible. This requires the fitting of devices to vehicles which can gather information from passive devices on the road. The information that is then transmitted to the central agency is only that which is needed to establish user charges. That is, there is no need to monitor and store information on the precise movements of each vehicle. Such an approach would enable vehicle owners to pre-pay for road use or potential fines and store this credit on a smart card. The system only needs to know that the vehicle has credit without knowing where the vehicle has travelled through the system.

In recognition of the need for protection of personal rights and freedoms, systems which are based on the concept of central monitoring of private trips are unlikely to be acceptable.

COST OF EQUIPPING VEHICLES

At this stage there is little information on which to judge the crash reducing impact, and therefore the potential cost effectiveness, of the various systems discussed in this paper. However, a useful analysis is to estimate the upper limit to the cost of equipping individual vehicles which would still achieve a benefit to cost ratio comparable to other road safety initiatives. This analysis for various technology proposals is set out in Appendix A.

In policy terms, there are a number of questions which need to be considered in deciding the economic worth of a programme to equip vehicles with safety devices. For example, if the equipment is to be funded from government programmes then it would be competing with other road safety measures which currently have quite high benefit to cost ratios. However if the cost of equipping is to be borne by vehicle owners then it is competing with a different set of priorities; whether or when to maintain the vehicle, fit new tyres, buy a new vehicle and other domestic expenditures. Many of these decisions could be shown to have a much lower (probably less than one) safety benefit to cost ratio than the fitting of equipment to vehicles. The policy question becomes one of whether the government should intervene in personal expenditure decisions to achieve a community safety objective, and if so, at which level of benefit to cost ratio.

ADVANCED TECHNOLOGY FOR TRANSPORTATION

This section provides a broad sketch of the ways in which advanced technology is being applied to transport needs as background to a more detailed consideration of technology for safety.

At the American Society of Civil Engineers First International Conference on Applications of Advanced Technologies in Transportation Engineering, held in San Diego, California in February, 1989, a number of themes seemed to emerge regarding the current areas of research interest and development of new applications. These themes can be summarised as follows:

- Machine Vision;
- Expert Systems;
- Traffic Incident Detection;
- Vehicle Location Systems
- Network Modelling; and
- Intelligent Highways.

Machine Vision

By machine vision is meant the ability to use machines to gather and interpret visual data. The application of this technology to transportation systems seems to be an outgrowth from the development of vision for robots. Applications at present fall into two relatively distinct groups; (i) monitoring of pavement condition; and (ii) detection of vehicles and pedestrians on the roadway.

Pavement Condition

With extensive road networks in most developed countries reaching the end of their useful pavement life, there is a rapidly increasing concern about the financial burden to maintain these roads at a reasonable level of traffic service. There seems to be very few road authorities with adequate systems for monitoring the serviceability of road pavements in terms of structural failure and pavement riding performance. Part of the difficulty in monitoring pavement condition on a systematic basis is the high cost of obtaining satisfactory data about surface cracking and deformation.

Developments in machine vision technology, however, appear to hold the promise of relatively inexpensive equipment that can be vehicle mounted and can operate in a semi-automatic mode for the collection of pavement condition data. Fukuhara *et al.* (1989) report on the development of an Automatic Pavement Distress Survey System in Japan which is mounted on a large vehicle and can measure cracking, rutting, and longitudinal profile without needing to contact the road surface. This system uses laser and video technology for measurement of pavement condition. The video image is processed on board and the data stored on tape for transfer to a central data base. Butler (1989) reports on a similar system being developed in Nevada. Caroff *et al.* (1989) report on the development of software to interpret digitised images of pavement surfaces taken from filmed images of the road surface. McNeil and Humplick (1989) presented a paper on the identification and estimation of errors in data acquisition for automated visual inspection systems.

On a related topic, Rennilson and Dejaiffe (1989) reported on the use of vehicle mounted laser technology to measure the serviceability of pavement markings. Wigan (1989) outlined work at Australian Road Research Board (ARRB) involving imaging applications to: road surface rating, measurement, and calibration; calibrated sieve measurement; vehicle outline detection; and, vehicle registration number recognition.

Detection of Vehicles/Pedestrians

A number of papers discussed the use of machine vision to replace traditional loop detectors. Vieren *et al.* (1989) reported on work in France to develop a method of detecting vehicles and pedestrians in the path of LRT vehicles using video scanning. Michalopoulos *et al.* (1989) demonstrated a detection system developed at the University of Minnesota which used an electronic camera overlooking a long section of roadway and a microprocessor which determined traffic parameters from images received from the camera. Their work suggests that machine vision technology can be cost competitive with conventional loops with potential maintenance savings of over 30%.

Video based vehicle detection systems have been in use at ARRB since 1985 for research purposes (Dods, 1987). The ARRB system is hardware specific whereas the system developed at Minnesota is designed to operate in a PC environment.

Information is also available on a camera and computer aided traffic sensor (CCATS) developed in Belgium and now available commercially (Devlonics Control of Belgium). Uses so far of the device are to; (i) warn drivers emerging from a tunnel of queues forming in the tunnel exit area; (ii) provide police with early warning of dangerous congestion building up; and, (iii) detect queue lengths. From video images, the system is able to provide information on direction of vehicle travel, vehicle numbers, occupancy, gap time, speed, length classification and queues. As with the American development, this system is designed to operate within a PC environment using readily available electronic equipment.

From a safety view point, the application of machine technology to vehicle and pedestrian detection holds considerable promise as a means of improving the safety performance of traffic control systems. It is an area of research which should be supported by Australian traffic authorities; perhaps by encouraging further work at ARRB.

Expert Systems

Judging by the number of papers at the Conference which dealt with the development and application of expert systems, this is an area of computer technology which is maturing into widespread usage in transport engineering.

A workshop on expert systems was held on the Sunday preceding the Conference and several sessions during the Conference were devoted entirely to papers dealing with expert systems.

Topics covered include the use of expert systems for highway infrastructure management (e.g. pavements), traffic control, traffic safety and route selection. The systems discussed do not appear to be any more sophisticated than the expert system for speed zoning developed by ARRB for the Road Traffic Authority (Jarvis & Hoban, 1988).

Lau and May (1989) discuss development of an expert system to assist in the identification of potentially hazardous locations. The primary purpose of the expert system seems to be to relieve traffic engineers of some of the routine activities associated with traffic safety investigations so that their time can be spent on the complex tasks requiring human judgement.

Session 41 of the Conference includes three papers (Seneviratne and Krishnan, 1989, Chen and Cantilli, 1989 and Zhou and Layton, 1989) which were directed at the use of expert systems in the identification of highway hazards and the selection of countermeasures. These presentations seem to suggest that there is a promising field of development in expert systems, but several years are needed to develop systems that can be used by practicing engineers.

Traffic Incident Detection

This is a highly topical subject because of the concerns of traffic managers that demand is rapidly outstripping supply. Incidents, which can be crashes, vehicle breakdowns or road maintenance activities, are particularly devastating on the operation of freeways with consequent high costs in terms of congestion or foregone trips.

In Europe and the U.S.A., there appears to be a significant research effort directed towards the development of technologies that can assist in the early detection of incidents so that suitable actions can be initiated to minimise adverse consequences. A paper by Kühne (1989) describes an early warning system which is triggered by changes in speed distributions. Vehicle speeds in this system are measured by a microwave sensor mounted above the roadway. Trial installations in Germany have been successful in positively affecting driver behaviour and minimising congestion due to incidents on the freeway network. The information provided to drivers in these trials has generally been advisory speeds using variable message signs.

Davis *et al.* (1989) reported research on the use of measures of freeway traffic conditions to predict the onset of congestion. By predicting impending congestion, ramp metering can be switched on to regulate the movement of vehicles onto the freeway to prevent the formation of congestion at "bottlenecks" in the system.

Incident prediction requires technology to detect changes in traffic characteristics. Although the work reported by Kühne (1989) uses a microwave sensor, there is potential to use video imaging detectors also as with the CCATS system developed in Belgium.

Vehicle Location Systems

As mentioned previously, technology to enable accurate positioning of vehicles in real time is fundamental to a number of applications in the advanced technology field. Potential applications would be for road user charging by location and time, navigational aids for drivers and fleet monitoring.

There appear to be three types of technology being developed: (i) dead reckoning by measuring distance travelled and changes of direction; (ii) reference to roadside transmitting beacons; and (iii) triangulation from radio transmitters or satellite signals. The strongest research and development effort appears to be in Japan, Germany and the U.K. using combinations of dead reckoning and roadside beacons (French, 1989). A research program has also recently started in California using a packet radio scheme to transmit traffic data to in-vehicle units.

The important research question, which does not seem to be covered in the conference papers, is how will drivers respond to better information about traffic conditions and route selection. The driver aid programmes in Europe are primarily aimed at improving road safety, however, while vehicles continue to be manually operated, the weakest link in the performance chain will be the driver. Human factors research, to examine the relationship between better information and driver behaviour, would be a potential area for investigations in Australia rather than being exclusively involved in technological developments.

Network Modelling

There seems to be a resurgence of interest in the modelling of traffic networks, but with the emphasis on simulation techniques rather than the deterministic models that underlie transportation modelling packages commonly in use. The emphasis on simulation seems to arise from the increasing interest in traffic management schemes - traffic signal systems - to deal with surface street congestion. Software developed and used in Australia appears to be as advanced if not better than software being developed in other countries.

There were presentations from Spain (Barcelo, 1989) and the Republic of China (Han, 1989) on the development of simulation techniques for traffic forecasting at the level of predicting temporal distributions of traffic demand. Hamed and Mannering (1989) used dynamic simulation models to examine the interaction between incident induced congestion, drivers' departure time and route choice and the effect of available traffic information.

Intelligent Highways

The ultimate dream of transportation futurologists seems to be the completely automated highway where vehicle control is taken away from the driver (Johnston *et al.*, 1989). In this area, the developers of technology are raising expectations which most likely cannot be fulfilled because of a lack of acceptance by society. There are major sociological/economic research issues to be addressed such as safety consequences in the event of failure, equity impacts, and in some cases, privacy needs. The generally held view is that implementation of automated highways, even in a pilot form, seems unlikely within 20 - 30 years.

The primary incentive for automation of highways is the growing concern about traffic congestion, particularly in the U.S., in spite of a very mature freeway system. Funds for new roads are declining, but traffic demand is continuing to grow at about 4% per annum.

Willis (1989) provides a well researched overview of the problems of growing traffic congestion which is driving the interest in intelligent highways in Japan and the U.S.A. He concludes that in the case of Europe the interest stems from concerns for safety as much as those for congestion. The range of technologies being developed and researched, according to Willis, are: (i) driver information technologies - electronic route planning, radio broadcasting of traffic information, on-board vehicle routing advice systems, and on-board navigation systems; (ii) traffic control technologies - signal synchronization programs, and freeway and corridor controls; and, (iii) vehicle control technologies - automatic vehicle identification, electronic vehicle location, and automatic vehicle control.

There were papers at the conference dealing with highly technical matters such as lateral control of vehicles (Liu and Frank, 1989) and vehicle location systems (Morlock and Spasovic, 1989). Parsons and Zhang (1989) reported on the Program of Advanced Technology for the Highway (PATH) in California which has the long term goal of determining the feasibility of upgrading selected freeway segments to "automated highway" status.

On another aspect of highway automation, Davies and Hill (1989) provided an outline of an automatic vehicle identification (AVI) project in Virginia to provide for automated collection of tolls on the Dulles Toll Road. This project will involve the fitting of transponders to vehicles and billing of owners on a regular basis. A survey, as part of the investigation, showed that there was minimal concern from vehicle owners over privacy issues.

In San Diego, CALTRANS have already installed an automatic toll collection facility on the Coronado Bridge connecting the downtown area with a residential and military area. Transponders are fitted to participating vehicle owners who benefit from fast access to the bridge during peak hours.

TECHNOLOGICAL PROPOSALS FOR ROAD SAFETY

This section provides brief descriptions of proposed applications of advanced technology which have been identified through a literature search and limited discussion with some system proponents.

Harmonic Radar System

This system was proposed in a paper by Shefer and Klensch (1973). The paper reported on an experimental system built and tested at the RCA Laboratories.

A primary objective in developing the harmonic radar system was to avoid the cross-talk - and, hence, false calls - problems of simple radar. The system involves the fitting of passive harmonic reflector "tags" to objects which are to be detected by the "search" vehicle. These objects may be roadside hazards or the rear of other vehicles. The "search" vehicle has an antenna fitted at its front which emits radar signals and receives reflected signals from "tags". By measuring certain characteristics of the returned signal the unit is able to compute the distance ahead to the "tag" and the differential speed between the "search" vehicle and the object being detected. Included in the design is a mechanism for automatically applying the vehicle's brakes when pre-determined criteria are met - e.g. distance below a certain range and closing speed above a certain level.

In the context of driver behaviour concepts, the harmonic radar system can be used as:

- a driver information system to warn of the onset of hazardous situations which could lead to a collision with a roadside object or another vehicle; and
- an system to over-ride driver control and stop the vehicle or at least moderate collision impact.

In 1973 values, the cost of "tags" was estimated at \$5 to \$10 per vehicle, or roadside object, while the cost of the device fitted to the front of the vehicle was estimated to be no more than the cost of an AM/FM automobile radio. On the potential benefits side, estimated societal costs from rear-end collisions was about \$100 per car per year. No estimate was given of the expected number of crashes that could be expected to be saved each year.

The technical feasibility of the system has been demonstrated by the trials at the RCA Laboratories. Presumably, with the advent of cheap micro-electronics, the costs of mass production can be reduced from the 1973 estimates and the versatility of the system can be greatly enhanced. The question which remains unanswered is whether the driving public would firstly accept the unit and secondly respond to the information provided if fitted to their vehicles. Perhaps a point worth recognizing is that while rear-ends are a significant proportion of all crashes, they are on average far less severe than other significant crash groups such as right-angles and pedestrians.

An analysis of crashes at intersections controlled by traffic signals in Victoria for the five year period 1982 to 1986, shows the comparatively low severity of rear-end crashes - 23% of crashes but 4% of fatalities and 10% of hospitalised - compared with the high severity of right angle crashes - 14% of crashes but 16% of fatalities and 18% of hospitalised - and of pedestrians hit by vehicles - 13% of crashes but 31% of fatalities and 15% of hospitalised.

Pavement Bar-Codes

This section provides an introductory review of a system recently announced by Tasani Pty. Ltd. (Towie, 1988) - for this report the terminology Pavement Bar-Code System (PBS) is used to describe the system.

Description of PBS

PBS involves the placing of fixed or portable pavement markings at locations where information needs to be transmitted to drivers about prevailing conditions. The pavement marking is in the form of a bar code which can be read by a device fitted to the underside of vehicles. In the vehicle, there is a micro-processor based device to de-code the signals from the bar-code reader - an infra-red scanner - and display information to the driver. The in-vehicle device also has a memory to store critical data - e.g. differences between vehicle speed and the speed limit indicated by the bar-code - for later interrogation.

The proponents suggest that the unit could be fitted with a smart card to record infringements and toll charges. The card would be sent to the road authority with a payment at suitable intervals.

Environmental information which can be transmitted by the bar-code include speed limits, road alignment ahead, presence of roadworks and other warning messages. An important feature of the system is a cleaning mechanism fitted to the bar-code reader to remove road grime.

Potential of PBS

Potential applications for PBS are to:

- enable monitoring of driver/vehicle performance against parameters such as speed limits and provide feedback to drivers about their performance;
- provide the basis for introducing a time/vehicle/location toll collection system;
- provide information to drivers regarding the conditions applying to sections of roads e.g. speed limits and potential hazards; and,
- enable fleet monitoring such as for the taxi and rental car industries.

In driver behaviour terms, the bar-code device has been advocated as a means of providing better information to drivers as well as the potential to provide a method of penalising drivers who disobey road rules. In a sense the developers are assuming that if a *drivers will perform better when they have better information* theory fails then the system falls back to relying on a *penalise the offenders* theory. The extent of effectiveness of each of these approaches in reducing crashes has not yet been determined.

As indicated in Appendix A, the system would need to achieve about a 40% reduction in crashes to be as cost effective as other traffic safety programmes, such as the Accident Black Spot programme. However, if the equipment is successful in reducing traffic speeds, there will be other non-safety gains such as reduced fuel consumption and reduced wear on tyres.

Quite apart from the assumptions regarding the effect of the device on driver behaviour, there is also little information to quantify the safety effects of achieving better observance of speed limits under Australian conditions. A number of studies in Europe and the United States have claimed that where speed limits have been lowered and the limits observed there have been reductions in the number of crashes, but Tasani's estimated 20% reduction is probably an upper limit and 10% would be a more realistic estimate.

Practical Considerations

There are a number of questions about the practicalities of the system which need to be investigated. These include:

- what quality of pavement marking is needed for reliable operation of the sensor unit;
- will the markings on the pavement need to be cleaned of grime and oil spills i.e. what are annual maintenance costs;
- can the bar-code markings be combined with stopline markings;
- can the system be implemented without government funding e.g. operated under a contract agreement with the operator financing the installation of pavement markings and sensor equipment and paying a fee to government based on operating surpluses;
- how will the system handle defaulters and drivers who tamper with the in-vehicle equipment;
- how will payment of charges be managed - a system where the smart card is sent to a central agency is fraught with potential administrative problems and potential delays to customers - perhaps automatic teller machines could be used for payment of charges and fines with an opportunity for the enforcement agency to specifically follow up drivers with excessive levels of offences;

Implementation of System

Several strategies for implementing the system would be worth exploring, including:

- trial in a commercial fleet of vehicles - taxis or rental cars - to develop and test the practicality of the system;
- involvement of the insurance industry on the basis of the opportunity to reduce crash costs and, hence, insurance payouts; and
- fitting the device initially to vehicles of repeat offenders.

Investigations and more detailed costings of these options will be needed before a recommendation on the system can be made.

PBS, as proposed by Tasani Pty. Ltd., is an application of new technology which shows promise as a means of achieving safety improvements. There are, however, a number of practical considerations which need to be examined in more detail before deciding whether to support a trial of the system.

Electronic Tachographs and In-vehicle Recorders

Tachographs have in the past been used to monitor the driving patterns of heavy vehicles. Monitoring can be for purposes of fleet management or driver observance of regulations about driving periods and vehicle speed.

Over the past few years, electronic tachographs have been developed which are more versatile, reliable and tamper proof than the earlier paper tape devices. Advocates of stricter controls of the trucking industry have looked to these devices as a means of policing driver observance of regulations. If these devices can be shown to be useful in policing truck drivers then perhaps the concept can be extended to all vehicles.

The underlying assumption in proposals to use tachographs is that stricter enforcement of regulations will result in less crashes.

In-vehicle recorders have been advocated as a means of gathering information about the events leading up to crashes (Howie,1989). These devices would operate in the same manner as the in-flight recorder box in modern aircraft. The proposition rests on the assumption that drivers would be less inclined to ignore speed limits if they know that their driving behaviour is being recorded. There may not be a need to fit devices to all cars if the driving population understand the consequence of being convicted of a speeding offence is that they would only be permitted to drive vehicles fitted with a recording device.

A significant difference between in-vehicle recorders and roadside detection of speeding vehicles is that the speeding offence would, generally, only be detected in the event of a crash. In this sense, the offence would be more clearly associated with the result of unsafe driving. Compulsory checks of vehicles would probably be needed to ensure that owners do not tamper with the in-vehicle device.

The indicative costings in Appendix A suggest that this system would be feasible where the device is fitted to selected vehicles - those owned by repeat offenders for example.

Assuming a life for the equipment fitted to vehicles of 10 years and a discount rate of 7%, then the cost per vehicle of equipment to achieve a benefit to cost ratio of 3 would need to be less than \$146 for a 10% reduction in crashes rising uniformly to \$438 for a 30% reduction. To fit the total vehicle fleet with recorders and achieve a break even benefit to cost ratio of 1, up to \$438 could be spent per vehicle for a 10% reduction in crashes and up to \$1314 per vehicle for a 30% reduction.

If the same safety effect could be achieved by fitting only say 20% of the fleet - the vehicles most likely to be involved in speeding offences - then the cost per vehicle could be raised to $\$146 \times 5 = \730 for a 10% effect and to \$2190 for a 30% effect.

Appendix B is a broad specification for an in-vehicle recorder.

Vehicle Navigational and Guidance Systems

Research and development of vehicle navigational and guidance systems has been reported from most of the larger motorised economies. The Transport and Road Research Laboratory (TRRL) in the U.K. are experimenting with Auto-Guide; a system to provide pre-journey advice to motorists on the fastest and/or cheapest routes. In Europe, a major industry co-operative project is underway called PROMETHEUS; to co-ordinate research into "intelligent" vehicle technology. In a separate initiative, the CEC has commenced DRIVE to co-ordinate research into automated highway technology. Japan is undertaking joint government and industry research also; particularly on in-vehicle navigational systems using video displays on vehicle dashboards.

There seems to be significant opportunities to build on technology already available in today's vehicles - such as cruise control to automatically maintain a pre-set travel speed - and, thereby, move towards an "intelligent" vehicle. Features of an "intelligent" vehicle could be safety oriented - e.g. automatic braking as in the RCA proposal of the early 70's - as well as navigational aids.

Automated Speed Detection

Speeding vehicles are a major concern in the traffic system because of the likelihood of more severe damage and injury in the event of a crash. Although there is a range of views about the relationship between vehicle speed with the incidence of crashes, there is a widely held perception that better observance of speed limits would reduce the severity of crashes. From a theoretical viewpoint, a reasonable conclusion is that the information processing load on drivers will be reduced as actual speeds are reduced and, hence, their ability to deal with traffic hazards will be improved.

With present technology, detection and apprehension of speeding vehicles is a time consuming procedure. There is equipment which can automatically respond to the presence of a speeding vehicle and record details which can then be used to trace the vehicle owner. These devices are based on the same technology as red light cameras. Having photographed the offending vehicle, the procedure for tracing the owner and issuing a summons or traffic infringement notice requires human intervention to interpret the photograph and extract details about the vehicle - such as the number plate.

Automating the procedure could greatly improve the effectiveness of speed enforcement programmes. There are three technologies which could be considered: (i) machine vision to recognize number plates; (ii) marking of vehicles with a bar-code which can be scanned automatically; and (iii) fitting electronic transponders to vehicles.

Number plates

Wigan (1985) has reviewed the literature on image processing for number plate recognition. This review indicates that the technique is feasible, however, there does not appear to be a practical field proven system available yet. There are also a number of practical considerations in addition to the technology of pattern recognition by machine vision. For example, how to ensure conspicuity of the number plate in adverse environmental conditions.

If the technology of automatically reading number plates can be perfected, this would be the most desirable approach as it could be implemented without needing to change or add anything to the existing vehicle fleet.

Bar-codes

The use of bar-codes painted on the roadway, as proposed by Tasani Pty. Ltd., provides a means of transferring information to a vehicle for display to the driver. This system requires a scanner under the vehicle to read the bar-code painted on the road pavement. Speed detection with this system would require the recording of offences in a memory within the vehicle for later checking by the enforcement agency at regular intervals - say annually. This would require each vehicle owner to present the in-vehicle recording device for interrogation by the enforcement agency regardless of whether the vehicle was involved in speeding offences or not.

An alternative approach would be to place the bar-code markings on the vehicles and to use roadside scanners to record the identification number - from the bar-code - of vehicles found to be exceeding the speed limit. Bar-code technology is well established in the packaging industry, although the reliability of reading bar-codes at speed needs to be tested. If Tasani have been able to prove the technology for codes on pavements and scanners on vehicles, then it should be expected to work in the reverse arrangement.

There would be a need to develop a roadside unit which incorporates existing technology for determining vehicle speed with a bar-code reader. A proposal developed in the United States involved the use of bar-codes fixed to the sides of containers to assist in keeping track of empty containers.

Appendix A sets out a preliminary computation of a comparison between a bar-code reader system and the present system of photo-recording of speeding vehicles and the coding of number plates manually from the photograph.

There may be a limit to the extent of funds which could be extracted from the community through speeding fines without widespread opposition from the community or distorting the economy. Provided funds raised through speeding fines were used to substitute for Transport Accident Commission (TAC) charges, the effect will be a transfer of charges from drivers who obey speed restrictions to those who disregard speed limits. In the sense that crash severity - and, hence, TAC compensation payments - are directly related to excessive speeds, then a transfer of incidence of TAC charges to motorists who disregard speed limits should be acceptable to the community.

In practical terms, speed enforcement would involve the use of bar-code reader devices which store, in the field, data on vehicles detected as exceeding the speed limit - speed, time of day, location and vehicle identification number. This information could be collected by an unattended device mounted in a secure position. At the end of the surveillance period, the scanner would be returned to the office where the information in its memory would be downloaded to a central database for automated preparation of Traffic Infringement Notices (TINs) to be sent to vehicle owners.

To ensure compliance with TIN's, continued registration of a vehicle could be dependent on payment of speeding fines incurred in the previous registration period.

There are significant practical considerations which need to be investigated before deciding the feasibility of this approach. These include reliability of scanners, maintenance of markings on vehicles and system security.

Transponders

Vehicle transponders are now a well proven technology - in Melbourne they are fitted to trams and buses to assist in traffic signal operations. In California transponders have been fitted to about 1000 vehicles in an experimental automatic toll collection for the Coronado Bridge in San Diego (Bushey, 1989).

Westinghouse Systems are offering a commercial product which "allows railways, trucking and shipping companies to track automatically large numbers of freight cars, trucks, containers or other modules" (Westinghouse Systems, 1988).

An electronically encoded tag is fitted to vehicles which can transfer a stored message to a roadside scanner. The message can be up to 24 characters in length and up to 5000 messages can be stored in the scanner before being sent to an external processing unit. In tests with tags fitted to railroad cars, Westinghouse report a 100% level of accuracy at speeds varying from 35 to 45 mph.

The cost of fitting transponders to all vehicles would probably be prohibitive for a speed management programme - from \$300-\$500 per vehicle. There would also be other infrastructure costs, such as roadside detectors to pick up signals from transponders and computer software to interpret these signals and initiate infringement notice procedures when a speeding vehicle has been detected.

However, the reliability of such a system would be far greater than other methods.

In regard to implementation, one approach may be to fit transponders to vehicles which have been involved in previous speeding offences. A difficulty with this approach is to provide a means for readily determining whether any particular vehicle should be carrying a transponder.