In-vehicle safety technologies - picking future winners!

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Abstract

In recent years, there has been an explosion of new technologies for incorporation within vehicles that are currently on the market or under development by suppliers to the automotive industry. A number of these technologies are aimed at improving safety either by reducing the risk of a crash occurring or by improving the protection offered by a vehicle in the event of a crash. But which technologies are worth backing? Which provide a strong business case to government and to the industry itself for active development, incorporation and marketing to the Australian consumer? This paper describes an analysis conducted on behalf of the Transport Accident Commission (TAC) in which a range of current and emerging in-vehicle safety technologies are assessed in accordance with a set of criteria including safety impact, cost, level of community acceptability, need for legislative or infrastructure support and the model for market penetration. Key technologies will be highlighted that score highly across these criteria as a basis for agreeing a core of technologies for subsequent support and promotion

Introduction

There is a wide range of safety features and products available for motor vehicles that can assist in avoiding crashes or making them less severe. The most promising recent developments have been with Intelligent Transportation System (ITS) technology.

Intelligent Transport System (ITS) technologies are now recognised and accepted as offering the potential to effect radical improvements in the safety and efficiency of operation of road transport networks. Safety-related ITS technologies typically involve engineering systems built into the vehicle and/or the road that intervene when users suffer lapses of concentration, make unsafe decisions, or fail to detect a developing unsafe situation.

There would be benefits in Australia and New Zealand arising from making some of these ITS safety features more widely available (that is, encouraging vehicle manufacturers to make them available as standard or optional equipment) and encouraging vehicle purchasers to buy vehicles with these features.

A comprehensive range of Intelligent Vehicle Technologies (IVT) has been evaluated in a project commissioned by the Transport Accident Commission of Victoria (TAC). The TAC was interested in assessing the key existing and emerging IVT systems in accordance with a range of specified criteria. These criteria were developed by the TAC to help guide priority setting in supporting a subset of these technologies while accounting for both road safety impact and practical aspects of implementation.

This methodology takes into account road safety benefits, readiness of the technology, regulatory and infrastructure requirements, costs, user acceptance and the potential influence of government initiatives on the uptake rate.

By choosing these criteria, the methodology lends itself to better assessing the relative merits of the technologies in accordance with factors that help build the business case for several of the most promising technologies related to driver compliance issues (i.e., may be regarded as "enforcement" related technologies). The European Transport Safety Council (2005) points out such technologies are unlikely to succeed through market forces alone - a co-ordinated, co-operative approach involving industry, government, and advocates within the community, is appropriate.

IVT in road safety strategies

Makeham (1997, in Faulks 2002) recognised that there were many emerging ITS technologies with the potential for significant safety impacts, asking the question: "How much could new technology improve safety?" Perhaps, he said, we may get closer to the right answer by re-phrasing the question: "How much could be gained by drastically reducing the role of human errors and foibles in the causal chain of road crashes?" Of course, many, if not most, of the IVT are effective even if human error occurs. That is, the technologies are operative even if the driver is alcohol or drug impaired, fatigued, medically impaired or disabled, inexperienced, or otherwise functioning at less than optimal performance. Makeham also suggested that an issue in the viability of ITS could be the psychological price experienced by road users (and particularly drivers) that could be at least as important as the economic or cost impacts, and so he proposed an additional, cognate question: "As a driver, how much control and autonomy are you prepared to hand over to your car’s computers?"

In a discussion of the potential of new technologies to affect road user safety during the life of the New South Wales Road Safety 2010 strategy, Cairney (1999, in Faulks, 2002) argued that there were two forms of technological advance which were likely to have a major impact on road safety: ITS, and Geographic Information Systems (GIS). Although the full import of his prediction has not, to date, been borne out, the potential of ITS and GIS to influence and improve road safety would nevertheless remain strong. ITS applications of information and communications technology to the management of transport systems, with the objective of making the transport systems more efficient and safer, should, in the longer term, have a major effect in reducing congestion and improving traffic flow, in reducing emissions and other environmental impacts, and in reducing road crashes. Particular technologies identified by Cairney as likely to have considerable safety benefits included variable speed controls, adaptive cruise control, and collision avoidance technology.

Cairney argued that most advanced ITS technology will be developed by global consortia of major companies, regulated through international standards, and driven by the demand of the global marketplace. It would, therefore, be unlikely that an individual jurisdiction's road safety strategies would have a role in determining the nature or pace of these developments. However, road users within individual jurisdictions could, with appropriate policy and legislative frameworks in place, be early beneficiaries of ITS developments.

Cairney suggested that there were areas where relatively modest ITS developments could have a major impact on the road toll in Australia, and noted that these developments did not seem to feature to any large extent in the ITS programs overseas. He identified three issues where ITS technologies could be beneficial to Australian road users: the non-use of restraints (use of seat belt interlocks/reminders), unlicensed driving (better control of access to the vehicle, either by means of a smart card drivers licence or the use of a biological identifier to restrict access to authorised individuals), and better emergency response systems (i.e., ‘mayday’ systems, equipping vehicles with an emergency response system combining cellular phone and global positioning system technology backed by a control centre, capable of automatic operation in the case of a severe impact). Of these only the 'mayday' systems have been substantially developed and promoted by automotive manufacturers. Smart seat belt reminders are now widespread with extensive promotion via the New Car Assessment Programs (NCAP) in Europe and Australasia - many cars that have earned a maximum five star rating need the bonus points from smart seat belt reminders to reach that rating.

Most state and national road safety strategies recognise the potential of IVT but very few incorporate strategies that will encourage the introduction of the technology. This is not unexpected since, as already stated, there are many uncertainties in the process. In 2003 the Australian Automobile Association stated:

> "The use of technology to reduce human error in road crashes is increasing, particularly at the prestige end of the vehicle market. Adaptive speed control, distance warning systems, computer assisted braking and other safety technology is likely to spread to most new vehicles over the next decade through a flow-on effect. . .
>
> While there have been trials of many safety systems such as intelligent speed signs and warnings, their wider application depends on government involvement. This involvement will cost money, and too often governments see such expenditure as a 'cost' rather than what it actually is, an 'investment', with substantial and measurable returns." (p.6)

Rakotonirainy (2006) quotes an OECD report that estimate ITS has the potential to reduce fatalities and injuries by 40% across the OECD. The US Federal Highway Administration has estimated similar savings for the USA (FHA 1998, FHA 2005).

Methods of prioritising ITS technologies

The TAC defined the following criteria as important in helping to assess IVT technologies. A business case needs to be developed that takes into account:

a) The potential for reducing overall road trauma - injuries and fatalities
b) The technical readiness and availability of the technology
c) Regulatory and organisational issues
d) Infrastructure and data needs
e) Growth model - potential for greater fleet penetration through government initiatives
f) Costs
g) Acceptance by road users and fleet owners

Methods of assessing each of these factors, and associated limitations, are discussed briefly below.

Trauma reduction

There are two steps to quantifying trauma reduction. The potential benefits of a safety feature can be estimated from the types of crashes that the safety feature is likely to influence and the effectiveness of the feature in such crashes (the percent that are likely to be saved). For example, a Following Distance Warning (FDW) system can usually only be expected to reduce the number of crashes where a vehicle crashes into the preceding vehicle in the traffic stream. This is estimated to be about 20% of all light vehicle crashes (Ference 2006). An FDW system might prevent 10% of these particular crashes (Paine 2003a). This gives an estimated reduction of 2% in all light vehicle crashes. In the absence of better information, it is assumed that injury reduction will be similar to crash reduction.

Table 1. Proposed Trauma Reduction Rating

Priority	Potential Effect
High	Features demonstrated to reduce the risk of injuries and fatalities by 10% or more in all car crashes
Medium	Features demonstrated to reduce the risk of injuries and fatalities by 2% to 9% in all car crashes
Low	Features shown or believed to have a low potential effect (less than 2%) on reducing injuries and fatalities in all car crashes.

As a quantifiable value is available the trauma score for each IVT is based on the following formula (integer values are used for the other parameters):

> Savings < 12%: score = 2 x savings%/12% (e.g saving of 8% gives trauma score of 1.33)
>
> Savings >= 12%: score = 2 (maximum available)

It should be noted that some safety features are highly effective in particular crashes but, because the relevant crashes make up only a small proportion of all crashes, they do not rate highly under this method. Consideration was given to a separate rating of effectiveness but it was found that it did not usefully enhance ranking of IVT. These highly effective, but accident-specific, safety features may be worthy of special attention from government but they do not necessarily deserve priority under the general policy-making information intended as output of this methodology.

Technical readiness and availability

Paine and Gibbs (1998) identified five phases in the development of technology (see Table 3).

The "Start-up" phase typically involves research and development and the technology is not ready for use by the general public. Although government support for start-up technologies has merit — particularly for enforcement technologies that are unlikely to get much industry support — there is often a risk involved that conservative funders such as governments are unwilling to take. Nevertheless, governments do show enterprise in promoting technology at the start-up phase through funding research (e.g., the TAC SafeCar project, Regan et al. 2006).

The "Take off" and "Harvest" phases tend to have the highest returns on government efforts to introduce the technology.

The "Saturation" and "Exhaustion" phases, if they occur, have little return on effort as the feature is already in widespread use or is being superseded by more effective newer technology.

Table 3. State of readiness

Phase	Description	Characteristics
Start-up	Initial research, prior to production. Prototypes have been developed and tested (this phase is sometimes separated into 'future technology', that is, technologies which are only at the concept, developmental, or early experimental stages, and 'emergent' technology, where the technologies are in use in prototype installations and experimental trials but have not been widely adopted).	High effort for little or no trauma reduction in the general population. Prospects of moving to take-off stage fuel the research.
Take-off	Introduced to market on a limited basis. Typically safety features on up-market vehicles.	Accelerating returns. Beginning of good returns for effort.
Harvest	Increasing market penetration. Eventually expected by consumers as optional equipment	Steady returns on efforts.
Saturation	Most new models have the safety feature. Expected by consumers as standard equipment. Regulations that require mandatory installation may be an option at this phase	Diminishing returns on efforts.
Exhaustion	Only models near the end of their production life do not have the feature.	High effort for little or no results, plus no prospect of further gains.

Table 4. Proposed Readiness Rating

Priority	State of readiness
High	Take-off and harvest technologies
Medium	Start-up technologies
Low	Saturation and exhaustion technologies

Regulatory and organisational issues

Vehicle safety regulations might need to be introduced or amended to cater for specific IVT. Regulation might require the inclusion of worthwhile IVT on certain vehicles and/or to ensure that there are no adverse effects from IVT.

There may also be a need for published standards/guidelines that set out design or performance requirements for IVT - amongst other things this may help protect innovative manufacturers from litigation. Society of Automotive Engineers (SAE) Recommended Procedures are an example of such standards (www.sae.org).

However, regulations can also unintentionally hinder the introduction of new technology. A typical example is the operating frequency of radar sensors that are used to detect approaching objects (Paine 2003b). The operating frequency of some sensor radars might not comply with Australian radio frequency regulations.

Many safety outcomes simply result from the setting of conventions - such as driving on the left-hand side of the road. However, regulations may be needed to ensure there are no adverse effects from an IVT and to promote compatibility. For example, Annex 18 of United Nations ECE Regulation 13 (*Commercial Vehicle* Braking) defines functional requirements, fault strategies and methods of verification of "complex electronic vehicle control systems" where fitted to commercial vehicles. The Annex was apparently developed to cater for commercial vehicle ABS braking systems in the 1980s, but its provisions are considered flexible enough to also cover new technologies such as Electronic Stability Control and could be used in Australian regulations.

There are several Australian Design Rules (ADRs) that specify design and performance requirements for optional equipment such as daytime running lights. It may be appropriate to introduce new ADRs to cover the optional installation of IVT.

Effective and mature IVT could be made mandatory for certain classes of vehicle by regulation.

Organisational issues include occupational health and safety policy, fleet purchase guidelines, driver training, taxation policy and other issues that influence the purchase and operation of vehicles and, in particular, the decision to invest in safety-related features for these vehicles.

From a government point-of-view, the need for regulation could be regarded as a negative business factor as it involves more "effort". More importantly, the need for regulation is likely to delay the implementation of an initiative. Therefore the scoring system rewards IVT that do not require new regulations or standards.

Table 5. Proposed Regulation Rating

Priority	**Need for Regulation**
High	No new regulations or standards required
Medium	Relatively simple new or amended regulations/standards required
Low	Complex regulations or standards required with likely long implementation times

Infrastructure and data needs

Some IVT require relevant data about the road system and the operation of the vehicle within that system. An example is Intelligent Speed Assist (ISA), where the system needs to be able to identify the legal speed limit relevant to the current location and direction of travel of the vehicle. This could be obtained through the combination of a GPS location system and an on-board digital map and/or via roadside transmitters. In the first case, the speed limit information needs to be added to digital maps (at the date of writing no commercial maps in the market have speed limit information) and a reliable system for updating this information needs to be implemented. In the second case, all relevant speed zone change locations need to be identified and a standard method of transmitting the information to passing vehicles needs to be developed. As well, a capacity to incorporate temporary speed limit changes due to roadwork activities, crashes or adverse weather is required.

In 1996, during a project concerning speed control in cars, speed limit information was discussed with manufacturers of early car navigation systems (Paine 1996). The comment was made then that many customers assumed that speed limit information would be built into the digital maps and yet, to date, this has not happened under market forces. There appears to be a role for government in promoting this capability.

Table 6. Proposed Infrastructure Rating

Priority	Need for Infrastructure
High	No new infrastructure or data requirements
Medium	Relatively simple infrastructure or data requirements (eg. a speed limit database)
Low	Complex infrastructure or data requirements (eg. widespread use of roadside transmitters)

IVT usually also needs to acquire data from vehicle systems. Integrated IVT, provided by the vehicle manufacturer is not an issue but after-market IVT may have difficulty obtaining relevant data. Communication standards for vehicle electronic systems may help this situation (there is some overlap with the "regulation" factor for this item).

Growth model - potential for greater fleet penetration through government initiatives

Some IVT are being actively promoted by vehicle manufacturers, particularly if they enhance the marketing image of the vehicle. Other IVT are associated with obeying legal requirements, such as speed limits and seat belt wearing, and these tend to be absent from most vehicle manufacturer's marketing strategies. Government initiatives are perhaps likely to have a greater influence on the implementation of these "enforcement" IVT technologies where the marketing image sought by a vehicle manufacturer is not associated with the particular technology (ETSC 2005).

It is difficult to predict the future uptake of safety features on vehicles. The uptake of optional safety features is very difficult to establish from industry data sources. Factors that influence uptake include cost, vehicle manufacturer promotion, consumer awareness, salesperson awareness and fleet purchase policies (Paine 2002b). Usually optional safety equipment is unlikely to be chosen by consumers. A case in point is the Toyota Yaris which has an optional safety package with side curtain and knee airbags for approximately $750. Side curtain airbags halve the risk of a serious/fatal head injury in a severe side impact (which includes an impact with a pole or tree at just 30km/h) yet it is reported that less than 5% of Yaris buyers choose this option. Similarly, Peirce and Lappin (2006) report that uptake of optional ESC is only about 5 to 10% in the USA.

Although there is considerable uncertainty about uptake of safety features, the influence of government initiatives can be strong in some cases. A mandatory regulation should ensure 100% uptake. A case in point is the Victorian Government’s decision to require ESC fitment as a condition of registration of all new vehicles registered in Victoria as of 1st January 2011. An initiative that results in the majority of fleet purchases having the feature (perhaps through OH&S) should result in at least 30% uptake.

Table 7. Proposed Growth/Support Rating

Priority	Likely influence of government support
High	Estimated improvement in uptake of feature > 20%
Medium	Estimated improvement in uptake of feature ~ 2% to 19%
Low	Estimated improvement in uptake of feature < 2%

Costs

There are various ways of assessing the costs of road safety initiatives. They can be analysed on a per-vehicle basis or for the whole vehicle population. Either way, there are initial costs necessary to develop and install the feature on the vehicle, and ongoing costs associated with the operation of the system. Savings resulting from the feature also need to be factored into the cost equation. These might be, for example, the dollar value of crashes prevented by the feature, or associated savings such as reduced fuel consumption.

Benefit/cost analyses can be based on the "present value" of the net annual savings (that is, annual savings in crashes, fuel, etc. minus annual maintenance costs) divided by the initial cost of the feature (RTA 1998). The Present Value method provides a convenient way of comparing ongoing (annual) costs with the initial (installation) costs.

Typically, the cost of IVT falls dramatically once there is reasonable uptake of the feature in the fleet (the "harvest" phase) but this is difficult to model for assessment purposes. Complicating the assessment further is the possible need for infrastructure to support the IVT. An example is speed limit mapping for ISA. How should the cost of such mapping be spread across the fleet? Should the cost be divided by the number of vehicles with the IVT feature concerned, all new vehicles or all vehicles?

Such issues go beyond the scope of this methodology but they should be taken into account in any more detailed assessments of particular IVT. On balance, for this assessment it is assumed that infrastructure costs are defrayed across the whole vehicle population (since all motorists will eventually benefit from the reduction in trauma crashes) and are therefore negligible, compared with the typical costs of IVT per vehicle.

Table 8. Proposed Cost Rating

Priority	Cost of installation per vehicle
High	Less than $300 (or $900 for start-up or take-off phases)
Medium	$300 to $1499 (or $900 to $4499 for start-up or take-off phases)
Low	More than $1500 (or $4500 for start-up or take-off phases)

User Acceptance

The user acceptance of a technology and its effects on driving need to be separated from other consumer issues such as price (Rivers 1998).

For example, with regard to Intelligent Speed Assist (ISA), the ETSC (2005) reports that "Different trials using informative and supportive systems across Europe have shown that approximately 60–75% of users would accept ISA in their own cars". In discussing user acceptance of ISA, Howard (2007) points out that opinions seem to be quite polarised, with a small but vocal minority strongly opposed to any speed control measures. Howard also notes that the wording of the questions, experience with an ISA-equipped car, and even the location where the questionnaire is completed can have an effect on responses. Subject to this caution, in a poll of 1,000 UK citizens 47% said they agreed with the statement "devices should be introduced which prevent cars exceeding the speed limit at any time". Howard notes this was much higher than most people in the ITS community expected, and was about the same as the level of support for mandatory wearing of seat belts some three years before a highly successful seat belt law was introduced in the UK. "Black box" data recorders were slightly less popular at 39%. Regan et al. (2006) reported that about 45% of participants in a Victorian ISA trial agreed that ISA should be compulsory for all drivers, while 9% strongly disagreed with this statement.

ISA is often thought of as a relatively intrusive ITS technology in that it takes away the driver's choice to exceed the speed limit. The surprisingly high level of support for ISA suggests that user acceptance for other less-intrusive technologies will not be an impediment to implementation.

Table 9. Proposed User Acceptance Rating

Priority	Percent of users willing to accept the technology*
High	75% or more
Medium	25% to 74%
Low	Under 25%

* Not accounting for cost

Assessment of IVT

The various IVT related to road safety are described in the appendix. It is noted that recently vehicle manufacturers have begun marketing CAPS (Combined Active and Passive Safety) as an IVT. CAPS was considered as a possible separate and distinct technology, but ultimately was not included and evaluated as its benefits arise from a combination of other technologies (it is a way of maximising these benefits, rather than a technology in and of itself).

Table 10 summarises the preliminary scores based on this methodology.

Table 10. Preliminary ratings for IVT

TECHNOLOGY	TRAUMA	READI-NESS	REGU-LATION	INFRA-STRUCT-URE	GROWTH	COSTS	ACCEPT-ANCE
ABS BRAKES	0.42	2	2	2	0	1	2
ABS WITH ELECTRONIC BRAKE DISTRIBUTION	1.25	2	2	2	1	1	2
ADAPTIVE CRUISE CONTROL	0.25	2	1	2	1	1	2
ADAPTIVE HEADLIGHTS	0.03	2	2	2	1	1	2
ALCOHOL/DRUG INTERLOCK	0.83	1	1	1	2	1	0
BRAKE ASSIST	0.83	2	2	2	1	2	2
CRASH RECORDER	0.67	2	1	1	2	2	0
INTELLIGENT DAYTIME RUNNING LIGHTS	1.48	2	2	2	2	2	2
FATIGUE WARNING SYSTEM	0.33	1	1	2	2	1	1
FOLLOWING DISTANCE WARNING	0.33	1	1	2	2	2	2
FORWARD COLLISION AVOIDANCE WITH BRAKING	0.50	1	1	2	1	1	1
INTELLIGENT SPEED ASSIST - ACTIVE	1.67	1	1	1	2	1	2
INTELLIGENT SPEED ASSIST - PASSIVE	0.83	1	1	1	2	1	2
INTERSECTION COLLISION WARNING	0.25	1	1	2	1	2	1
LANE DEPARTURE WARNING	0.33	1	1	2	1	1	2
NIGHT VISION ENHANCEMENT	0.07	1	2	2	1	1	1
REVERSING COLLISION AVOIDANCE	0.23	2	1	2	2	1	2
ROLLOVER WARNING	0.03	1	1	2	1	1	1
SIDE BLIND SPOT/ LANE CHANGE WARNING	0.08	2	1	2	1	1	1
SMART LICENCE	0.42	1	1	0	2	1	1
TOP SPEED LIMITER	0.17	2	0	1	2	2	1
TRACTION CONTROL	0.04	2	2	2	0	2	2
TYRE PRESSURE MONITORING	0.10	1	2	2	2	2	1
ELECTRONIC STABILITY CONTROL	1.50	2	1	2	1	1	2
WORKLOAD MANAGER	1.00	1	1	2	2	2	1
ACTIVE HEAD RESTRAINTS	0.83	2	1	2	1	1	2
BONNET FOR PEDESTRIAN PROTECTION	0.80	1	1	2	2	1	1
PRE-EMPTIVE COLLISION PREPARATION	1.00	1	2	2	1	1	1

SEAT BELT INTERLOCK/REMINDER	0.92	2	1	2	2	2	1
SIDE AIRBAGS WITH HEAD PROTECTION	1.25	2	1	2	2	1	2
MAYDAY DISTRESS CALL IN SEVERE CRASH (ACN)	0.83	1	1	0	1	1	2
NAVIGATION SYSTEM (GPS)	0.08	2	2	2	0	1	2

Key 2=high, 1=medium 0=low

Prioritising IVT

A primary purpose of the project was to enable priorities to be assigned to each IVT and to set out ways that government organisations might be able to expedite the uptake of these technologies.

One method of prioritising is to assign weights to each of the assessment parameters and to calculate weighted scores for each IVT.

The following indicative weights have been assigned to give an indication of how this might work.

Table 11. Indicative weights for assessment parameters

PARAMETER	TRAUMA	READI-NESS	REGU-LATION	INFRA-STRUCT-URE	GROWTH	COSTS	ACCEPT-ANCE
PROPOSED WEIGHT	3	1	1	1	2	1	1

Table 12 shows the resulting weighted scores, sorted so that the the best-performing safety feature appears at the top of the list.

Table 12. Weighted scores for each IVT - best returns for government effort (maximum possible score 20)

IVT	***Weighted Score***
INTELLIGENT DAYTIME RUNNING LIGHTS	18.43
SIDE AIRBAGS WITH HEAD PROTECTION	15.75
INTELLIGENT SPEED ASSIST - ACTIVE	15.00
ABS WITH ELECTRONIC BRAKE DISTRIBUTION	14.75
SEAT BELT INTERLOCK/REMINDER	14.75
ELECTRONIC STABILITY CONTROL (ESC)	14.50
INTELLIGENT SPEED ASSIST - PASSIVE	14.50
BRAKE ASSIST	14.50
WORKLOAD MANAGER	14.00
FOLLOWING DISTANCE WARNING	13.00
REVERSING COLLISION AVOIDANCE	12.70
ACTIVE HEAD RESTRAINTS	12.50
BONNET FOR PEDESTRIAN PROTECTION	12.40
TYRE PRESSURE MONITORING	12.30
CRASH RECORDER	12.00
PRE-EMPTIVE COLLISION PREPARATION	12.00
ADAPTIVE HEADLIGHTS	11.10
FATIGUE WARNING SYSTEM	11.00
ADAPTIVE CRUISE CONTROL	10.75

ALCOHOL/DRUG INTERLOCK	10.50
TOP SPEED LIMITER	10.50
ABS BRAKES	10.25
TRACTION CONTROL	10.13
LANE DEPARTURE WARNING	10.00
INTERSECTION COLLISION WARNING	9.75
FORWARD COLLISION AVOIDANCE WITH BRAKING	9.50
MAYDAY DISTRESS CALL IN SEVERE CRASH (ACN)	9.50
SIDE BLIND SPOT/ LANE CHANGE WARNING	9.25
SMART LICENCE	9.25
NAVIGATION SYSTEM (GPS)	9.25
NIGHT VISION ENHANCEMENT	9.20
ROLLOVER WARNING	8.10

Discussion

Table 12 contains some departures from conventional analyses of the benefits of safety features. This is mostly because the methodology is attempting to identify the best returns for government efforts. Some IVT that are likely to be highly effective at saving lives are likely to become popular with minimal government effort. Others will likely languish if consumers and governments do not take the initiative.

Some comment on notable IVT are provided below.

Intelligent daytime running lights (DRLs)

Intelligent daytime running lights stand out as the best performer. The system evaluated was the most effective DRL available - energy-efficient dedicated bright white lights at the front of the vehicle that are wired to an "intelligent" daylight-sensing switch (Paine 2005). These provide optimum conspicuity during a wide range of daytime conditions but automatically switch to low-beam headlights when ambient light levels fall. This avoids complaints about excessive glare from the DRLs if the driver forgets to turn on the headlights.

There tend to be many myths and misunderstandings about DRLs. One is the so-called latitude effect where studies of DRL effectiveness appear to show increased effectiveness in high-latitude countries like Norway. This has been used to suggest that DRLs are not particularly effective in Australia. A serious flaw with this conclusion is that most of the studies were based on the use of low-beam headlights as DRLs in the 1970s and 1980s. Paine (2005) found through photometric analysis that these are marginally effective as DRLs on all but very dull days (by design headlights aim the light away from oncoming drivers). A study of DRLs fitted as standard to all General Motors vehicles in the USA found that dedicated, bright DRLs are far more effective at preventing accidents than low-beam headlights. Paine (2005) showed that this was correlated photometric performance - the brightest DRLs are highly effective at preventing relevant crashes. That paper also addresses other misunderstandings about DRLs.

Apart from General Motors in the USA, manufacturers have been reluctant to introduce DRLs as standard (although they are optional on many vehicles in the USA). Canada made DRLs mandatory (minimum "hard wired" headlights) in 1989 and the European Union proposes to make dedicated DRLs (i.e not headlights) mandatory within a few years.

It is estimated that well-designed DRLs would save 15% of all serious/fatal *daytime* crashes, equivalent to 9% of all serious/fatal crashes. They are relatively cheap, simple and maintenance-free. Given the lack of industry interest, government action could strongly influence the uptake of DRLs in Australia and New Zealand. This combination of factors has resulted in a high score for DRLs.

Side airbags with head protection

The most common device is an inflatable side curtain airbag that is deployed in a side impact. It is estimated that side airbags with head protection halve the risk of a serious/fatal head injury during an intrusive side impact. These comprise about 15% of all light vehicle crashes and so the overall saving is estimated to be 7.5% (Paine 2002a) . Recent designs of inflatable side curtain airbags are designed to deploy in rollover crashes, which account for about 25% of occupant fatalities in Australia. Such curtain airbags could be expected to be highly effective in these crashes but the benefits have not been included in the above analysis.

The uptake of side airbags with head protection has improved in the past year - are now standard on the Toyota Aurion, Holden Commodore and new Ford Falcon. ANCAP is likely to have been a factor in the improvement since the rating system rewards vehicles with these devices (subject to the manufacturer funding the optional pole test). Another way the governments can affect the uptake is to make the devices a requirement for fleet purchases.

Active intelligent speed assist

Intelligent Speed Assist (ISA) determines the posted speed limit for the current section of road and takes action if the vehicle exceeds that speed limit. The action taken may be to alert the driver through visual, audible and/or haptic signals (passive ISA) or to prevent the vehicle being driven beyond the speed limit (active ISA) for prolonged periods. ISA technology has been proven in numerous demonstration projects in Europe and Australia. One stumbling block to widespread implementation is the lack of suitable digital maps/databases of posted speed limits. Increasingly governments are becoming involved in the development of these databases.

A speed-limited car does not fit the usual marketing image desired by automotive manufacturers (despite Formula One racing cars being speed limited in the pit lane for many years). It is evident that government initiatives will be needed to introduce this technology (ETSC 2006). The potential savings are very high, since 40% of fatal crashes and at least 20% of other crashes are estimated to be speed-related. Research on speed effects and the physics involved shows that even minor speeding carries an unexpectedly increased risk of a casualty crash

(Paine 2007). An Adelaide study of urban crashes found that each 5km/h over the speed limit doubled the risk of involvement in a casualty crash. Due to the large proportion of vehicles exceeding the speed limit by up to 10km/h about half of the savings could be realised if this group did not exceed the speed limit.

It has been conservatively estimated that active ISA systems would halve the risk of a speeding-related crash, meaning that the technology could prevent at least 10% of all serious crashes (and a higher proportion of fatal crashes).

Electronic stability control

Electronic stability control (ESC) detects if the vehicle is nearing the limits of traction during cornering and braking and adjusts braking to individual wheels and engine torque to improve stability. ESC is now widely fitted as standard to many models and is being promoted by automotive manufacturers as a "sporty" safety feature. It is hoped that this does not lead to increased risk-taking by drivers (e.g increased speed when entering corners) as an increase of only a few km/h would negate any safety benefits from ESC. The studies in Europe, Japan and the USA showing remarkable effectiveness of ESC have mostly involved drivers who were unaware of the operation and advantages of the technology - unlike ABS brakes, no special action or training is needed by driver in order for ESC to be effective.

Subject to this caution, a study by MUARC in 2007 found that ESC reduced single vehicle car crashes by 27% and single vehicle four-wheel-drive crashes by a remarkable 68%. However, multi-vehicle crashes were unaffected and the overall reduction was found to be about 5% (Scully & Newstead, 2007). Effectiveness in serious crashes is likely to be better and it is estimated that ESC will save about 9% of serious/fatal light vehicle crashes in Australia and New Zealand. This is somewhat less than some estimates derived in Europe and the USA but is similar to studies in the UK by Professor Thomas, who cautioned that ESC effectiveness was likely to be highly dependent on local conditions (Thomas 2007).

Conclusion

At the request of the TAC, a review of current and emerging IVT systems has been conducted and assessed in accordance with a range of outcome and priority criteria. A methodology has been developed that compared with conventional benefit/cost analyses, is less sensitive to the uncertainty about the crash savings and installation costs that is inherent with most emerging technologies .

The ranked lists of IVT systems that emerge as ‘high priority’ for government consideration should be considered as ‘indicative’ only because weights and criteria are subject to further refinement. Nevertheless, the project has shown that the methodology is feasible and represents an important step in helping government agencies to assess the IVTs that warrant support in the short to medium term.

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Disclaimer

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Appendix. Brief description of each IVT

CRASH AVOIDANCE	
ABS BRAKES	Prevents individual wheels from lock up during heavy braking (or on slippery surfaces) and subsequently assists driver to maintain control
ABS WITH ELECTRONIC BRAKE DISTRIBUTION	As with ABS but distribution of braking forces is optimised to maximise the available friction (similar to brake proportioning valves)
ADAPTIVE CRUISE CONTROL	Detects distance and speed of preceding vehicle and maintains appropriate headway
ADAPTIVE HEADLIGHTS	Motorized headlamps linked to sensors that measure the vehicle's angle, pitch, steering direction and orientation; as such, they can adjust their direction and intensity to provide additional illumination on curves, turns, and hills.
ALCOHOL /DRUG IGNITION INTERLOCK	Require driver to perform and pass a breath alcohol test before the vehicle can be driven, and includes rolling re-test capability during driving
BRAKE ASSIST	Detects fast brake application. Provides emergency braking assistance
CRASH RECORDER	Continuously records vehicle speed and other parameters and stores this in the event of a collision ("Black box" recorder)
DAYTME RUNNING LIGHTS (INTELLIGENT)	Dedicated daytime running lights with a sensor that automatically switches to low beam headlights at dusk
ELECTRONIC STABILITY CONTROL (ESC)	Detects if vehicle is nearing the limits of traction during cornering and braking and adjusts braking to individual wheels and engine torque to improve stability.
FATIGUE WARNING SYSTEM	Detects whether the driver is exhibiting signs of fatigue (doze alert)
FOLLOWING DISTANCE WARNING	Detects distance to preceding vehicle and alerts driver if the gap is less than recommended headway for the current speed.
FORWARD COLLISION AVOIDANCE WITH BRAKING	Detects distance and closing speed of objects in path of vehicle and automatically decelerates if driver does not heed warning
INTELLIGENT SPEED ASSIST	Determines current speed limit (mainly from digital map) and alerts driver if the limit is being exceeded (passive ISA) or limits the speed of the vehicle (active ISA).
INTERSECTION COLLISION WARNING	Detects vehicles approaching from the side at intersections. Alerts driver if a collision is possible
LANE DEPARTURE WARNING	Recognises lane markings and alerts driver if the lane boundary is crossed
NIGHT VISION ENHANCEMENT	Generally uses non-visible light frequencies to enhance driver vision
REVERSING COLLISION AVOIDANCE	Sensors detect objects in the path of a reversing vehicle plus visual aids (cameras) to improve the rearward field of view
ROLLOVER WARNING	Alert drivers when the lateral forces or vehicle dynamics indicate a risk of rollover (this is mainly a heavy truck application).
SEAT BELT INTERLOCK/ REMINDER	Require driver to put on seat belt before the vehicle can be driven (interlock), or provide alert to driver that seated occupants do not have seat belts connected

SIDE BLIND SPOT/ LANE CHANGE WARNING	Detects distance and closing speed of objects in adjacent lanes and alerts driver if a collision is imminent
SMART LICENCE	Vehicle will not operate without an appropriate electronic licence. This might have speed or time-of-day restrictions.
SPEED ALARM (MANUAL)	Alert drivers when the vehicle speed exceeds a pre-set limit (driver selects a speed for an audible alert)
TOP SPEED LIMITER	Vehicle is rendered incapable of traveling above a set speed for prolonged periods
TRACTION CONTROL	System detects potential wheel spin due to excessive driving torque and limits this torque.
TYRE PRESSURE MONITORING	Detects when a tyre drops below 75% of recommended pressure and alerts driver
VEHICLE2VEHICLE COMMUNICATIONS	Standards for exchange of information between vehicles and roadways.
WORKLOAD MANAGER	Filters and prioritises the information made available to the driver. Postpones or cancels certain distractions, such as non-urgent vehicle warnings or integrated mobile telephone calls.

INJURY PREVENTION AND POST-CRASH RESCUE	
ACTIVE HEAD RESTRAINTS	Seat design responds to rearward collision by moving head restraint foward and other actions that reduce the risk of whiplash type injuries. Electronic detection of collision may offer better protection, compared with mechanical systems.
BONNET FOR PEDESTRIAN PROTECTION	Detects collision with pedestrian and either deploys external airbag or raises bonnet to lessen impact
PRE-EMPTIVE COLLISION PREPARATION	Detects imminent collision. Deploys safety devices such as seat belt pretensioners
SEAT BELT INTERLOCK/REMINDER	Sounds alarm if driver seat belt not buckled. Some systems apply to passenger seating positions
SIDE AIRBAGS WITH HEAD PROTECTION	Side airbag or curtain airbag deploys in side impact and protects the head
MAYDAY DISTRESS CALL IN SEVERE CRASH	Alerts emergency services (or a contractor) if a severe collision occurs
NAVIGATION SYSTEM (GPS)	Displays dynamic map of roads. Some give voice instructions for route following. Some give known hazard warnings such as blackspots.