Road Safety

IMPACT OF NEW TECHNOLOGIES

OECD

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Impact of New Technologies

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ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

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– to contribute to sound economic expansion in member as well as non-member countries in the process of economic development; and
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FOREWORD

The OECD brings together 30 member countries and helps governments meet the challenges of a globalised economy. The OECD's Programme of Research on Road Transport and Intermodal Linkages (RTR) takes a co-operative international approach to addressing transport issues among OECD member countries.

The mission of the RTR Programme is to promote economic development in OECD member countries by enhancing transport safety, efficiency and sustainability through a co-operative research programme on road and intermodal transport. The Programme recommends options for the development and implementation of effective transport policies for members and encourages outreach activities for non-member countries.

This study was carried out by the OECD Working Group on Safety and Technology, and details the impact that new transport technologies can have on road safety based on research from around the world. It provides recommendations to government and industry to ensure that road safety is enhanced and not compromised by the introduction of new technologies.

ABSTRACT

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In recent years, there has been rapid and significant development of road transport technologies. These include safety technologies, advanced traveller information systems and convenience and entertainment systems. This report compiles current knowledge on the impacts of these systems on road safety. It is estimated that safety technologies could reduce fatalities and injuries by 40% across the OECD, saving over USD 270 billion per year. These optimistic figures must be tempered, however, by the potential side effects or drawbacks that could result from implementation of new technologies that do not target road safety. In particular, OECD member countries are urged to aggressively resist the unregulated proliferation of technologies that will further distract the driver or otherwise worsen road safety. The report examines deployment challenges and provides recommendations for governments and industry to maximise the safety benefits or new technologies and minimise their drawbacks.

Fields: vehicle design and safety; accident statistics; economics and administration.

Keywords: accident prevention; design (overall design); driver information; government (national); improvement; intelligent transport system; OECD; passenger information; policy; risk; safety; technology.

[*] The OECD International Transport Research Documentation (ITRD) database contains more than 300 000 bibliographical references on transport research literature. About 10 000 references are added each year. Each record contains an informative abstract, from the world's published literature on transport. ITRD is a powerful tool to identify global research on transport, each record containing an informative abstract.

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EXECUTIVE SUMMARY AND CONCLUSIONS

Road crashes exact a tremendous human and societal toll in OECD member countries. Each year, more than 125 000 people are killed in such crashes and millions more are injured, many of them permanently. The cost of the road safety problem in the OECD area amounts to 2% or more of gross domestic product (GDP).

Recently, much attention has been paid to the development of intelligent transport systems (ITS) that can improve the safety and efficiency of road transport while improving user comfort and convenience. All OECD member countries have been involved in developing or deploying these technologies to some extent. As this process has moved forward, a great deal of information has been developed concerning the benefits that can be realised over time with the full deployment of ITS. Among other things, safety benefits have been measured or estimated for a wide variety of technologies. This report summarises and documents the current international perspective concerning the ability of ITS to address the road safety situation in OECD member countries.

In addition to ITS technologies that improve road safety, considerable development has also gone into advanced traveller information systems as well as convenience and entertainment systems. The global market for in-vehicle devices will exceed USD 40 billion by 2010. These technologies can have a considerable impact on road safety and are outlined in this report.

Deployment of new technologies: benefits

Most OECD countries suffer from similar safety problems. In particular, run-off-the-road, intersection and head-on crashes are the main crash types of concern in OECD countries, which also share a common set of factors that contribute heavily to all crash types. Specifically, alcohol, speed, fatigue and seatbelt usage patterns all play a role in crash scenarios. As a result, there is a generally common expectation among the countries that four types of technology (collision avoidance, driver status and performance, speed control, and automated enforcement) offer the greatest potential for lessening the number or severity of road crashes.

These technologies are described in this report, including evaluation results where these have been carried out. Based on the available data, ITS safety technologies have the potential to dramatically impact road safety in OECD countries. Using only conservative estimates, the following outcomes are possible:

- ITS safety technologies can save as many as 47 000 lives per year in OECD countries.
- ITS safety technologies can potentially reduce the total number of road crash injuries and fatalities by approximately 40%.

- The cost savings associated with the reduction in fatalities alone can conservatively be placed at over USD 73 billion per year.
- The savings related to a 40% reduction in injuries and fatalities would be approximately USD 194 billion annually.

The benefits outlined here and the resulting reduction in crashes, injuries and fatalities assumes that these technologies are fully deployed in OECD countries. Thus, the benefits outlined here may not be realised for another 20 or 30 years. However, the mere indication that such benefits can be realised should spur OECD governments to actively support and promote full deployment of as many of these safety technologies as possible.

Deployment challenges

These optimistic figures must be tempered, however, by the potential side effects of safety technologies or drawbacks that could result from implementation of technologies that are not safety-related. Primary concerns are that technologies may distract the driver from the driving task, or induce in the driver a false sense of security and thus encourage riskier behaviour. Governments are urged to aggressively resist the unregulated proliferation of technologies that will further distract the driver or otherwise worsen road safety.

Funding

Attaining the benefits suggested in this report is possible, but several challenges remain before these benefits can be fully realised. The most basic of these challenges is financial, the high cost of new safety systems being the primary constraint. This creates a barrier to implementation in that it prevents most consumers from purchasing the new technology. This can be overcome in time by market forces if the technologies truly provide a quantifiable benefit to the consumer and if the prices decline as a result of increased production and further technological development.

Many countries already lack budgets for fundamental safety technology investments, and even more so for newer, untried technologies. This can lead to a lack of political will to fully pursue technologies that can make a difference. Though there are efforts in countries to overcome these challenges, further promotion and outreach is called for.

Evaluation

As with any new technology or approach, there may be unknown risks or drawbacks associated with their use. Many technologies introduced in the past (*e.g.* airbags or seatbelts) made a difference early even though they had technical drawbacks that led to some much smaller problems. As more knowledge was gained, adaptation of the technology occurred and the safety record improved even further. Sometimes this knowledge was gained reactively – *i.e.* from complaints or negative reports from safety agencies – rather than proactively – *i.e.* creating an evaluation plan and carrying it out over a long period of time. Clearly, the latter approach is preferred. It is therefore essential to plan and maintain a focussed ongoing evaluation programme to monitor the continuing performance of ITS safety technologies.

Driver training

New technologies may compensate for driver errors, but is important that drivers be aware of the capabilities and limitations of systems. To fully realise the benefits of new technologies, drivers need to learn to use them and gain experience. Proper design is important to ensure that drivers are not overwhelmed. Training cannot compensate for badly designed technologies.

Liability issues

One of the large deployment challenges revolves around responsibility. Problems regarding product liability are likely to occur with assistance systems that cannot be overruled by the driver or which intervene beyond human performance limits (*e.g.* anti-collision systems). There are two possible alternatives in dealing with this issue. The first is to allow uncontrolled deployment of new technology trusting to product liability controls to ensure that products, primarily produced by manufacturers to sell vehicles, are safe. Another alternative is to try to influence deployment, promote technology that promises improved road safety, minimise the effects of inappropriate technology, and educate the driver to take full advantage of the existence of affordable electronics.

The former approach carries the risk that certain technologies will never be developed despite the enormous potential safety benefits. Manufacturers may consider that certain systems will make their products less attractive and therefore quote legal and product liability obstacles to the introduction of such systems even when they do not exist. The latter approach runs the risk of stifling invention by introducing inflexible regulation based on insufficient proof. The challenge is, therefore, for liability issues to be overcome by finding a balance between the two alternatives such that manufacturers pursue invention and other promising technologies are promoted and deployed.

Infrastructure issues

Another deployment challenge is the need to introduce a robust infrastructure, enabling architecture and standards platforms. Robust infrastructure, for example, accommodates older vehicles, interfaces with existing infrastructure, requires minor training, is fault-tolerant, and fails in a safe manner. In the first instance, this challenge centres on making appropriate architectural decisions that take account of and facilitate introduction and integration of ITS safety technologies. Most countries have approaches in place for establishing ITS architectures. Explicit attention and information on safety-related ITS needs to be incorporated into architectures to ensure that deployment is facilitated. As with any ITS technology, standardisation is also essential to successful deployment and use of safety technologies. Standardisation can aid in both the broadest and quickest penetration of the vehicle fleet and road system by ITS safety technologies. It can also contribute to global efficiencies in production of either complete or component products that are essential for ITS safety deployment. Without such standardisation, there are many questions related to assurance that systems will behave as expected when they are needed most. Again, explicit attention to safety and the unique issues presented by safety technologies in the development of standards is called for.

Another infrastructure-related issue that could be a core element of effective deployment of ITS safety technologies is digital maps of highway networks and location-identifying infrastructure. Digital maps and the infrastructure will form the core of many ITS safety applications, but the current quality of these maps, where they exist, is insufficient for effective safety applications. The lack of quality maps and the location-identification environment is a major obstacle to deployment. Country-wide and regional efforts to develop consistent digital maps are strongly supported. These should form a basis and impetus for rapid development and deployment of automated vehicle location technologies in safety applications.

Training of safety professionals and outreach

There is a specific need to provide training to ITS and safety professionals in OECD member countries. Such training should raise awareness of the possibilities of technology to address road safety and generate cross-speciality understanding (*i.e.* road safety professionals understanding ITS and *vice versa*). In addition, training would stimulate increased co-operation and, ultimately, accelerate the acceptance of ITS and the adoption of specific, available ITS technologies as workable countermeasures for safety. Examples exist of this type of training as well as international co-operation, and information sharing is encouraged.

One aspect of this issue is to understand the role of manufacturers and, ultimately, their responsibilities. A mutual understanding between manufacturers and public officials on which technologies are most likely to serve the interests of road safety will ensure that arguments related to liability and risk can be addressed early, appropriate architectures and standards can be created and that technologies will be rapidly developed and deployed. Training that targets the private sector and facilitates dialogue on issues of relevance to both the public and private sectors is recommended.

Research and development

A critical aspect of successful deployment is a commitment to carry out targeted research and development. This includes developing outreach programmes to communicate information on technologies, their benefits and drawbacks, and better understand how to make systems simple and understandable. Other areas for research and development include human factors, various individual technologies, legal issues and ongoing technology evaluations. Another critical issue for research and development is related to data. Specifically, better knowledge and understanding about safety data and evaluation would be desirable because this could lead to the development of technologies that better target specific crash causes. Also, a focus on better storage and use of archival data generated by ITS technologies could lead to overall better safety systems and countermeasures.

What governments can do

It is often stated that the best thing for technological development is to reduce or eliminate the role of government as it will have the negative consequence of stifling development. However, private companies are developing and promoting the use of such things as fax machines, on-board computers supporting Internet access, games and video/entertainment systems for use in vehicles. These developments are taking place without governmental links and pose a real risk of increasing driver distraction and task load. The ultimate effect on road safety, though not certain, is predictable. The introduction of such non-safety ITS systems can pose a risk if the systems are not designed with the safety of the driver in mind. The introduction of after-market technologies or products poses the greatest challenge.

The natural role of government in preserving and protecting the safety of road transport operations leads to a certain conclusion that a "do nothing" posture by governments in the face of technological development and deployment is not appropriate. The following tactics are suggested:

- Development and use of safety performance indicators for ITS and other technologies for use in vehicles. This report provides a starting point for the types of indicators that could be used and the rationale for such indicators. The use of indicators will also support the recommendation of the Working Group on Safety and Technology for governments to stress ongoing evaluation of technologies and their deployment from a safety standpoint.

- The introduction of new technologies should be managed by ensuring they are part of national safety plans and strategies. Such an approach assures a high level of government commitment to the safety focus and stresses the importance of the technologies in question. Managing the introduction of technologies requires standardised processes to achieve the full safety benefits inherent in the technologies. Achieving these results would mean that development takes place in a highly focussed way that targets the most important technologies first. These processes will also encourage co-operation and communication across non-traditional lines in the road transport agencies, among ITS specialists, safety specialists, maintenance officers and others who will have new responsibilities and require new skills for successful deployment.

- Basic infrastructure needs to be provided by governments to ensure the most rapid and successful deployment of ITS safety technologies. One example of this is digital road maps and the location-identifying infrastructure that can motivate the development and deployment of location-based safety technologies. Other examples might be any roadside hardware or technology that would eventually be needed for vehicle/infrastructure co-operative systems. The presence of such hardware can in itself be a motivation for technological innovation and deployment.

- Governments should encourage and fund targeted research and development on specific safety technologies, particularly where the private sector is not involved.

- Governments should be involved to ensure new products have real safety benefits and are not unsafe. Whether such involvement comes in the form of setting standards, product testing, research or otherwise is less important at this stage then the acknowledgement of the role and a commitment to fill that role. For instance, human-machine interface (HMI) issues are real *vis-à-vis* distraction and call very strongly for government involvement. Governments should therefore note the statements of principles referenced in this report and endorse or support their adoption. Another example from this report is the emphasis that should be placed on ensuring that ITS safety systems fail logically so that the driver is aware of the failure and can take appropriate action without relying on the technology.

- Governments should be setting priorities for the deployment of infrastructure-related technologies that will facilitate more rapid technological development and deployment by the private sector and other independent sources.

- Government should take the lead in outreach and education for communities and decision-makers to ensure that the public, governmental leaders and elected officials will fully support ITS safety deployments.
- Governments should lead the effort for ongoing international co-operation in the development and dissemination of architectures and standards that will lead to regional harmonisation as needed or global harmonisation when called for.

What industry can do

While governments set the framework to ensure a safe road environment for all users, industry plays a vital role in the development and improvement of road safety. For example, many of the benefits being sought by the application of ITS technologies hinge on successful development and marketing by private industry. In considering the areas for action by industry, it is best to keep in mind their strengths and weaknesses. For instance, industry does excellent work in research and development that serves to gain competitive advantage and satisfy customer needs. They also do excellent work in setting standards, particularly those that concentrate on commonisation of and intercommunication between systems. However, industry has limited ability to carry out large co-ordination tasks and little incentive or interest in introducing systems that appear to have no commercial demand, such as electronic vehicle identification, black box data recorders, or intelligent speed adaptation. Using this as a backdrop, some of the suggestions supported by this report include:

Maintaining a high-level commitment to safety

One of the promising possibilities for ITS technologies is to respond to the increasing importance of road safety in a number of OECD countries. In order for ITS technologies to truly achieve their safety potential, private sector developers and manufacturers must establish and maintain a credible commitment to road safety. Such a commitment is characterised in the most basic sense by a clear understanding of the road safety problem. With such an understanding, unambiguous statements to ensure that systems do not degrade the situation are taken more seriously. Also, understanding the safety situation provides a better basis to achieve a better balance between safety, reliability and cost.

Once a high level commitment is established and acted upon, it is more likely that resistance to the development of technologies that primarily target safety and seem "unexciting" can be overcome. In addition, with a paramount concern for safety, industry is better positioned to make realistic assessments of how a driver will use any ITS technology in order to better measure and report the potential safety benefits or risks of product introduction. This would require and demand the performance of analyses aimed at identifying the potential failures of the technologies and the effects of such failures.

Developing meaningful partnerships with appropriate government agencies

Much of what government does in relation to ITS technologies can have a direct and sometimes profound effect on industry. From this standpoint alone, effective and ongoing partnerships are essential to the long-term success of technological deployment. From another perspective, there are often mutual or shared interests between government and industry that can only be achieved if there is a means for active dialogue among the players. There is a common desire to ensure that appropriate standards are in place that will on one hand provide some level of road safety assurance and on the other hand encourage rather than limit private sector development of consumer products. An example is to avoid driver confusion by ensuring consistent provision of information and consistent and safe human interface with in-vehicle technologies, or, in a similar vein, to create scenarios for the development of systems that provide only appropriate or prioritised delivery of information to prevent driver overload. In either case, it can be a highly productive and positive reason for partnerships.

Another aspect is in the development of standards for interactive systems across jurisdictional boundaries. Such co-operation and collaboration can lead to systems that address the primary road safety concerns of the government while at the same time improving the market capabilities of new consumer products.

As described in this report, there is a need for iterative safety evaluation throughout the life cycle of new products. Both government and industry should have a stake in this and an interest in the results of such evaluation. Effective partnerships can facilitate collaboration on data collection, sharing and analysis. Such collaboration may help in the development of regulatory frameworks that allow safe performance of vehicles with new technologies and do not put vehicles without the technology at a disadvantage or assist in managing liability issues that will arise from technology deployments.

Another area that is relevant to industry is the classification of technologies as either primarily comfort-related or safety-related. To ensure the highest attention to road safety, it is probably best for government and industry to work together to determine what constitutes a comfort technology and what constitutes a technology with a safety implication (good or bad). Such determination will drive decision-making regarding appropriate applications, use and communications with the public, all of which affect the approaches that will be pursued by manufacturers and others.

Establishing clear and concise communication capabilities with the public

Industry has a primary role in communicating to the public about the capabilities and limitations of their systems. If systems are only for comfort, industry should create communication packages that clearly explain this to consumers to ensure that expectations of the technology do not exceed its abilities to improve their safety. In particular, industry must communicate warnings to the public about how some technologies might introduce challenges to the driver and what those challenges might be. In addition, industry must communicate clear expectations concerning the limits of technology and in which situations the technology is no longer effective and total reliance is returned to the driver. Finally, industry has a responsibility to inform the public of what new technologies do, as well as about their positive and negative effects on travel risk.

A framework for action

The recommendations captured in this report form a framework within which governments can begin to examine the possibilities and directions for ITS technologies to be developed and deployed for safety. This information should be used to augment existing national safety action plans in individual countries and to spur the development of new actions and plans by individual countries or across international borders. Ultimately, these actions will drive further development and deployment and assist all countries in achieving a common aim: saving lives.

Chapter 1

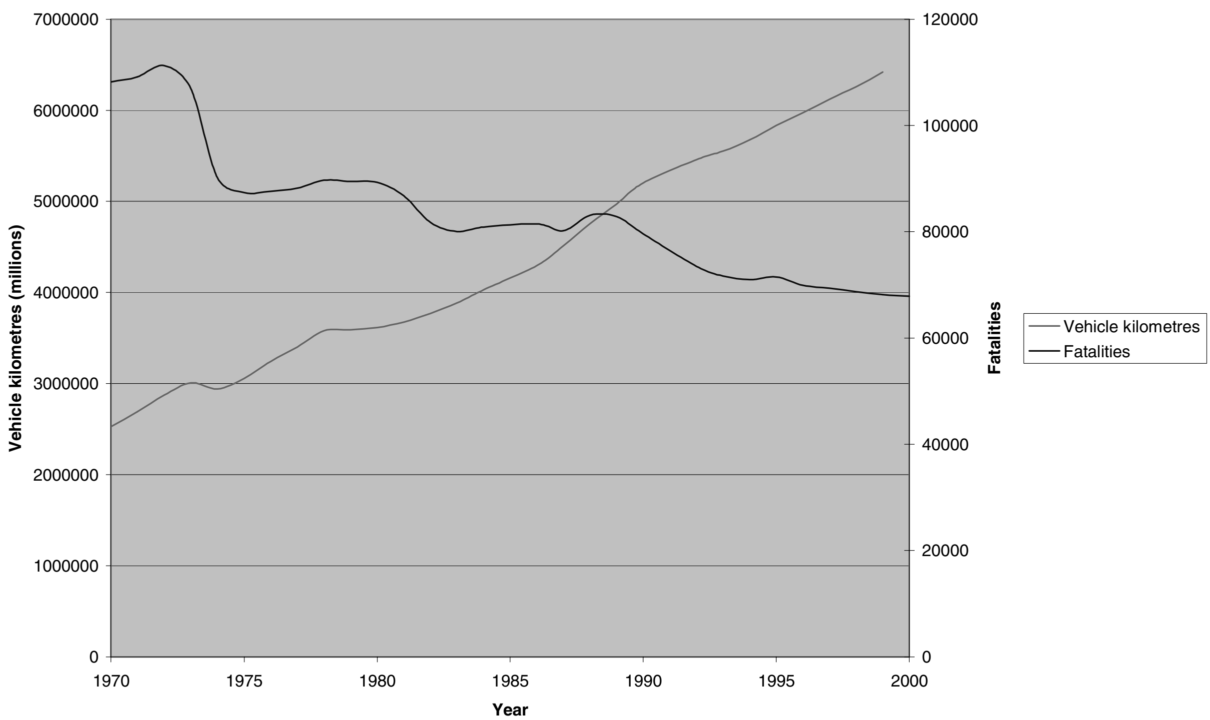
INTRODUCTION

Abstract. This chapter describes the evolution of road safety and introduces the impacts that technology can have on road safety. In addition, it discusses the social and economic impacts of road-related fatalities and injuries, and political barriers to improving safety.

Background

Since the early 1970s, when many OECD countries started to seriously tackle road safety problems, road fatalities have declined overall as illustrated in Figure 1.1. Factors that have contributed to this decline include an increased use of safety belts, reduction in drunk driving, more crashworthy vehicles, and improved infrastructure.

Figure 1.1. Road fatalities and vehicle kilometres travelled in nine* OECD countries



* Austria, Belgium, Denmark, France, Great Britain, Japan, Sweden, Switzerland, United States.

Source: OECD International Road and Traffic Accident Database (five-year intervals).

Another aspect of these changes is the evolution of driver behaviour over the last 20 years. Specifically, the awareness of the general public in most OECD countries to the dangers of certain behaviours has led to some fairly dramatic changes in people's attitudes on the road. For instance, the evolution of social acceptance of drinking and driving has gone from the perspective of there being no real harm associated with driving under the influence of alcohol to one of intolerance for such behaviour. Likewise, the use of seatbelts has become the norm in most countries for a majority of drivers. In a similar vein, the use of child restraint systems – *i.e.* child safety seats – has also gained in popularity and widespread acceptance.

Generally speaking, dramatic increases in traffic occur during economic booms, while stagnation or even declines are seen during recessions. This increased exposure on the roads often contributes to increased numbers of crashes, injuries and fatalities. Referring to Figure 1.1, periods of rapid growth in traffic coincide with two peaks in fatalities in the late 1970s and late 1980s, countering the safety improvements that were introduced during the same period. Clearly, without the safety improvements introduced by many countries and shifting driver behaviours, road fatalities would have far surpassed the reported levels.

Naturally, economic cycles will continue and their impacts on traffic and safety are somewhat predictable. On the other hand, the rapid development and introduction of various technologies will affect safety, but the effects are less predictable. It is likely that safety-related technologies have the potential to feed changes in driver behaviour that are no less dramatic than the changes we have witnessed in the last 20 years. For instance, one of the main contributing factors to safety on our roads is speed – *i.e.* over the limit, differential and inappropriate speeds. New technologies such as adaptive cruise control, intelligent speed adaptation and automated enforcement all have the potential to radically change the way vehicles are used on the road, and perhaps ultimately the fundamental driver behaviour that makes speed such a major contributor to crashes on our roads. However, with so many other safety and non-safety technologies being developed, the cumulative effects on driver behaviour are not explicitly predictable, but they certainly can be reasoned to alter the current behaviours witnessed on the roads of OECD countries.

This report primarily addresses those technologies that are included under the category of intelligent transport systems (ITS). Specifically, it focuses on ITS technologies that have as their primary intended outcome the reduction in the number of crashes, injuries and fatalities on roads. The report also provides information on ITS technologies that do not have a primary objective of improving safety – *e.g.* route navigation systems – but may have either a positive or negative effect on safety. Additionally, the report examines some technologies such as cell phones and entertainment systems that have rapidly emerged and have the potential to negatively affect road safety.

New technologies

In recent years, there has been rapid and significant development of numerous technologies. At one extreme, the technology is now available for vehicles to drive safely in traffic independent of human input (though deployment is still some way off). At the other extreme, some quite simple technologies (such as seatbelt wearing detection) could dramatically reduce fatalities if compulsory in vehicles for all seats. Even in countries that have achieved very high rates of seatbelt wearing (95% or higher) through publicity and enforcement campaigns, unbelted drivers are considerably over-represented in fatality statistics. Technology is likely to be the most cost-effective way to target the remainder of unbelted drivers whose lives could be saved.

There has been widespread development in, and introduction of, technologies which are not designed for safety purposes but which could have a direct impact on road safety. Although some may facilitate the driving task (possibly making it easier and thus safer), other technologies (such as mobile phones) can be distracting and have a detrimental effect on safety.

This report attempts to generate support for new technologies that improve safety and raise caution and debate concerning new technologies that may have a detrimental impact on safety. Historically, improvements in road safety have been decided upon using a retroactive approach, based on fatality and injury statistics. This is contrary to the approach used in many other health and safety areas, where measures are put in place to avoid death and injury rather than after a problem has developed. Since many of these technologies are only just being introduced to the market or are still under development, their impacts on fatalities and injuries are not yet known and some of the findings of this report may therefore prove controversial among traditional road safety commentators. Nevertheless, the results are based on the best available knowledge at this time and necessarily take a different approach to evaluation.

While many countries can still significantly improve road safety through traditional technologies, designs and measures, these are presented in other reports (*e.g*. OECD, 2002). The focus of this report is innovation and technologies that have recently been introduced.

Crash types and causal factors

The OECD Working Group on Safety and Technology reconfirmed much of the crash information reported in earlier OECD reports (OECD, 1999 and 2002). Specifically, the primary crash types that result in deaths on the roads in OECD countries are head-on, run-off-the-road, pedestrian and intersection crashes. The primary causal factors of crashes are inappropriate speed, alcohol and fatigue. The report therefore primarily focuses on technologies that target these crash types and causal factors.

Different categories of road users also need to be considered. Technologies that may benefit some road users may not be compatible with others. This report therefore considers the needs of commercial vehicle drivers, pedestrians and two-wheeled vehicle riders. In addition, the rapidly ageing population in OECD countries means that the needs of elderly road users are of prime significance (OECD, 2001). The acceptance and usability of these technologies by all age groups is therefore an important consideration for the technologies discussed. These issues will be addressed in depth in another OECD study (forthcoming, 2004).

Legal and political constraints

A culture of road safety has now developed in some countries where innovation and new measures to further reduce fatalities are encouraged. This is reflected in the safety improvements they have achieved and the ambitious targets they have set. In many more OECD countries, however, new measures often face considerable obstacles in terms of political will and public acceptance.

In certain countries, the national, state/provincial or local legal systems can also be a constraint to deploying road safety technologies. For example, while automated enforcement has the potential to be a very cost-effective method to change driver behaviour and reduce crashes, some jurisdictions (national or local government entities) cannot muster the political support necessary to enact legislation that will allow it to be used. Several other new or emerging technologies that are controversial but beneficial may also require legislative changes that can be complex, time-consuming and require political support, all of which makes progress slow or impossible. This can be further complicated where international legislation or standards are in force, such as in Europe where integration requires many more decisions to be made for all of Europe. Ultimately, legal and political factors can be major inhibitors of technology deployment. This report therefore covers these issues in some detail.

The economics of road safety

Any new safety measure should only be implemented after assessing the costs of its introduction and the benefits that accrue. To that end, this report attempts to estimate the costs of new technologies, although costs for many technologies will decrease markedly as their deployment becomes more widespread. In terms of benefits, putting a value on a human life is controversial and many countries explicitly avoid using monetary values. Nevertheless, a number of studies have been carried out on the cost of road crashes. Examples include a cost of 2.2% of gross domestic product (GDP) in the United States (Blincoe *et al.*, 2002). An Australian study (BTE, 2000) estimated the economic loss resulting from deaths and injuries to be 3.6% of GDP. Fatal crashes represented almost 20% of that cost, while injury crashes amounted to nearly two-thirds of the total cost of road crashes.

In this report, 2% of GDP is used for the cost of road crashes, where benefits are calculated. Most OECD countries do not carry out cost-benefit analysis for road safety measures. Road safety investment is done as a social benefit. However, since investment in road safety is quite considerable and increasing, it is clear that the value of improved safety is considered to be worth this investment and the figure of 2% of GDP is therefore a conservative estimate for most OECD countries.

This report contains five chapters:

- Chapter 2 introduces the features and problems of representative new technologies related to safety. The results from case studies are presented and the effectiveness of these technologies are also described.
- Chapter 3 presents an overview of technologies that do not target road safety but have an impact on safety.
- Chapter 4 evaluates the impact of new technologies on road safety.
- Chapter 5 discusses overarching issues such as human factors, systems safety, legal issues, education and social acceptance issues, data requirements and implementation issues.

References

Blincoe, L., A. Seay, E. Zaloshnja, T. Miller, E. Romano, S. Luchter and R. Spicer (2002), *The Economic Impact of Motor Vehicle Crashes*, NHTSA, Washington, DC. www.nhtsa.dot.gov/people/economic/EconImpact2000/index.htm

Bureau of Transport Economics (BTE) (2000), *Road Crash Costs in Australia,* Report 102, Canberra.

OECD (1999), *Safety Strategies for Rural Roads*, Paris.

OECD (2001), *Ageing and Transport: Mobility Needs and Safety Issues*, Paris.

OECD (2002), *Safety on Roads: What's the Vision?*, Paris

OECD (forthcoming, 2004), *Human Factors of Transport Technology for Elderly Users*, Paris.

Chapter 2

REVIEW OF TECHNOLOGIES FOR ROAD SAFETY

Abstract. This chapter focuses on crash reduction and prevention technologies that are activated while a vehicle is in operation. Systems that minimise damages following a crash are also covered. The majority of these technologies are intelligent transportation system applications (ITS), although a number of new technologies that are effective but strictly speaking not ITS are also presented.

Introduction

Intelligent transportation systems (ITS) include the application of electronic, computer and communication technology to vehicles and roadways to increase safety, reduce congestion, enhance mobility, minimise environmental impact, increase energy efficiency and promote economic productivity for a healthier economy. OECD countries use and evaluate ITS technologies in order to improve transportation safety. Despite barriers to the implementation of several ITS safety technologies, the majority of OECD countries advocate the importance of evaluating the impact of safety technologies and driver information systems to prevent crashes. These systems include autonomous vehicle-based systems, infrastructure-based systems, and co-operative systems. Where relevant, a distinction is made between these types of systems.

Vehicle-based systems

In-vehicle safety technologies primarily include on-board sensors that collect data and on-board units (OBUs) that issue warnings or take partial control of the vehicle. The advantage of these systems is that they can warn the driver of potential dangers or override to some degree the driver's control of the vehicle in attempt to avoid collisions. These benefits are only available to vehicles equipped with such on-board equipment. Some unresolved issues concerning these systems include the need to ensure reliability and establish system standards to avoid driver confusion and potential dangers due to variations in commercially available OBUs. Moreover, it is important to make drivers aware of the extent to which the system is able to reduce danger, in order to avoid excessive reliance on OBUs.

Infrastructure-based systems

Infrastructure-based safety systems are primarily comprised of: (*1*) roadside sensors that collect information and (*2*) roadside equipment that issues warnings and advisories. The advantages of these systems are detection of phenomena that on-board sensors cannot detect, such as weather conditions, obstacles and traffic around curves or in the distance. Variable data can be provided on roadside signs and information can be provided to all potentially affected vehicles in the vicinity. A problem associated with infrastructure-based systems is that the data must be standardised to improve driver understanding of the provided information.

Co-operative systems

Co-operative safety systems utilise both infrastructure-based and vehicle-based systems with communication links between them. The advantage of these systems is that information is received from the infrastructure (*e.g.* speed limits, traffic and road conditions) and provided dynamically at the appropriate time to individual vehicles. Information can also be transmitted in the opposite direction, *i.e.* from vehicle to infrastructure, for example to automatically notify emergency services when a vehicle is in a collision. Such services can only be provided to vehicles that are equipped with OBUs. Digital maps and technologies to pinpoint exact locations are also considered to be co-operative technologies, since safety-related information can be combined with the maps stored in the on-board equipment, and a wider service area can be set as compared with information provided by the infrastructure. Issues particularly related to co-operative systems include: (*1*) the need to maintain a balance between system safety, reliability and cost and (*2*) the standardisation of the human-machine interface (HMI).

This report provides an overview of advanced vehicle-based safety systems, infrastructure-based systems, and co-operative systems that are being evaluated and implemented in OECD countries: speed control systems; driver/vehicle status performance systems; collision avoidance systems; commercial motor vehicle systems; and automated enforcement systems.

Advanced vehicle speed control safety systems

Inappropriate and excessive speed are primary causal factors of traffic crashes in OECD countries (OECD 2001, 1999). In addition, there is overwhelming evidence that the risk of injuries and fatalities increases as a function of pre-crash speed, (Baruya, 1998; Finch *et al.*, 1994; Transportation Research Board, 1998). In addition to preventing a portion of crashes, speed control technology will also decrease the severity of crashes that do occur.

Speed governors

Speed governors, which limit the maximum speed of a vehicle, are required in heavy trucks in the European Union and Australia. Some US trucking companies also use speed limiters, although increasingly sophisticated truck engines enable speeds to be controlled electronically. The primary reasons for using speed governors on heavy vehicles are fuel efficiency, safety, and equipment wear.

Intelligent speed adaptation

Intelligent speed adaptation (ISA) is a co-operative speed control technology. ISA requires accurate information on vehicle locations and speed limits, which can be achieved through a combination of a global positioning system (GPS) and digital road maps. It also requires a link with some or all of the elements of the vehicle's power train: throttle, ignition, fuelling system, gearbox and brakes.

A critical aspect of ISA is the level of intervention provided by the system. An active system intervenes directly to affect the speed of the vehicle through a haptic throttle (the resistance to push the accelerator increases) or a speed limiter making it impossible to drive faster than the posted speed limit. Passive systems rely primarily on auditory or visual advisory outputs that alert the driver of the speed difference. ISA can be categorised as:

- Advisory: the speed limit is displayed for the driver to determine whether or not to comply.
- Driver select: the driver has the ability to switch ISA on and off, so that compliance is voluntary.
- Mandatory: the system does not permit the speed limit to be exceeded at any time.

Another dimension of ISA is related to the way that information on speed limits is gathered and processed.

- Fixed: the vehicle is informed of the posted speed limits.
- Variable: the vehicle is additionally informed of certain locations in the network where a lower speed limit is implemented at locations such as pedestrian crossings or the approach to sharp curves.
- Dynamic: additional, temporary lower speed limits are implemented due to network or weather conditions, to slow traffic in fog, on slippery roads, around major incidents, etc. The more dynamic forms of ISA require real-time data on traffic flow and weather.

Various combinations of these approaches have been used in ISA field tests in Denmark, France, the Netherlands, Sweden, and the United Kingdom. The primary advantage of ISA is that it addresses one of the key causal factors of road unsafety, *i.e*. speeding or inappropriate speed. The results of various field tests show a high level of effectiveness as detailed in Table 2.1.

Possible negative effects of ISA are diminished driver attention and shorter headways. The inability to accelerate beyond the limiting speed to avoid collisions is an initial concern raised by testers of the system, however, the field trials have not shown this to be an added danger. In at least one trial in the Netherlands, drivers without ISA were seen to be more aggressive and initiate more dangerous overtaking manoeuvres when confronted with a mandatory ISA-equipped vehicle.

Driver/vehicle status and performance systems

Driver/vehicle status and performance systems include in-vehicle systems to unobtrusively monitor driver performance and vehicle parameters. In addition, infrastructure-based systems collect and disseminate information to drivers – *e.g.* animal detection systems and dynamic message signing (DMS) – which affect their performance.

Table 2.1. Estimated safety benefits from OECD countries for speed control technologies

	Technology	Country	Project-level crash reductions	System-level crash reductions	Reference
Speed control	Intelligent speed adaptation	United Kingdom (by simulation)	N/A	Advisory system: 18-24% of fatal crashes	Carsten *et al.* (2001)
				Driver select: 19-32% of fatal crashes	
				Mandatory: 37-59% of fatal crashes	
		Netherlands	N/A	15% of injuries and 21% of fatalities	Besseling and van Boxtel (2001)
	Intelligent cruise control	Various	N/A	5.9% all crashes	Elvik *et al.* (1997)
	Speed governors on heavy goods vehicles	Sweden	N/A	2% of all injury crashes	Elvik *et al.* (1997)

Vehicle-based systems

Alcohol detection systems

Internationally, drunk driving is considered to be a crucial road safety issue. An alcohol ignition interlock device is a breath alcohol analyser connected to the ignition of a vehicle, which cannot be started unless the driver passes the unit's breath alcohol tests. Currently, alcohol lock programmes are operating in Canada and the United States and can be a major deterrent to drinking and driving.

Preliminary data from the Quebec interlock programme provide encouraging evidence to suggest that the crash rates of interlock participants are actually lower during the interlock period than before: 60% reduction in the rate of casualty crashes (Dussault and Gendreau, 2000). This effect is also maintained in the six-month period immediately following the removal of the interlock. Even though interlock participants are driving, they appear to be driving more safely and/or less often, and without the impairing effects of alcohol. Further research is necessary to validate what appears to be a general traffic safety benefit associated with participation in an interlock programme (Beirness, 2001). Other OECD countries should consider such programmes to further reduce the influence of drinking and driving on road safety.

Drowsiness detection systems

In-vehicle systems such as brain wave monitors, eye-closure monitors, devices that detect steering variance and lane tracking devices are being evaluated to address adverse driving behaviour due to sleepiness (Dinges, 1995). This technology is currently being examined in physiologic, psychophysiologic and crash prevention domains. Some of these devices alert drivers when indications of sleepiness appear. Controlled trials are needed to evaluate the usefulness of these tools. An inherent deficiency in all types of alerting devices is that many people continue to drive even when they are drowsy and fighting to stay awake. Some safety experts have expressed concern that alerting devices may in fact give drivers a false sense of security, encourage them to drive long after impairment, and inhibit their taking effective behavioural measures to prevent or relieve sleepiness (Lisper *et al.,* 1986; Dinges, 1995; Horne and Reyner, 1995).

Other systems monitor lane departure and irregular movements of the vehicle. These include systems that monitor the lane markers on the road or use gyro sensors to monitor weaving of the vehicle and warn the driver. Experiments have shown that some persons will trust such monitoring systems even when the warnings are intentionally made unreliable, indicating that caution is needed in predicting the safety effects of such systems (Rudin-Brown and Noy, 2002). In the United States, a commercially available lane departure warning device is being tested and evaluated in commercial vehicles. In Japan, a lane-keeping assist system has been demonstrated. The vehicle's position relative to the lane markers is continuously monitored by computer analysis of a video image. When the vehicle strays too close to the lane markers, the system exerts a small torque in the opposite direction that the driver can feel through the steering wheel, and continued deviation produces an audible warning. The system does not function during lane changes if the direction indicators are switched on.

*Event data recorders (*a.k.a. *black boxes, crash recorders)*

Event data recorders (EDRs) have the potential to improve highway safety by increasing the accuracy of crash reconstructions and benefiting researchers, crash investigators and manufacturers with access to EDR data. Crash EDRs record the physical parameters of the vehicle prior to and shortly after an incident or crash. The National Highway Traffic Safety Administration (NHTSA) Truck and Bus Event Data Recorder Working Group listed the top ten data elements for storing in an EDR:

- Longitudinal and lateral acceleration and principal direction of force.
- Location of crash.
- Seatbelt status by seating location.
- Number of occupants and location.
- Pre-crash data.
- Time of crash.
- Rollover data.
- Yaw data.
- Antilock braking system, traction control, and stability control information.
- Air bag data, such as deactivation status, deployment time, stage of deployment, etc.

Although these data are used for post-crash analysis of the collisions, EDRs may also affect crash prevention. In the early 1990s, one European study looked into the effects of EDRs in a large commercial fleet. It concluded that the feedback mechanism (whether or not a driver was confronted with the results of the EDR and was punished in case of abuse of the vehicle) was more important than the type of technology. In a 1998 German study, EDRs in police cars helped the Berlin Police to decrease car damage costs by 25%. Despite potential safety advantages, data ownership, privacy and confidentiality are major institutional obstacles to the use of EDRs and recorded data.

Seatbelt monitoring systems

Seatbelts are recognised as one of the best measures for preventing fatalities in car crashes. Fifty percent of fatalities of unrestrained drivers and passengers could have been prevented if they had been wearing seatbelts according to international studies (OECD, 2002).

Some countries have achieved high wearing rates for drivers and front seat passengers, but even the most aggressive education and enforcement campaigns do not target the final 5-10% of drivers and front seat passengers. In all countries, the wearing rates for rear-seat passengers are much lower.

Given the high rate of driver and passenger error in neglecting to wear seatbelts, there are strong arguments to design vehicles that ensure seatbelts are worn, either through compulsory systems (the vehicle cannot be driven until the seatbelt is fitted) or continuous warning systems. Such systems should target rear-seat passengers as well, as these are the most likely not to be wearing seatbelts.

A recent independent study by the Insurance Institute for Highway Safety in the United States (IIHS, 2002) reports that a new seatbelt reminder system in Ford cars results in a 5% increase in seatbelt usage over traditional systems in older Ford models, and these reminders could reduce 1.7% of all fatalities. The system emits gentle chimes and warning lights over a period of five minutes to encourage seatbelt usage versus traditional reminder systems with alerts that last only four to eight seconds. A 5% increase in seatbelt use in the United States could result in saving about 700 lives per year. A recent Australian study (Fildes *et al.*, 2003) examined the likely costs and benefits of seatbelt reminder systems for a range of design and implementation options. It concluded that the cost-benefit ratios for all configurations were very favourable, and even for the most expensive options the benefits would offset the costs.

Infrastructure-based systems

Animal detection systems

Collisions between animals and vehicles are an on-going problem that is getting worse as development, traffic volumes, and deer populations increase. This problem is widespread throughout North America and results in significant costs in terms of property damage, injuries and deaths. Two types of animal detection systems are currently under development. One system uses a simple beam parallel to the road that initiates flashing warning lights when the beam is broken. One drawback is that there is not a way to verify if an animal actually entering or leaving the roadside broke the beam. As a result, drivers may learn to ignore false warnings. The next generation of technology uses infrared camera detection that detects large animals in a zone and initiates warning flashers on a sign. The advantage of this system is that the flashers should only operate when a large animal is in the zone; however, a system failure may not be evident to the driver and could cause them to be less cautious if they rely on the technology.

Speed feedback indicators

Speed feedback indicators monitor the speed of a vehicle from the roadside and display the actual vehicle speed next to the speed limit on a variable message sign (VMS). Unlike ISA, a speed feedback indicator does not intervene as a vehicle control device; however, it effectively reminds drivers of their vehicle speed.

Weather/road/traffic information display system

Weather/road/traffic information display systems use variable message signs to display various traffic-related information, such as road surface condition, weather and traffic jams, which affect driving performance and increase safety. Some countries regard these signs as being primarily for driver information and traffic management, but other countries also use them for safety messages or to post temporary or advisory speed limits. The non-safety-specific uses of such displays are discussed in Chapter 3.

Evaluation of infrastructure-based systems

Several studies evaluated the effectiveness of infrastructure-based systems. According to Elvik *et al.* (1997), it is estimated that feedback on speed using VMS and other measures can reduce 65% of pedestrian crashes, 41% of injuries, and 16% of rear-end crashes. Project level studies include ATEC/ITS-France (2002), which surveyed various study results in Europe. In the United Kingdom, 28% of the injuries were reduced, 10-30% in Germany and 35% of all crashes in Switzerland.

Similarly, PIARC (2000) surveyed the accident reduction by weather information systems in various countries, and reported an average crash reduction of 30-40%.

Table 2.2. Estimated safety benefits for driver status

	Technology	Country	Project level crash reductions	System level crash reductions	Reference
Other technologies	Variable message signs (for speed regulation and other targets)	Various	N/A	65% pedestrian crashes	Elvik *et al.* (1997)
				41% of all injury crashes	
				16% of rear-end injury crashes	
		United Kingdom (M25)	28% of injury crashes	N/A	ATEC/ITS-France (2002)
		Germany (A8) unusual (foggy) conditions	10-30% property damage only and injury crashes		
		Switzerland (A1)	35% reduction of all crashes		
	Weather monitoring with VMS	Various (Europe)	N/A	30-40%	PIARC (2000)
	Emergency response	Various (Europe)	N/A	7-12% of all crashes	PIARC (2000)
	Seatbelt reminders	United States	N/A	1.7% of all fatalities	IIHS (2002)

Co-operative systems

Automated collision notification (ACN)

Increasing numbers of new vehicles are equipped with systems that automatically contact emergency services when a collision that is severe enough to deploy an air bag occurs. The vehicle location information allows a service centre to contact the appropriate authorities and advise them of the location and nature of the incident. By reducing the time between the occurrence of a collision and notification of emergency service providers, automated collision notification systems can help emergency responders get to the scene faster and reduce the consequences of a crash. Shorter notification times are linked to reduced risk of fatalities and disabilities arising from injuries. In a field operational test in the United States, the average incident notification time was less than one minute with ACN, and three minutes in a fleet of comparison vehicles without ACN. By means of a single button in the vehicle, occupants can also use the system to speak with emergency or information services (Bachman and Preziotti, 2001).

Collision avoidance systems

Collision avoidance systems are preventative, pre-crash measures for improving traffic safety. Collision avoidance systems can be divided into three categories: vehicle-based systems, infrastructure-based systems and co-operative systems.

In-vehicle collision avoidance systems

Two vehicle-based collision avoidance systems are discussed: advanced driver assistance (ADA) already available in some European markets, and vision enhancement systems marketed by manufacturers in the United States.

Advanced driver assistance

Advanced driver assistance (ADA) includes systems to automate or assist all or a portion of the driver's workload. ADA systems provide assistance for dangerous or difficult driving situations. The basis for many ADA systems is adaptive cruise control (ACC) – also referred to as intelligent cruise control – that maintains a vehicle's speed while keeping a safe distance from the vehicle ahead. This technology is marketed primarily as a comfort technology although it has important safety implications (see Chapter 3). ADA improves on ACC technologies by including forward collision avoidance systems and lane departure systems. They are designed to avoid head-on, roadway departure, merging, overtaking and turning collisions. They can also prevent crossing/angle collisions and optimise speed and distance between vehicles, thereby reducing driver workload.

As a separate function, ADA systems can also monitor the status of the vehicle and driver, the road environment and other road users. ADA systems can also provide various levels of assistance, from warnings in risky situations to intervening functions that adjust vehicle speed or position in the longitudinal and/or lateral direction. New ADA systems will be developed and implemented in several countries on a step-by-step basis, with the focus on easing the driver's workload brought about by the increasing complexity of the driving environment.

Vision enhancement

Vision enhancement systems enhance visual input, the most important information that the driver needs in order to manage the road environment. Reduced visibility is an important element accounting for 42% of all traffic collisions. Reduced visibility may be caused by illumination (glare, artificial light, etc.) and weather conditions (setting sun, dust, darkness, rain, sleet, snow, fog, etc.). In-vehicle vision enhancement systems augment the information in the forward field of view and provide this information to the driver. An on-board system utilises infrared radiation to detect pedestrians, animals, buildings on side streets and other vehicles. Rapid progress is being made toward further improvements to this type of system. Future versions may include information from highway infrastructure improvements such as infrared reflective lane-edge markings. Manufacturers are already introducing night vision enhancement products.

Infrastructure collision avoidance systems

This section will introduce two examples of infrastructure-based systems that protect pedestrians and provide information about traffic outside the field of vision.

Pedestrian protection systems

Pedestrians are among the most vulnerable road users. Even before pedestrian protection systems are introduced, measures can be taken such as reducing the number of traffic signals that are unsafe or whose operation is non-standard, appropriately increasing the length of time that pedestrian traffic signals are green, and making sure that drivers strictly observe traffic signals. Technologies designed to prevent collisions involving vehicles and pedestrians include lights embedded in the sidewalk, illuminated push-buttons, dedicated pedestrian traffic signals, and pedestrian sensors that lengthen the duration of the signal to meet the needs of slow-walking pedestrians. These technologies can be beneficial in reducing the number of collisions caused by driver inattention that occur overwhelmingly in urban and semi-urban areas.

Infrastructure-based information-providing systems to compensate for loss of visibility

Infrastructure-based systems are designed to warn of the approach of oncoming vehicles at curves using roadside sensors that detect vehicles. The information is provided to drivers by means of information panels. These systems will develop into infrastructure-vehicle co-operative systems, providing information directly to the vehicle.

Infrastructure-vehicle co-operative collision avoidance systems

Forward danger warning systems

One application of collision avoidance systems is to provide safety information by detecting oncoming vehicles in curves that are outside a driver's field of vision. This is made possible through communication between the road infrastructure and the vehicle. The use of digital maps that store information on the shape of the road enables curves and other potential dangers to be identified in advance, so that speed can be controlled and a safe distance between vehicles can be maintained. The use of road-vehicle co-operative systems to provide safety information adds the benefit of making it possible to determine whether an oncoming vehicle poses the danger of a head-on collision.

In Japan, the R&D approach to the scope within which vehicles can be detected is to primarily use vehicle-based systems. Co-operative systems handle areas that are beyond the range of vehicle-based systems.

Also in Japan, the development of road-vehicle co-operative technologies is actively being pursued. Nevertheless, in light of the characteristics of infrastructure-based technologies and the problem of widespread adoption of vehicle on-board equipment, plans are to begin with infrastructure-based technologies in the deployment of driving safety support technologies.

Intersection collision avoidance

Infrastructure-based intersection collision avoidance systems use roadside sensors, processors and warning devices, roadside-vehicle communication devices, other roadside informational or warning devices and traffic signals to provide driving assistance to motorists. The intersection collision avoidance systems can be classified as either infrastructure-only or as infrastructure-vehicle co-operative. Infrastructure-only systems rely solely on roadside warning displays to communicate with drivers. Co-operative systems communicate information directly to vehicles and drivers. Major advantages of co-operative systems lie in their ability to improve the driver-system interface, and hence to virtually ensure that a warning is received. This could also take advantage of the potential to exert control over the vehicle, at least in situations where the system can be confirmed as reliable and the driver cannot reasonably be expected to take appropriate actions given the imminent hazard and response time available.

Intersection collision avoidance systems warn drivers of potential collisions by monitoring a vehicle's speed and position relative to the intersection, along with the speed and position of other vehicles in the vicinity and by advising the driver of appropriate actions to avoid a right-of-way violation or impending collision. In the United States, a warning system will be tested first through in-vehicle technologies and will be augmented with information from map databases and co-operative communication with the highway infrastructure. Technologies would be tested that sense the position and motion of other vehicles at intersections and determine whether they are slowing, turning, or violating right-of-way laws or traffic control devices.

System evaluation

Examples of the effect of these collision avoidance systems are:

- According to Ferlis (2000), the introduction in the United States of systems to prevent collisions at intersections resulted in a 50% reduction in this type of accident.
- In Japan, although results are only available from the few locations with such systems, infrastructure-based systems designed to provide warnings of vehicles approaching from the opposite direction reduced accidents by 46%, while rear-end collision warning systems reduced accidents by 78%.
- PIARC (2000) reported that rear-end collision prevention systems in the United States reduced accidents by 17%.

These results are summarised in Table 2.3.

Table 2.3. Evaluation of safety benefits of CAS technologies in OECD countries

	Accident	Country	Project level reduction of accidents	System level reduction of accidents	References
Accident avoidance	Collisions at intersections	United States	N/A	50% of collisions at intersections	Ferlis (2000)
	Rear-end collisions	Japan	50–80% of all accidents at the locations in which the system was introduced	N/A	Road Bureau (2001)
	Rear-end collisions	United States	N/A	17%	PIARC (2000)

Box 2.1. Advanced cruise-assist highway systems

Interactive vehicle/infrastructure co-operative systems called advanced cruise-assist highway systems (AHS) are designed to counteract 75% of traffic collisions excluding reckless driving. Japan conducted demonstration tests and has been continuing with this study of safety technologies for priority research and development.

These systems send information determined by the infrastructure to vehicles in real time, using road-vehicle communications to transmit data on forward obstacles, crossing vehicles, road position and road conditions.

Japan has been developing AHS and selected seven devices that are effective against traffic collisions: lane departure warning, collision avoidance at crossing and forward obstacles, prevention of overshooting on curves, right-turn collision avoidance, pedestrian warning and road surface monitoring.

Demonstration systems have appeared and AHS tests including on-road testing were carried out in 2002.

Commercial motor vehicles

Commercial motor vehicles include large trucks (heavy goods vehicles) and buses. Due to their size, longer stopping distance and cargo that may include hazardous materials, crashes involving large trucks tend to be severe. Also, many trucking operations require long-haul trips involving significantly longer driving time than average passenger vehicle trips. While numerous factors contribute to commercial motor vehicle crashes, both non-commercial and commercial vehicle driver error (*e.g.* excessive speed and illegal or unsafe manoeuvres such as failing to yield right of way, tailgating, running red lights and incorrect overtaking) is generally cited as the principle factor in these crashes, with inattention and drowsiness being major contributing factors.

International measures to increase truck and bus safety include: separation of heavy traffic from other traffic, rerouting of heavy vehicle traffic around urban areas, mandatory use of seatbelts, prohibiting overtaking, weigh-in-motion technology, and new logistics for traffic and goods distribution. Several countries are testing, evaluating and implementing the following technologies in commercial motor vehicles: speed limiters; digital tachographs; front, rear and side protection to protect other road users; collision avoidance systems; adaptive cruise control; anti-drowsiness systems; rollover stability and control technology; lane tracking technology; electronic brakes for stability and improved stopping; fatigue detection and warning technology; and in-vehicle recorders to record driving performance data as a means to potentially reduce the numbers of crashes.

Vehicle and cargo tracking systems are also in wide use, which has safety implications in addition to enhancing logistics and security. Hazardous material transportation management systems are widely used to ensure that pre-registered routes are observed and to enable swift response to incidents. Also, commercial vehicle operation technologies such as electronic credential checking, weigh-in-motion and vehicle-to-roadside communications improve logistics and contribute to safe operations by generally allowing drivers with proper documentation to have their vehicles cleared without stopping at weigh stations or ports of entry.

In the United States, the commercial motor vehicle programme consists of initiatives aimed at: deploying life-saving, intelligent vehicle safety technologies; enforcing regulations relevant to carriers and drivers; improving occupant protection and safety by working with interagency groups and industry to identify, evaluate, and disseminate information on new innovative commercial motor vehicle concepts and designs; and supporting the development of new policies and standards to promote the deployment of new safety and security enhancing vehicle technologies.

Automated enforcement

Through automated enforcement, ITS can be used to monitor and enforce traffic control through detection of traffic violations on roadways and at intersections. A significant effect of automated-enforcement systems is prevention. When automated enforcement measures are in place, people tend to act more safely. Advantages of automated enforcement include: reduction in collisions, enhanced safety through deterrence, positive influence without excessive penalty, and more efficient deployment of police officers. Current issues surrounding the implementation of red light cameras involve: invasion of privacy, lack of police involvement, profit motives, court decisions, and incentives to issue more citations.

Automated speed enforcement

Automated speed enforcement technologies, particularly photo radar, offer an efficient means of substantially increasing the intensity of speed limit enforcement and deterring speeding. Photo radar is widely used for speed control in Europe and Australia, with a reduction in excessive speeding and related reductions in casualty crash frequency. Most automated speed enforcement systems incorporate both radar technology to determine vehicle speed and supplementary photographic equipment to record the speed and document information on the vehicle. A major benefit of these systems is reduced driving speeds and improved safety; however, their success depends on how they are introduced. The use of speed cameras at known accident or high-risk locations can be very effective and generate local support. Random deployment of speed camera enforcement has the potential to achieve substantial crash reductions across a wide area by providing general deterrence. Public relations programmes are important to ensure community acceptance.

Average speed driven over a stretch of road can also be measured. These can either be over shorter distances (*e.g.* five kilometres) or in the case of toll roads over long stretches of motorway. An advantage of these systems is that the effect on speed is not temporary as in case of single cameras. In addition, drivers judge this system as being fairer – a temporary increase in speed while overtaking can be compensated for.

Red light evasion detection

Red light cameras are widely used in several countries to enforce traffic signals at intersections, since running red light offences are the principal cause of major crashes in urban areas. For example, in the United States, running red lights accounted for some 200 000 collisions per year, causing approximately 150 000 injuries and 1 100 deaths. Along with speed cameras, red light cameras are the most common type of automated enforcement in several countries. Typically, red light evasion detection systems consist of a single camera in front of the traffic signal, facing the direction of travel, which takes two photographs at fixed intervals of the rear of the vehicle running a red light, which includes the red traffic signal. The camera is activated by the car passing over inductive loops while the signal is red.

Railway level crossing

Every year, collisions at level crossings not only cause death of or injury to many thousands of road users and railway passengers, but also impose a heavy financial burden in terms of interruption of railway and road services and damage to railway and road vehicles and property. Camera enforcement of railway level crossings normally occurs at half barrier and open crossing types of railway crossings. It involves the photographing of any vehicle passing a level crossing once the barriers have started to descend across the roadway, or of any vehicle which weaves around the barriers. These systems typically use inductive loop detectors.

Railway level crossing enforcement is unique in terms of traffic enforcement because the roadway is interconnected with the railway system. The railway signal control which operates the crossing requires close co-operation between the highway and railway authorities. Similar to red light running applications, automated enforcement at rail crossings is valuable because police cannot safely pursue an offender through a crossing.

In the United States, the Los Angeles Long Beach Blue Line successfully introduced automated enforcement at 17 crossings, which together with a publicity campaign considerably reduced the number of violations and collisions. At one crossing, it reduced violations from one per hour to one per 12 hours, a 92% reduction. From 1995 to 1999, approximately 9 000 citations were issued to drivers violating the crossing barriers. (ITE, 1999).

System evaluation and issues

Several studies have evaluated the effectiveness of these automated enforcement systems and are summarised in Table 2.4.

- CERTU (2001) reports that speed cameras have significantly reduced crashes in Australia. For example, in New South Wales, a 22% reduction in crashes was reported; in Victoria, reductions of 30% in crashes on urban trunk roads and 34% in fatal collisions were achieved. PIARC (2000) has also surveyed such studies, and summarised that 50% of all crashes may be reduced by such systems. In the United Kingdom, 35% reductions in fatalities and injuries were observed at camera sites, with a 56% reduction in pedestrian fatalities and injuries (Department of Transport, 2003).

- The effectiveness of red light cameras has been demonstrated in many countries. Flannery and Maccubbin (2002) report a 26% reduction in crashes caused by running red lights, and IIHS (2001) reports a 29% reduction in injury crashes at Oxnard, California. CERTU (2001) and Retting *et al.* (2002) also report reduction of varying degrees in injury crashes in Australia and Singapore. However, some studies have found that a range of factors may influence intersection crashes that may moderate the effectiveness of red light cameras (Andreassen, 1995, Mann *et al.*, 1994). A synthesis report of red light camera research (NCHRP, 2003) shows that, although not conclusive, red light running camera systems improve the overall safety of intersections where they are used. Conclusive findings are not possible because nearly every study and crash analysis reviewed had some experimental design or analysis flaw. The studies usually show a reduction of adjacent approach crashes, and, in some situations, rear-end crashes increase, although to a lesser extent.

Automated enforcement would require new legislation in a number of countries, which can be a severe barrier. However, the proven effectiveness in other countries should encourage policy makers to implement the necessary reforms.

Conclusion

In conclusion, OECD countries are testing, evaluating and implementing ITS safety technology to reduce collisions and improve road safety. In-vehicle systems, infrastructure-based systems, and co-operative systems have shown promise in preventing collisions and minimising damages following collisions.

Advances in information technologies have fostered the development of sensing technologies for determining potential danger and pinpointing vehicle location, in addition to wireless communication and digital road map technologies. These technical advances have made it possible to create new traffic safety measures that provide detailed information in real time to meet the needs of individual drivers. Examples of these technical advances include: (*1*) advance warning and rapid detection of changes in traffic status relayed through infrastructure-based technology, in-vehicle technology and co-operative vehicle-infrastructure technology, and (*2*) optimal dynamic information, warnings and driving support to individual vehicles and road users.

This overview has shown that many different technologies are becoming available. A number of these technologies tackle similar problems, with varying effectiveness. Chapter 4 provides an evaluation of these technologies.

The pace of development is fast and further advances can be expected as vehicle fleets are renewed. Co-operative systems will be expanded to enable signals and information to be sent between vehicles in the same traffic. In most cases ITS technologies will be implemented through governments and vehicle manufacturers. A number of issues will have to be addressed to ensure maximum benefits are achieved. These issues are dealt with in Chapter 5.

Table 2.4. Estimated safety benefits from OECD countries for automated enforcement technologies

	Technology	Country	Project-level crash reductions	System-level crash reductions	Reference
Automated enforcement	Speed cameras	Various (Europe)	N/A	50% all crashes	PIARC (2000)
		Australia	N/A	22% in New South Wales	CERTU (2001)
				30% all crashes on urban arterials in Victoria	
				34% reduction in fatal crashes in Queensland	
		United Kingdom	35% reduction in deaths or seriously injuries. 56% reduction in pedestrians killed or seriously injured at camera sites		Department of Transport (2003)
	Red light cameras	United States	N/A	26% of RLR crashes	Flannery and Maccubbin (2002)
			29% of injury crashes in Oxnard, California	N/A	IIHS (2001)
		Australia	10.4% of fatalities and 24% of injury crashes	N/A	CERTU (2001)
			46% of injury crashes in Queensland	N/A	Retting *et al.* (2002)
			20% of injury crashes in Adelaide	N/A	
			7% of injury crashes in Victoria	N/A	
			26% of injury crashes in New South Wales	N/A	
		Singapore	9% of injury crashes		

References

ATEC/ITS-France *(Association pour le transport, l'environnement et la circulation/* Intelligent Transport Systems-France*)* (2002), *Road Safety and Telematics*, Paris.

Andreassen, D. (1995), "A Long-Term Study of Red Light Cameras and Accidents", Report ARR 261, ARRB, Victoria, Australia.

Bachman, L.R. and G. R. Preziotti (2001), "Automated Collision Notification (ACN) Field Operational Test (FOT) Evaluation Report", DOT HS 809 304, National Highway Traffic Safety Administration, Washington, DC.

Baruya, A. (1998), "Speed-Accident Relationship on Different Kinds of European Roads", http://www.vtt.fi/rte/projects/yki6/master/d7_r114.pdf

Beirness, D.J. (2001), *Best Practices for Alcohol Interlock Programs,* Traffic Injury Research Foundation, Ottawa.

Besseling, H. and A. van Boxtel, (2001), *Intelligent Speed Adaptation: Results of the Dutch ISA Tilburg Trial*, Ministry of Transport, Directorate General of Public Works and Water Management, Transport Research Center, Rotterdam.

Carsten, O., M. Fowkes and F. Tate (2001), *Implementing Intelligent Speed Adaptation in the United Kingdom: Recommendations of the EVSC Project*, Institute of Transport Studies, University of Leeds, Leeds.

CERTU and ISIS (2001), *Automatic Traffic Enforcement Systems Study,* Synthesis Report on International Practice, ISIS, Lyons, France.

Department of Transport (United Kingdom) (2003), "A Cost Recovery System for Speed and Red Light Cameras: Two-Year Pilot Evaluation", Road Safety Division Research Paper, 11 February, London.

Dinges, D.F. (1995), "An Overview of Sleepiness and Accidents", *Journal of Sleep Research*, Vol. 4, Supp. 2, pp. 23-29.

Dussault, C. and M. Gendreau (2000), "Alcohol Ignition Interlock: One Year's Experience in Quebec" in *Proceedings of the Fifteenth International Conference on Alcohol, Drugs, and Traffic Safety (ICADTS)* (CD Paper 905), Stockholm.

Elvik, R., A. B. Mysen and T. Vaa (1997), *The Traffic Safety Handbook, Third Edition*, The Institute of Transport Economics, Oslo.

Ferlis, R. (2000), "Intelligent Transportation Systems, Analysis of Infrastructure-Based System Concepts, Intersection Collision Avoidance Problem Area", Internal Paper, October 30, Federal Highway Administration, Washington, DC.

Fildes, B., M. Fitzharris, S. Koppel and P. Vulcan (2003), *Benefits of Seatbelt Reminder Systems*, Report CR 211, Australian Transport Safety Bureau, Canberra, Australia.

Finch, D.J., P. Kompfner, C.R. Lockwood and G. Maycock (1994), *Speed, Speed Limits and Accidents,* TRL, Crowthorne.

Flannery, A. and R. Maccubbin (2002), *Using Meta Analysis Techniques to Assess the Safety Effect of Red Light Running Cameras*, Department of Transportation, Washington, DC. http://www.itsdocs.fhwa.dot.gov//JPODOCS/REPTS_TE//13623.html

Horne, J. and L. Reyner (1995), "Driver Sleepiness", *Journal of Sleep Research*, Vol. 4, Supp. 2, pp. 23-29.

Insurance Institute for Highway Safety (IIHS) (2002), "The Effectiveness of the Belt-Minder System in Increasing Seatbelt Use", Status Report, Vol. 37, No. 2, 9 February, Arlington, Virginia.

Insurance Institute for Highway Safety (IIHS) (2001), "Red Light Camera Enforcement Reduces Crashes, Not Just Violations", Status Report, Vol. 36, No. 4, 28 April, Arlington, Virginia.

Intelligent Vehicle Initiative (IVI), www.its.dot.gov/ivi/ivi.htm

Institute of Transportation Engineers (ITE) (1999), *Automated Enforcement in Transportation,* ITE, Washington, DC.

Lisper, H.O., H. Laurell and J. Van Loon (1986), "Relation Between Time to Falling Asleep Behind the Wheel on a Closed Track and Changes in Subsidiary Reaction Time During Prolonged Driving on a Motorway", *Ergonomics*, Vol. 29 (3), pp. 445-453.

Mann, T, S. Brown and C. Coxon (1994), *"Evaluation of the Effects of Installing Red Light Cameras at Selected Adelaide Intersections",* Report 7/94, Office of Road Safety, Adelaide, Australia.

NCHRP (National Cooperative Highway Research Program) (2003), *Impact of Red Light Camera Enforcement on Crash Experience - A Synthesis of Highway Practice,* Synthesis 310 Transportation Research Board, Washington, DC. http://gulliver.trb.org/publications/nchrp/nchrp_syn_310.pdf

PIARC (2000), *ITS Handbook 2000,* Committee on Intelligent Transport, PIARC, Paris.

Retting, R., S. Ferguson and A. Shalom Hakkert (2002), *Effects of Red Light Cameras on Violations and Crashes: A Review of the International Literature*, Insurance Institute for Highway Safety, Arlington, Virginia.

Road Bureau (2001), *Benefits from ITS Deployment in Japan*, Ministry of Land, Infrastructure and Transport, Japan

Rudin-Brown, C. and I. Noy (2002), *Investigation of Behavioral Adaptation to Lane Departure Warnings*, Transportation Research Record 1803, Transportation Research Board, Washington, DC.

TRB (Transportation Research Board) (1998), *Managing Speed*, Special Report 254, National Research Council, Washington, DC.

Chapter 3

REVIEW OF TECHNOLOGIES NOT TARGETING ROAD SAFETY

Abstract. This chapter reviews non safety-related technologies that are used in road transport and have an impact on road safety.

Introduction

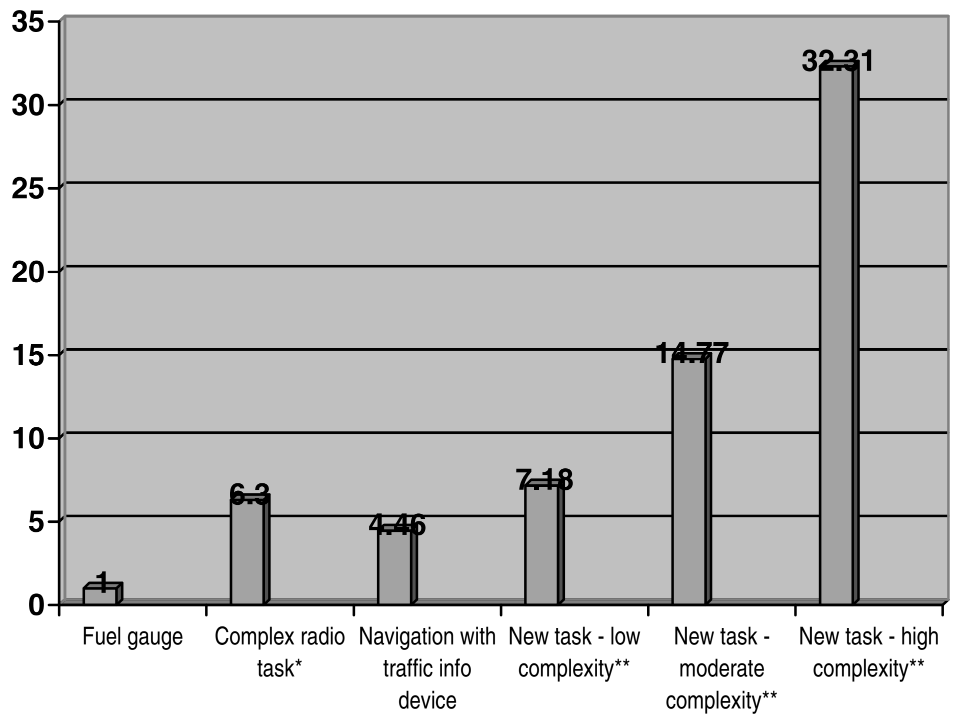
There are many technological advances occurring today that can affect road safety. Kantowitz and Moyer classify driver information inside the vehicle as follows: *1*) safety and collision avoidance; *2*) advanced traveller information systems; and *3*) convenience and entertainment systems. This chapter deals with technologies that can be grouped under items 2 and 3. These technologies target both driving-related technologies – *i.e.* in-vehicle navigation systems, commercial vehicle diagnostics/prognostics, adaptive cruise control – and technologies that make no contribution to the driving task – *i.e.* cell phones, televisions, facsimile machines, laptops and PDAs.

As we move closer to the generation of "e-cars," "cyber-cars" and "network vehicles" (Crawford *et al.*, 2001), the impacts on safety will become more obvious than they are today especially when one considers that the global market for in-vehicle devices – *e.g.* information and entertainment – will exceed USD 40 billion by 2010 (Sundeen, 2001).

Dingus (2000) has considered the introduction of new tasks associated with new technologies. Figure 3.1 illustrates his concept. On the left side of the figure is a traditional task (viewing a fuel gauge) and, moving to the right, there are newer, more complex tasks associated with new technologies. He suggests that some of these new tasks require substantial visual and higher order cognitive processing than traditional tasks.

Referring to Figure 3.1, Dingus suggests that a fuel gauge requires some kind of visual demand with little or no cognitive processing. As you move right on the chart, you might consider your speedometer. If you look at it and see that you are going too fast, you lift your foot off the accelerator and perhaps apply the brake. Further to the right and considering newer tasks, you might have visual or auditory input or the combination of the two. In these instances you can have substantial cognitive processing and you can have a demand for both a manual and a speech response. This can interfere with driving and potentially compromise safety.

Figure 3.1. Estimated relative crash rate



* Such as inserting a CD or manual tuning. ** Typical values seen across many tests. Does not represent a particular device or task.

Source: Dingus (2000).

In a survey of OECD countries carried out during the development of this report, very few studies related to the safety impacts of these or other technologies were reported. The survey did point out that a large concern in most OECD countries is the use of cell phones while driving. There were also mixed responses to the effects of in-vehicle navigation and information systems.

Driving-related technologies

This section looks at technologies designed primarily for driver comfort, transport efficiency and environmental objectives. They include driver information technologies, adaptive cruise control, infrastructure-based traffic control and demand management systems. In terms of their intended effects, these technologies are mainly associated with reductions in driver workload, travel times, traffic congestion, energy consumption and vehicle emissions. However, because they can influence exposure and behavioural patterns, they also have the potential to affect road safety outcomes. Critical situations can also which can be linked to the usage of these systems (Pauzié, 2001).

Driver information systems

The expected expansion of route navigation and other on-board equipment is very high. It is predicted (Shelton, 2000) that all new vehicles will have some form of on-board computer that is accessible by the driver by 2010. Among these systems, navigation or route guidance systems constitute one of the more mature in-vehicle ITS technologies and there are now numerous products commercially available. They assist drivers in selecting the shortest or fastest route to a chosen destination. They range from simple directory systems that provide a set of navigation instructions at the start of a trip, to dynamic route guidance systems incorporating real-time traffic information. Vehicle and cargo tracking systems are also in widespread use among commercial vehicles, primarily to enhance logistics and security. Hazardous material transportation management systems are used widely to ensure that pre-registered routes are observed and to enable swift response to incidents.

A core feature of these systems is the combination of computerised street maps with some means of generating verbal or graphical advice about the most efficient travel route. Most are also capable of tracking the vehicle position in order to provide the driver with continuous navigational assistance. Vehicle tracking systems adopt one of three basic methods:

- Autonomous navigation systems rely on dead reckoning techniques to estimate distance and direction travelled, without feedback from external positioning aids.
- Radio navigation systems use satellites to track the position of the vehicle, often in combination with dead reckoning processes – the global positioning satellite (GPS) system is the most common.
- Proximity beacon systems use land-based short-range transmitters to periodically update the position of a vehicle.

GPS-based systems are becoming increasingly common and are now widely available in new and rental cars throughout Europe, North America, Japan and Australia.

NHTSA (1995) discusses the difficulties of assessing the safety effects of these technologies. Specifically, it is relatively simple to determine how much more time – *i.e.* distraction time – it takes a person to enter a destination into a route navigation system, but it is extremely difficult to estimate the number of crashes that can be attributed to this action. In a separate study of a specific route navigation system in Florida, Inman *et al.* (1996) found no adverse safety effects. When a network-wide evaluation (equipped and unequipped vehicles) was performed in this study, an overall reduction of crash risk of up to 4% was predicted for motorists using the system. The system in question could not be programmed while the vehicle was in motion. In another study on the same system, Inman *et al.* reported that while users were no more likely to be involved in near misses than non-users, users of the system were more likely to report that they had contributed to the close call.

Another study (Tijerina *et al.*, 1998) carried out on a test track found that the distraction effects of visual-manual destination entries while the vehicle was in motion were greater than those found for radio tuning and cell phone dialling. Distractions associated with voice-activated systems were equivalent to cell phone dialling and radio tuning.

A separate study (McKeever, 1998) found an overall 1% reduction in specific fatal and injury crash types for people using navigation devices. Elvik *et al.* (1997) reported on two studies targeting route guidance systems. One study found that dynamic route guidance would not affect the number of crashes, but that it would reduce crash costs by 1.5%. The other study showed that route guidance that provided the shortest journey time often resulted in a higher number of crashes because the traffic is spread evenly throughout the network, including at higher conflict areas such as intersections.

The United States Department of Transportation (2001) reports that simulation modelling predicts that access to pre-trip traveller information systems can reduce user crash risk by as much as 8.5% in the event of a major freeway incident. They go on to report that users of *en route* information, such as that provided by in-vehicle navigation systems, would experience an 11% crash risk reduction in a similar incident scenario.

Tijerina *et al.* conclude that the prospect of predicting the number of crashes that might arise with the use of a particular ITS technology – *i.e.* in-vehicle information and telecommunications systems – is poor. They go on to say that iterative safety evaluation is necessary throughout the life cycle of the product.

The National Police Agency of Japan (1998) reported substantial increases in fatal crashes and injuries after the initial introduction of vehicle navigation systems; however, fatalities and injuries quickly reverted to the pre-1997 figure after the introduction of an appropriate regulation in late 1999. Also, a survey conducted by the Tokyo branch of the Japanese Automobile Foundation in October 2001 showed that car navigation systems enhance perceived safety and confidence by providing better information.

Look and Abdulhai (2000) compared dynamic route guidance systems (DRG) with safety-enhanced route guidance systems (SRG) using a hypothetical transportation network to measure travel time savings, throughput and vehicle crashes. The DRG application enabled familiar/informed drivers to receive real-time traffic information and choose routes with the least travel time. The SRG application provided familiar/informed drivers with turning decision information every five minutes and enabled them to choose routes with minimal accident risk. With DRG, they found a 15.5% increase in crashes at a market penetration of 60%. With SRG, they saw an initial increase (4%) in crashes, but with higher market penetration the SRG system was able to reduce crashes by an average of 10%.

The European Commission (2000) examined several projects using in-vehicle navigation devices. The CLEOPATRA project in Turin, Italy demonstrated positive time savings and customer satisfaction. On the safety side, however, 20% of the test drivers in Rotterdam expressed concern over being distracted from the driving task.

Regan *et al.* (2001) reported that route guidance systems appear to reduce cognitive workload and enable drivers to devote more attention to risk perception and vehicle control. Studies cited in this report found that:

- Drivers using a paper map for guidance showed a significantly greater number of dysfunctions in driving control relative to drivers using the "turn-by-turn" CARiN system, both in terms of traffic violations and observed unsafe driving behaviours (Forzy, 1999).
- Drivers using a paper map were involved in more near-crash incidents than drivers using route guidance systems (Inman *et al.*, 1996).

In theory, route guidance systems can affect safety outcomes by influencing general traffic exposure patterns, although the net impact of these influences is difficult to predict. On one hand, they may lower general risk exposure by reducing the amount of unnecessary travel; on the other hand, they may encourage motorists to take more trips in unfamiliar areas.

An issue highlighted by ETSC (1999) is the potential for navigation systems to divert motorists to routes with different inherent relative risks. Quantitative studies have shown very small crash reductions associated with route guidance systems, but a risk of more crashes if route diversions from motorways are frequent (FHWA, 1997; Elvik *et al.*, 1997; Perrett and Stevens, 1996; cited in ETSC, 1999).

Ultimately, there has been little direct evaluation of the effects on road crashes. However, as prices continue to fall and the technologies become more prevalent in vehicles, it is likely that the amount of usage will increase and the amount of time that drivers spend in a distracted state will increase. This increased exposure may lead to an increase in crashes. Clearly, more detailed data collection of near misses as well as actual crash information is needed to adjust appropriately in the future.

Concerns are often raised about the potential of these technologies to distract drivers from their normal driving task, highlighting the importance of a well-designed human machine interface. It has been suggested for example (ETSC, 1999), that in-vehicle navigation systems:

- Should not permit the use of map displays while driving.
- Should issue turn-by-turn instructions during the trip.
- Should be based on complete and up-to-date information to avoid driver confusion.

Cairney and Green (1999) and Regan *et al.* (2001) have also pointed to the importance of heads-up displays and non-visual modality to minimise the need to look away from the road.

Forms of driver information systems other than navigational systems are designed to provide motorists with real-time information about the road and traffic environment. Transmitted information commonly includes up-to-date advice about traffic congestion, road works, alternative routes, weather conditions, accidents and other incidents. Delivery systems may be limited to external information displays (variable message signs), but more advanced systems involve direct-to-vehicle communication using radio broadcast technologies.

Among the latter, traffic message channel (TMC) services are becoming widely available throughout Europe and North America. These systems transmit silent data as RDS (radio data system) signals within normal FM radio programmes. In-vehicle receivers, typically advanced radio or navigation systems, decode the information and present it in the motorist’s preferred language via loudspeakers or an on-screen display.

Roadside devices are part of the system used to provide information to the driver, along with in-vehicle and vehicle infrastructure co-operative technologies. Roadside devices that contribute to advanced traveller information systems are:

- Variable message signs providing information such as weather, speed, incidents and available routes, etc.
- Incident detection systems.
- On-coming vehicle warning and rear-end collision warning.

- Weather management systems, including sensors which can detect weather conditions, accurate weather predicting software and warning devices such as VMS or highway advisory radio.

Road surface condition and road construction/traffic warning systems are infrastructure-based sensors can detect wet or icy road surfaces which necessitate lower travel speeds. Together with advance warnings of construction zones or major collision detours entered in the system by road authorities and emergency services, this information can be relayed to vehicles and presented to drivers by visual and audible warnings several minutes before they would arrive at the pertinent location. Advance warnings will allow drivers to select alternative routes and avoid abrupt speed changes that can lead to multiple vehicle collisions.

These systems, like the navigational systems, are mainly intended to help motorists avoid travel delays. They therefore have the potential to affect safety outcomes by influencing general exposure patterns. There is little evaluation data available. However, clear safety effects have been demonstrated for systems that warn drivers of specific high-risk conditions. ETSC (1999) and Cairney and Green (1999) cite various studies showing safety benefits, including reduced mean speeds, linked to weather advisory systems.

Adaptive cruise control systems

Adaptive cruise control systems extend the speed management capability of conventional cruise control systems by incorporating a headway maintenance function. They enable the pre-set cruise speed of a vehicle to be automatically reduced in order to maintain a minimum time or distance headway to the preceding vehicle. Typical systems incorporate radar-based or LIDAR (light detection and ranging)-based sensors to detect forward objects, as well as curve detection sensors to ensure the vehicle ahead is in the same lane. Data from these components are processed and linked to the vehicle's engine management and braking systems. Currently, systems available from a variety of vehicle manufacturers allow up to about 0.3g[*] braking force. This is equivalent to fairly hard braking in a non-emergency situation. The technology is therefore developing to a level that is becoming more consistent with collision avoidance rather than cruise control alone. However, if the system allows drivers to set target following distances (time gaps) much shorter than the response capabilities of the system (as has happened with some European vehicles), there are potential safety disbenefits. Forward collision warning systems with adaptive cruise control are already being evaluated and implemented as safety technologies in commercial vehicles.

It is generally recognised that adaptive cruise control systems were developed primarily to enhance driver comfort and are not designed to respond to emergency or critical braking situations. In theory, however, the automatic speed reduction capability of these systems could lead to some lowering of crash risk or crash severity. Regan *et al.* (2001) cited desktop research suggesting that rear-end crashes could be reduced by an estimated 29% if drivers used these systems at speeds of 48 km/h and above. Simulation studies have raised concerns about negative behavioural adaptation such as higher average speeds and smaller headway times.

Adaptive cruise control systems, like the familiar fixed-speed cruise control systems, automatically deactivate and return control to the driver at speeds below about 40 km/h or

[*] $g = 9.81 m/s^2$.

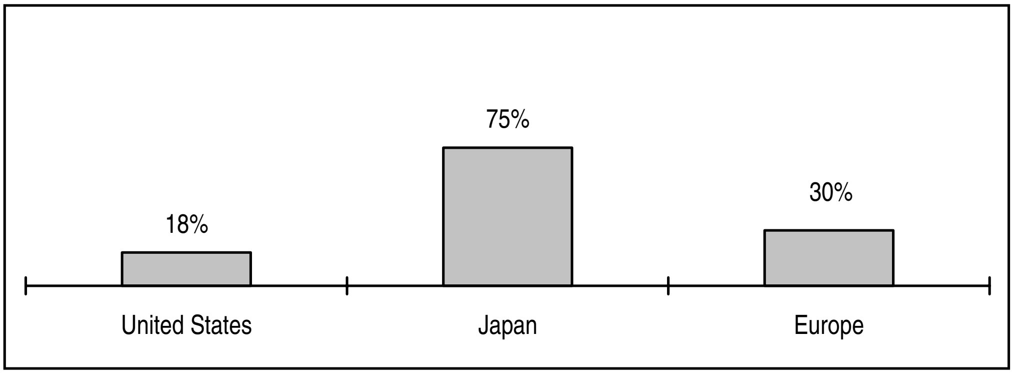
if the driver applies the brakes at any speed. "Stop and go" adaptive cruise control systems have been demonstrated to brake the vehicle to a stop and accelerate it again in response to the preceding vehicle's movements, without driver intervention. The behavioural adaptation effects of reducing or removing the driver's involvement in controlling the vehicle's linear motion need to be closely evaluated.

Traffic management systems

Traffic management systems encompass a range of detection and signalling technologies to regulate the flow of vehicles on urban roads and freeways.

- *Co-ordinated traffic signal control* refers to the use of synchronised traffic signals to harmonise vehicle movement in a given area. Simple control systems use pre-set signal timings based on historical data. More advanced systems, such as the Australian developed SCATS and British SCOOT, incorporate traffic response technologies. Figure 3.2 shows the safety benefits of traffic signal co-ordination systems in various parts of the world. These examples clearly show the potential for technologies to make a significant positive difference on the road safety situation.

Figure 3.2. Crash reduction by introducing advanced signal control system



Note: The Japanese figure shows the effect of such a system where there had previously been no signals.
Source: PIARC, 2000.

- Better protected left-turn phasing. Although protected left-turn phases have long been used in traffic signal programming, the main application has been to optimise traffic flow. The increasing attention on safety may bring up deeper research on protected left-turn phasing to address safety needs.
- Ramp metering is the particular use of signals at freeway on-ramps to optimise the rate of freeway traffic flow and minimise congestion. Again, the metering rate in these systems may be fixed or dynamic.
- Incident management systems enable the rapid detection of and response to accidents, breakdowns and other incidents. Once an incident is detected via camera images or induction loops, emergency vehicles respond and can clear the problem quickly and efficiently with minimal delays. At the same time, variable message signs, radio and other media can be used to direct traffic onto alternative routes.

There is potential for traffic management systems to achieve significant safety benefits by reducing the level of traffic conflict. However the overall effects will depend to a large extent on the level of systems integration and the criteria for optimisation. Evaluation evidence reviewed by ETSC (1999) suggests the following:

- Implementation of basic traffic signals can reduce serious junction crashes by 15% to 30%, but the additional benefits of co-ordinated systems are less clear. They may reduce rear-end crashes by decreasing the number of stops, but may also increase the number of serious crashes by enabling faster speeds through junctions.
- Ramp control can lead to motorway crash reductions of 10% to 15%.
- Incident management systems have been found to reduce the occurrence of secondary collisions by 28%.
- Modelling has shown that network optimisation could reduce collisions by 12% to 30% while increasing travel time by 10% to 15% in a congested network.

Demand management systems

Demand management strategies aim to lower levels of traffic congestion by modifying travel patterns and modal preferences. Measures in this category can affect transport demand by imposing physical restrictions or financial incentives, or by improving the availability of relevant travel information.

- *Access control* involves the use of electronic systems to restrict vehicle entry to a town centre or other defined area. Access can be limited to particular vehicle types and times of day, controlled through the use of electronic surveillance systems or code operated barriers.
- *Electronic road pricing* or *congestion pricing* systems adopt market-based strategies to shift peak period trips to less congested times or routes, or to achieve overall reductions in traffic volume (for example by encouraging car sharing). They also feature in "user pay" schemes to help finance more efficient road infrastructure, such as motorways, tunnels and bridges. Traditional motorway tolling systems commonly adopt simple fee per distance formulae. However, more comprehensive pricing schemes are technically feasible using GPS and other new technologies. Such schemes could factor in a range of variables, such as location, time of day, vehicle type and distance travelled.
- *Demand reduction* measures can directly affect exposure levels by reducing the dependence on car travel. These can be grouped into two broad categories: those encouraging a modal shift to alternative forms of transport (typically public transport) and those fostering social or working arrangements that circumvent physical transport altogether (such as telecommuting). New communication technologies can be expected to play a major role in supporting these strategies.

Demand management systems have obvious potential to influence safety outcomes by changing exposure patterns, but evaluation data remains very limited in this area. Furthermore, apart from measures that have a general exposure reduction effect, the likely direction of net safety impacts is open to conjecture. For example, while road pricing schemes might facilitate investment in higher standard road infrastructure, there is evidence that road tolls can divert some traffic to less safe routes.

Non-driving task technologies

The items described in Chapter 2, whether they are collision avoidance systems or road monitoring systems, have been developed in order to increase the safety in road traffic. Other items as described in this chapter, such as navigation systems or driver information systems, have been designed to make road traffic easier in one way or another. The items which are described in the remainder of this chapter, such as PCs or mobile phones, have been designed for other purposes. There is currently an increasing tendency to also use such devices in vehicles, and hence they may have an impact on the road accident situation.

Classification of technologies

The technologies/functions and devices described in this section are:

- Radios, cassette/CD players.
- Cell phones (GSM/SMS/WAP).
- Driving computers.
- Laptop PCs.
- Printers, faxes, etc.
- PDAs (personal digital assistants; handheld/pocket PCs).
- Infotainment.

Description of the different technologies and evaluation of their impact on traffic safety

Criteria for evaluation of different technologies

Evaluation of the different technologies should be based on a set of criteria covering the qualities of the device and services provided, the efficiency and user-friendliness, and how they influence the behaviour and attention of drivers. Accident analysis (Wierville and Tijerina, 1996) shows that the risk of using in-vehicle technologies are related to *where* the information is located, *how often* the information is focused, *how long* the interaction or focus on the device is, *how impending,* or *obtrusive* the information is as well as *user experience* with the interface.

The new recommendations to the EU commission on safe and efficient in-vehicle information and communication systems (EC, 2000) take into account to some extent the risk factors mentioned above in the principles for in-vehicle human machine interface (HMI). The principles focus on overall design, installation, information presentation, interaction with displays and controls, system behaviour and principles for information about the system.

Some aspects are more important than others in a safety evaluation: The following criteria are thus here applied:

- Impact of the specific user interface (tangible/visual/acoustic).
- Positioning and accessibility of the device.
- Driver control.
- Frequency of disturbance.
- Distraction from the driving task.
- Duration of the specific task.
- Information content.

Studies of the impact of different functions/devices used when driving a car has so far mainly focused on normal distraction from traffic and that of watching/operation of the car's instruments and devices, radio, etc. Cell phones have also been a focus in a considerable number of research projects. When it comes to the use of laptop PCs, PDAs, Internet, etc., little research has been carried out that can verify the impact of these technologies.

Information about the risk associated with use of in-vehicle technologies is available from four sources:

- Laboratory/simulator studies.
- Field studies/test tracks.
- On-road studies.
- Police accident analysis or self-reported incidents.

Radios, cassette/CD players

Radios and cassette players have been more or less standard equipment in cars for the last 20 years, and CD players for the last 5-10 years. As traffic information sent as RDS (radio data system)/TMC (traffic message channel) messages has gradually become more common, radio is also to be considered as a relevant technology in this connection.

Evaluation

According to a recent US accident analysis (Stutts *et al.*, 2001), radio/cassette/CD is the most cited cause of driver distraction (11%) in the period 1995-1999. Risk is associated with the position of the device in the car, complexity of the tangible interface, and the possibility of losing cassettes/CDs on the floor. The new RDS radios are not only a possible acoustic distraction source but also display visual information. So far RDS radios do not have a large share of the market.

Cell phones

The use of cell phones has rapidly increased during the last decade. At an early stage, cell phones were primarily equipment for professional drivers, but today they are almost to be considered as standard equipment for the majority of drivers.

Cell phone technology has been rapidly developing, from the first GSM (global system for mobile communication) phones (as well as other systems) to the introduction of SMS (short message system) messages, WAP (wireless application protocol) and GPRS (general packet radio service) standard.

Evaluation

According to a recent US accident analysis (Stutts *et al.*, 2001) cell phones represent 1.5 % of reported driver distractions over the period 1995-1999. Simulator studies show that risk is associated with the manual interaction with the device as well as with the conversation itself. Typical problems are related to driving behaviour (headway, lane departures) and reduced situational awareness (less frequent check of mirrors, frequent and long glances away from traffic, increased response time, etc.). Test track and on-road studies show increased lane departures, reduced speed and increased heart rate when cell phones are used while driving. Research has shown that the major risk when using cell phones is related to the conversation itself, but there is also risk while dialling. There are clear indications that the risk may be reduced through improved interface design, *e.g.* hands-free or voice-operated phones (Haigney, Taylor and Westerman, 2000). Nevertheless, it is the distraction caused by the telephone that is the cause of the risk, which hands-free and voice-activated technologies cannot overcome (Pachiaudi, 2001).

There are few accident studies which actually prove the involvement of mobile phones in accidents. This is, however, no surprise. Most accident studies rely on self-reported accidents and accident causes, and few people may be willing to admit that they used the phone immediately prior to the crash. Policing the ban of hand-held mobile phones is difficult, and a ban on hands-free phones would be virtually impossible with traditional means. In light of the fact that mobile phones represent a danger, one could imagine the development of road-side equipment creating phone-free roads, where cell phone communication would be impossible. Given that more and more vehicles are built with an integrated phone, it will be technically feasible to make it impossible to use the phone when speeding, or when driving to close to the vehicle in front and so forth.

According to a 1998 study found on the National Police Agency of Japan's Web site, there has been a rapid increase in the number of traffic crashes involving cellular phone use. Specifically, in 1998, there were 2 648 crashes in Japan involving cellular phones. This was a 15% increase over the preceding year. With regard to cellular phones, most crashes occur when the driver is receiving a call (43% of the total). Tables 3.1 and 3.2 summarise the study's findings. Figures improved rapidly, however, after the introduction of appropriate regulation in 1999. In 2002, there were 212 accidents, one fatality and 254 injuries from road crashes involving mobile phone use.

Table 3.1. Traffic crashes involving cellular phones in Japan

	1997	1998	Increase
Number of accidents with fatalities or injuries	2 297	2 648	15.3%
Fatalities	25	33	32.0%
Injured persons	3 328	3 814	14.6%

A report from the SWOV Institute for Road Safety Research in the Netherlands provides information about cell phone usage and related road safety risks. In particular, SWOV made certain estimates of the road safety impact of mobile phones based on car stock data, total kilometres travelled, road crash victims and information on mobile phones. They have estimated that there were 26 deaths and 284 injuries in the Netherlands as a result of a driver using a cell phone. This would represent an increase of about 88 victims (four fatalities) over the estimated numbers for 1998.

In the United States, the debate has shifted to consider cell phones as part of the larger problem of distracted driving. It is reported that distracted driving contributes to 20% to 30% of all crashes (Shelton, 2000). When considered in this light, the case can be made that cell phone usage while driving is not as important as other distracted driving issues.

Table 3.2. Specific sources of distraction among distracted drivers in order of frequency

Specific distraction	% of drivers
Outside person, object, or event	29.4%
Adjusting radio/cassette/CD	11.4%
Other occupant	10.9%
Moving object in vehicle	4.3%
Other device/object	2.9%
Adjusting vehicle/climate controls	2.8%
Eating and/or drinking	1.7%
Using/dialling cell phone	1.5%
Smoking-related	0.9%
Other distractions	25.6%
Unknown distraction	8.6%

Source: Stutts *et al*., 2001.

Table 3.3. Distracting activities that drivers admit to performing while operating a moving vehicle

Distraction	% of drivers
Listening to music or news	95%
Drinking beverages	71%
Eating	66%
Changing tape or CD	64%
Reading a map	33%
Talking on a cellular phone	18%
Combing hair	16%
Putting on make-up	14%
Reading a newspaper or magazine	6%
Shaving	4%

Source: NHTSA, 1997.

Finally, a report by Virginia Commonwealth University (2001) reports on fatal crashes that involve distracted driving. The report details that out of 2 704 fatal crashes in 3½ years, about 444 (16%) were reported as being due to “driver inattention”. The types of distractions are reported in Table 3.4.

Table 3.4. Reasons identified for distracted driving crashes in fatal crashes over 3½ years in Virginia

Distraction	Number of fatal crashes
Unknown	349 (79%)
Asleep/fatigued	77
Driver ill	10
CD player	1
Avoid animal	1
Looked down	1
Delivery mail	1
Bug in eye	1
Being tailgated	1
Previous crash	1
Flashlight	1

Source: VCU, 2001.

VCU (2001) and others (Sundeen, 2001; Shelton, 2000) conclude that the data are insufficient to determine the extent of the related safety problem or to make the case for legislation that will limit the use of cell phones while driving.

In general, it is estimated that cell phones increase the risk of a crash by a factor of two (SWOV, 2000) to four (Redelmeier and Tibshirani, 1997), though more exact information and data is not available. Sundeen (2001) reports that many subscribers use their cell phones while driving to report emergencies, call for assistance, or report drunk or aggressive drivers. Balancing this positive safety payoff with the negative safety impacts is a challenge faced by safety professionals everywhere and has not been fully addressed.

Driving computers

Driving computers are displays providing the driver with continuous accessible information about fuel consumption, average speed since the start of the trip, etc. Such computers are standard equipment in many cars.

Evaluation

Only a weak relationship to risk is shown in accident studies. There are many different models on the market. Some of the functions might be quite disturbing due to noise alarms, blinking lights, etc. Risk level will depend on the position of the device, readability, etc.

Laptop PCs

Laptop computers can be categorised into two main categories: fixed installation from the car/truck manufacturer and add-on installations (mainly for “professional” drivers).

Evaluation

Using a PC while driving is not acceptable, and negative effects should be eliminated by filtering or giving limited or no accessibility while the vehicle is rolling, *e.g.* the Volvo DynaFleet system, which only allows the driver to access the system when the truck is stopped. Weak relationship to risk in accident studies can be related to limited exposure/ use in vehicles (for the time being).

Printers (fax, etc)

Such devices are primarily for professional drivers that need a hard copy of documents, receipts, etc.

Evaluation

There is only limited knowledge as to associated risk. Risk level will depend on the type of messages or documents that are received on the printer/fax. There is a potential risk if messages are read while driving. Operating these devices (in particular sending faxes) should not be allowed while driving.

PDAs (handheld/pocket PCs)

PDA devices are becoming increasingly popular. Several services intended or not intended for use in cars (*e.g.* traffic information, route planners, restaurant guides, etc) have recently been developed for PDAs. The market share and in-vehicle use is expected to increase rapidly.

Evaluation

There is only limited knowledge as to associated risk. Risk level will depend on which functions that are accessible or in use. When used for navigation purposes, the risk is not necessarily higher than reading from a map book. Studies on safety aspects are planned or being conducted in simulator environments.

Infotainment

"Infotainment" is a concept including functions, services and devices aimed at car passengers – including TV, video screens, movies, games, Internet surfing, etc.

Evaluation

The driver might be distracted by the sounds from the movie/device, as well as comments, laughter and other reactions from the passengers using these facilities. Reduced risk may be associated with potentially less disturbance caused by or anger directed to quarrelling children in the back seat. The risk level depends on the type of infotainment and how much noise it creates. TV, video screens, etc should not be available to the driver while operating the vehicle. Knowledge from existing studies as to the increase in risk related to such devices is limited.

Conclusions

Distracted driving is already a major contributing factor of crashes on roadways and there are valid concerns that the introduction of newer and better technologies will only increase the potential for distracted driving. This chapter has shown that the more complex the cognitive task, the more likely there is to be a distracted driving risk. Thus, depending on the complexity of the task or the emotions of the driver involved in the task, even the use of voice-activated mechanisms could be detrimental to safety. On the other hand, many of the safety technologies discussed will likely not be any more distracting than other tasks and will therefore not represent an undue danger of increasing crash risk.

The current rate of development of in-car technologies is phenomenal. Much of this development is without links to governmental and car industry projects aiming at safer and more efficient travel. Development of in-car technologies without governmental involvement or integration with existing in-vehicle technologies from car manufacturers may represent development toward increased driver distraction and task load from after-market in-vehicle devices. Conversely, it is possible that overregulation by governmental bodies to prevent on-board technologies can lead to a situation where people take a variety of easily available technologies (laptops, cell phones, PDAs) to achieve similar objectives or functions in a less safe manner.

It should also be recognised that after-market devices (cell phones, Internet, PDAs, etc.), can be used to convey pre-trip or on-trip dynamic traffic information about incidents, obstructions, road conditions, road work, and other things that can enhance the drivers situational awareness and reduce accident risk. Mobile phones may also be used to call for an ambulance when an accident has occurred. The risk depends to a certain extent on how the devices are integrated in vehicles and how well the driver interfaces are adapted to drivers and driving conditions.

With all equipment aimed communicating with the driver, there is reason to ask how and when information should be conveyed. This communication will be based on visual, acoustic or tangible interfaces. The management of the information given to the driver and that required from the driver, both in time and space, is crucial for the smooth and safe operation of such systems. Systems for prioritising messages according to their importance and related to the attention demanded by the road and traffic situation are required as such communication systems become more common.

Safe use of in-vehicle technologies can be ensured by:

- User-friendly design, taking into account human limitations (distractibility, limited memory, field of view, attention, etc).
- Integrated solutions (*e.g.* automatically turning down the radio when a phone call comes in or turning off the computer when the vehicle is moving).
- Adaptive solutions (*e.g.* adapted to driving conditions).
- Standardised testing procedures of the total task load (visual, cognitive manual).
- Certification.

Governments clearly have a role in establishing an environment conducive to these actions.

References

Cairney, P. and F. Green (1999), *The Implications of Intelligent Transport Systems for Road Safety* (RC 7032), ARRB Transport Research, Vermont South, Australia.

Crawford, J.A., M.P. Manser, J.M. Jenkins, C.M. Court and E.D. Sepúlveda (2001), "Extent and Effects of Handheld Cellular Telephone Use While Driving", Research Report 167706-1, Texas Transportation Institute, College Station, Texas

Dingus, T. A., (2000), "Driver Distraction: New Features, New Tasks, New Risks", Public Meeting On The Safety Implications of Driver Distraction When Using In-Vehicle Technologies, 18 July 2000, US Department of Transportation, National Highway Traffic Safety Administration, Washington, DC.

Elvik, R., A. B. Mysen and T. Vaa (1997), *The Traffic Safety Handbook, Third Edition*, The Institute of Transport Economics, Oslo.

ETSC (European Transport Safety Council) (1999), *Intelligent Transportation Systems and Road Safety*, ETSC, Brussels, www.etsc.be/systems.pdf.

European Commission (2000), "Commission Recommendation of 21 December 1999 on Safe and Efficient In-Vehicle Information and Communication Systems: A European Statement of Principles on Human Machine Interface", *Official Journal of the European Communities*, L19/64, 25 January, Brussels.

Federal Highway Administration (FHWA) (1997), *Review of ITS Benefits: Emerging Successes*, FHWA, Washington, DC.

Forzy, J.F. (1999), "Assessment of a Driver Guidance System: A Multilevel Evaluation", *Transportation Human Factors*, Vol. 1(3), pp. 273-287, Lawrence Erlbaum Associates, New Jersey.

Haigney, D.E., R.G. Taylor and S. J. Westerman (2000), "Concurrent Mobile (Cellular) Phone Use and Driving Performance: Task Demand Characteristics and Compensatory Processes", *Transportation Research Part F: Traffic Psychology and Behaviour*, Vol. 3, Issue 3, 113-121, Pergamon.

Inman, V., R. Sanchez, L. Bernstein and C. Porter (1996), *TRAVTEK Evaluation Orlando Test Network Study*: USDOT, Washington, DC.
www.itsdocs.fhwa.dot.gov//jpodocs/repts_te/1gv01!.pdf

Kantowitz, B. and M.J. Moyer, *Integration of Driver In-Vehicle ITS Information*, Federal Highway Administration, Washington DC.
http://www-nrd.nhtsa.dot.gov/departments/nrd-13/driver-distraction/PDF/28.PDF

Look and Abdulhai (2000), "Accident Risk Assessment Using Microsimulation for Dynamic Route Guidance", paper presented at the 80th Transportation Research Board Annual Meeting, Washington, DC, 7-11 January 2001.

McKeever, B. (1998), "Estimating the Potential Safety Benefits of Intelligent Transportation System", Working Paper, Mitretek Systems, November.

National Police Agency of Japan (1998),
http://www.npa.go.jp/koutsuu/keitai/sokuhou2.html

NHTSA (National Highway Traffic Safety Administration) (1997), *An Investigation of the Safety Implications of Wireless Communications in Vehicles*, NHTSA, Washington, DC.

NHTSA (National Highway Traffic Safety Administration) (1995), *Safety Evaluation of Intelligent Transportation Systems: Workshop Proceedings*, *May 1-2, 1995, Reston, Virginia*, NHTSA, Washington, DC.

Pachiaudi, G. (2001), *Les risques de l'utilisation du téléphone mobile en conduisant,* INRETS, Lyons.

Pauzié, A. (2001), *L'ergonomie des systèmes communicants dans les véhicules : usage et sécurité*, *Actes no. 71,* INRETS, Lyons.

Perret, K.E. and A. Stevens (1996), *Review of the Potential Benefits of Road Transport Telematics*, TRL Report 220, Transport Research Laboratory, Crowthorne.

PIARC (2000), *ITS Handbook 2000,* Committee on Intelligent Transport, PIARC, Paris.

Redelmeier, D.A. and R.J. Tibshirani (1997), "Association Between Cellular Telephone Calls and Motor Vehicle Collsions", *The New England Journal of Medicine*, Vol. 336, No. 7.

Regan, M., J. Oxley, S. Godley and C. Tingvall (2001), *Intelligent Transport Systems: Safety and Human Factors Issues*, Royal Automobile Club of Victoria, Noble Park, Australia.

Shelton, R. L. (2000), "Statement Before the Subcommittee on Highways and Transit, US House of Representatives", Washington, DC, 9 May 2000. www.nhtsa.dot.gov/nhtsa/announce/testimony/distractiontestimony.html

Stutts, J.C., D.W. Reinfourt, L. Staplin and E.A. Rodgman (2001), *The Role of Driver Distraction in Traffic Crashes*, AAA Foundation for Traffic Safety, Washington, DC. http://www.aaafoundation.org/pdf/distraction.pdf

Sundeen, M. (2001), *Cell Phones and Highway Safety: 2001 State Legislative Update*, National Conference of State Legislatures, Washington, DC.

SWOV Institute for Road Safety Research (2000), *The Use of In-Car Information Systems That Are Not Relevant to the Driving Task*, SWOV, Leidschendam.

Tijerina, L., E. Palmer and M.J. Goodman (1998), "Driver Workload Assessment of Route Guidance System Destination Entry While Driving: A Test Track Study", *Proceedings of the 5th ITS World Congress,* Seoul, Korea, 12-16 October.

United States Department of Transportation (2001), *Deploying and Implementing ITS: 20 Questions*, US Department of Transportation, Washington, DC.

VCU (2001), "Driver Inattention and Driver Distraction Study", Special Report No. 15, Virginia Commonwealth University, Richmond, Virginia.

Wierville, W. W. and L. Tijerina (1996), "An Analysis of Driving Accident Narratives as a Means of Determining Problems Caused by In-Vehicle Visual Allocation and Visual Workload", in A.G. Gale (ed.), I.D. Brown, C.M. Haslegrave and S.P. Taylor (co-eds.), *Vision in Vehicles*, V. Elsevier, Amsterdam.

Chapter 4

EVALUATION OF NEW TECHNOLOGIES

Abstract. This chapter discusses evaluation methods for new technologies. It also estimates the reduction in injuries and fatalities that can be achieved by new technologies and the associated economic savings.

Introduction

"Society thinks this is a behavioral problem, rather than a problem that requires both changes to behaviour and technology."
– Brian O'Neill, Executive Director, Insurance Institute for Highway Safety

Previous chapters covered the variety of intelligent transport systems (ITS) and other technologies that have the potential to impact road safety. This chapter will examine more specifically the positive and negative impacts that could arise as a result of significant market penetration or public sector deployment of these technologies. As with any new device or approach, it is extremely difficult to gauge the full extent of the safety impact with little or no history. Therefore, in this chapter, estimates of benefits are based on the best information available, whether derived from broad use, experimentation, or a predictive assessment. The conclusions represent the best information available globally today but may not, in fact, represent the true situation in 20 or 30 years when the technologies are more fully developed and deployed.

Evaluation principles

Evaluation principles have been used since the widespread testing of ITS began in the late 1980s. Several ITS services are aimed at safety goals, and focus on reducing the number of crashes and lessening the probability of a fatality should a crash occur. Typical measures of effectiveness include overall crash rate, fatality crash rate, and injury crash rate. Crash rates are typically calculated in terms of crashes per capita or crashes per million vehicle kilometres of travel.

Evaluation of the benefits of ITS technologies and services have been assessed on the basis of more than 200 operational tests and early deployment experience in North America, Europe, Japan, and Australia (PIARC, 2000). Three broad-based categories of evaluation approaches are currently being used (Proper and Cheslow, 1998):

- Measured: empirical results from field measurement, which are the most compelling.
- Anecdotal: estimates made by people directly involved in field projects, which are also compelling but less reliable.
- Predicted: results from analysis and simulation, which can be useful tools to estimate the impact of an ITS deployment.

Many early evaluations fall into the second category above and contained some bias based on the involvement of project staff. Several categories can be combined to give a fuller picture with both qualitative and quantitative results.

ITS represent a wide collection of applications and technologies. Often, several technologies are combined, creating a greater synergistic benefit than that of a single technology. Integrated systems often have more than one institutional partner, and different funding mechanisms and schedules for deployment.

There are several problems associated with current evaluation techniques. Data from previous history may not be available, data collection methods may be incomplete, assigning specific benefits to a specific technology when numerous factors are present constitutes a delicate task, and finally, the measurement of driver behaviour and acceptance is difficult to isolate.

In addition to the above problems, system-wide factors may influence a particular occurrence of technology deployment. In the case of system-wide evaluation, full deployment is usually not possible. Extrapolating single deployment project results to predict the effects of full system deployment is very difficult.

Another influence is the effect on driver behaviour over time. As drivers adapt to new systems and technologies, their behaviour evolves so that initial data and observations may be irrelevant in the longer term.

Much data has been gathered over the past few years. The United States DOT ITS Joint Program Office has been actively collecting data since 1994. Significant knowledge is available for many ITS services, but gaps in knowledge also exist (Proper *et al.*, 2001).

Ultimately the overall system performance levels will depend on deployment by institutions or the level of use by drivers, perceptions of effectiveness in improving driving safety and the potential for market acceptance.

Evaluations ensure ITS deployment goals are achieved and progress is made towards the vision of integrated ITS. Evaluations are also essential to understand the value, effectiveness, and impact of ITS programmes and allow for the continual refinement of programmes.

In order to evaluate the road safety impact of ITS or other technologies, it is essential to understand how these systems influence driver safety. The European Transport Safety Council (ETSC, 1998) has suggested that ITS can affect three main variables that influence the level of road safety — exposure in traffic, risk of crash at a given exposure, and the consequences of a crash. They summarised how ITS may influence these variables as follows:

- Direct in-vehicle modification of the driving task by giving information, advice, assistance or taking over part of the task. This may influence driver attention, mental load, and decision about action, for example, driver choice of speed.
- Direct influence by roadside systems mainly by giving information and advice, *e.g.* change of route choice.
- Indirect modification of user behaviour. This will often not appear immediately after a change but may show up after a behavioural adaptation period. It can appear in many ways, *e.g.* a driver who has an automatic collision avoidance system on board may tend to drive more aggressively assuming better protection from the device.
- Indirect modification of non-user behaviour. Non-equipped road users may imitate the behaviour of equipped users, *e.g.* following more closely or driving faster than they should when they are actually under higher risk.
- Modification of interaction between user and non-users. ITS will change the communication between equipped users. This change may influence the traditional communication with non-equipped users, *e.g.* pedestrians.
- Modification of accident consequences by intelligent injury-reducing systems in the vehicle, by quick and accurate crash reporting and by reduced rescue time.

A great number of reports and studies exist that detail the types of indicators used to measure or monitor safety. These reports range from the so-called microscopic level to the more global level. Microscopic indicators are often used in the modelling process. For example, Saka and Glassco (2001) suggest that reducing hard braking and truck queue spill-over incidents were useful indicators for examining the safety effectiveness of changeable message signs and weigh-in-motion technologies. Though these types of indicators are meaningful for technological applications, higher level measures are far more relevant when examining the potential system-wide safety benefits of these technologies. Along these lines, two OECD publications in particular discuss the types of indicators or measures that are used in various OECD countries.

Road Safety Principles and Models (OECD, 1997a) states that quantitative road safety indicators are needed to define current safety situations and to express targets to be met. Similar to the ETSC above, it also indicates that exposure, crash risk and injury consequence are the three dimensions of the road safety problem and the magnitude of the safety problem is the product of these three factors. The report goes on to state that injuries and fatalities form the basis of all indicators used to identify the safety problem whether they are expressed as absolute values or rates based on population, number of vehicles or kilometres/miles travelled. Actual measures for the road safety situation must be highly correlated with these basic measures and easily measured. Thus, such things as speed, alcohol use and seatbelt usage are considered in this context. Other potential measures exist that are generally not used today, *e.g.* time to rescue or speed at the moment of conflict.

In *Performance Indicators for the Road Sector* (OECD, 1997b) road safety indicators are presented from three viewpoints – *i.e.* the government, the road administration and the road user. The sets of indicators relevant to road safety that result from this analysis are summarised in Table 4.1.

Table 4.1. Road safety performance indicators from three perspectives

Government (Ministry)	Road administration	Road user
• Crash risk: fatalities and/or fatal and/or injury crashes per vehicle km (number of fatalities and injuries) • Existence of national traffic safety programme/plan • Percentage of crashes involving drunken drivers	• Existence of method to assess results of safety programmes (yes/no) • Percentage of traffic flow speeding (weighted) • Percentage of roads not meeting minimum design standards • Exposure of pedestrians and cyclists to vehicle traffic	• Unprotected road user risk • Time from alert to treatment • Percentage of population considering traffic injuries as a public health problem

Clearly, not all of the indicators suggested in the two publications are necessarily relevant to evaluating ITS applications. However, they do provide a starting point and good guidance on what indicators could potentially be used for assessing or monitoring the safety effectiveness or impact of various technologies.

The World Road Association (ITS Handbook 2000) identifies two safety measures for ITS operational tests, namely: percent reduction in crashes and percent reduction in rescue time. The handbook notes that the former is a direct indication of safety, but difficult to obtain empirically in an operational test. The latter is only a surrogate for safety and may not correlate with reductions in fatalities because of confounding factors, such as the severity of the crash.

One study from the United States (Mitretek, 2000) suggests that safety performance may be measured directly by using safety-specific indicators such as crash frequency, rate and severity, or may be anticipated indirectly by using “safety-related indicators” such as incident response times, warning information effectiveness and traffic conflicts. Proper and Maccubbin (2000) show crashes and fatalities as measures for ITS evaluation.

Road safety indicators for ITS

From the above, it is quite clear that the bottom-line road safety indicator for any technology will be its impact on injuries and fatalities, which are the base for determining the effectiveness of technologies to either impact specific crash types or to more globally impact the safety of a road network. In fact, many estimates that will be discussed later in this chapter have been made on how ITS will affect safety from these standpoints. In summary, considering the above and the indicators that have already been considered in ITS deployment tests, some indicators are suggested in Table 4.2.

Naturally, the items suggested in Table 4.2 are only indicators and would have to be tracked against the backdrop of total fatalities and injuries across the system. If fatalities and injuries are not dropping, it is possible that the technologies that have been deployed are not addressing the most significant safety problems.

Table 4.2. Possible road safety indicators for ITS technologies

Indicator	Rationale
Existence of national traffic safety programme/plan that promotes the use of ITS to achieve national road safety objectives	This would be a measure to estimate the progress made in realizing the full potential of ITS technologies to address road safety and the level of commitment to full deployment.
Ratio of vehicles with ITS safety technologies to total sales	These would indicate the degree of market penetration of ITS technologies for safety. In other words, how widely used are the technologies and/or how accepted they have become to the public.
Number of infrastructure-based ITS technologies deployed	
Percentage of traffic flow speeding	If speed-related technologies (*i.e.* speed adaptation, photo radar, etc.) are applied, fewer cars would presumably be speeding and overall crash severity would be reduced.
Time from alert to treatment	Difficult to measure now, ITS technologies will facilitate a more accurate monitoring of this time and therefore provide opportunities for improving response within the "golden hour".
Violation rates	For certain dangerous behaviours – *i.e.* speeding, running red lights, etc. – where automated enforcement can be applied, violation rates would be an indicator of the effect of the technologies to change the behaviour.
Trips made/not made	Though it would be difficult to measure, some ITS technologies will cause some travellers to choose not to travel because weather, incidents or other information make the trip undesirable. Exposure will be reduced.

Challenges of ITS safety evaluation

Road safety is usually defined in a negative way. Safe road traffic is characterised by the absence of crashes, injuries and fatalities. Therefore, improving road safety is naturally translated as reducing crashes, injuries and fatalities along the road. Unfortunately, these crash-based measures have fairly low reliability. They measure with low precision since crashes are statistically rare events. Therefore, they require large-scale implementation in traffic and long periods of exposure. Such statistics obviously cannot be collected until systems have been on the road for a long period of time, while safety must be assessed before systems are marketed. The gradual market penetration of ITS can also modify road user behaviour in a way that is very hard to study at an early stage. Continuous modification therefore may be required to achieve the best benefit of ITS.

Another approach for measuring the safety impact of ITS is by using performance indicators, such as conflicts, exposure, speed, wearing of personal protection and other such measurement which have no direct relation to crashes but which have a known relation or correlation with the direct road safety measures. These measures have comparatively high reliability but lower or unknown validity since they are not directly measuring crashes. Decision-makers tend to trust the direct road safety measure more than these indirect measures.

Different laboratory, simulation and statistical methods as well as real-world tests and follow-up studies after initial deployment are employed in the safety evaluation of ITS. The follow-up studies are especially important for they enable quick identification and response to any safety problem, as well as appropriate adjustment to systems and standards.

From all of the foregoing, it is clear that good evaluation relies on the availability of good data for effectiveness analysis. Some possible scenarios for obtaining this data involve the use of on-board electronic data recorders (EDR). EDR data are proving very useful for analysing driver actions prior to crashes, and are already being used in court as evidence when questions such as the timing and appropriateness of airbag deployment are raised.

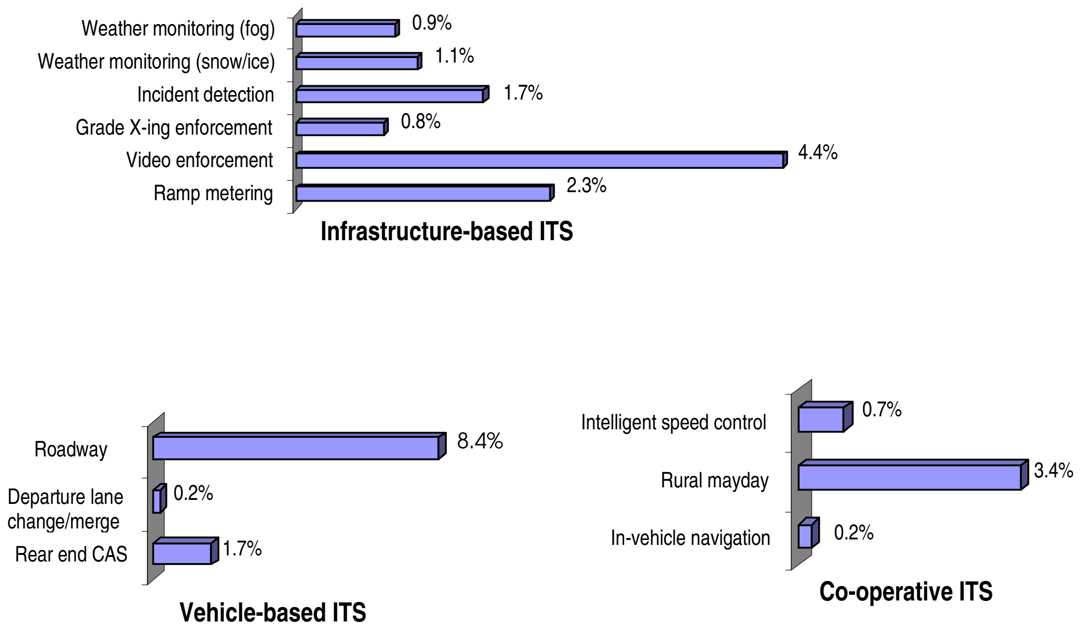
Another possibility is that ITS systems could incorporate means of monitoring their own performance; this is conceptually similar to EDR. If this option were pursued, monitoring variables would need to be included in systems standards. Agreements between administrative agencies, service providers, vehicle and ITS equipment manufacturers are needed to ensure the collection and analysis of relevant safety data – *i.e.* traffic conflicts, crashes, etc. – and efficiency (travel times). EDR downloads to monitor how on-board ITS systems are working could be voluntary, with reimbursement to vehicle owners, *e.g.* discount on monthly hook-up fees.

Other traditional or tried alternatives are available for evaluation as well. For instance, the use of probe vehicles is effective for some systems and some situations. Seeking anecdotal evidence through public surveys and Internet polls can provide valuable information although these are sometimes flawed by bias.

Potential safety benefits

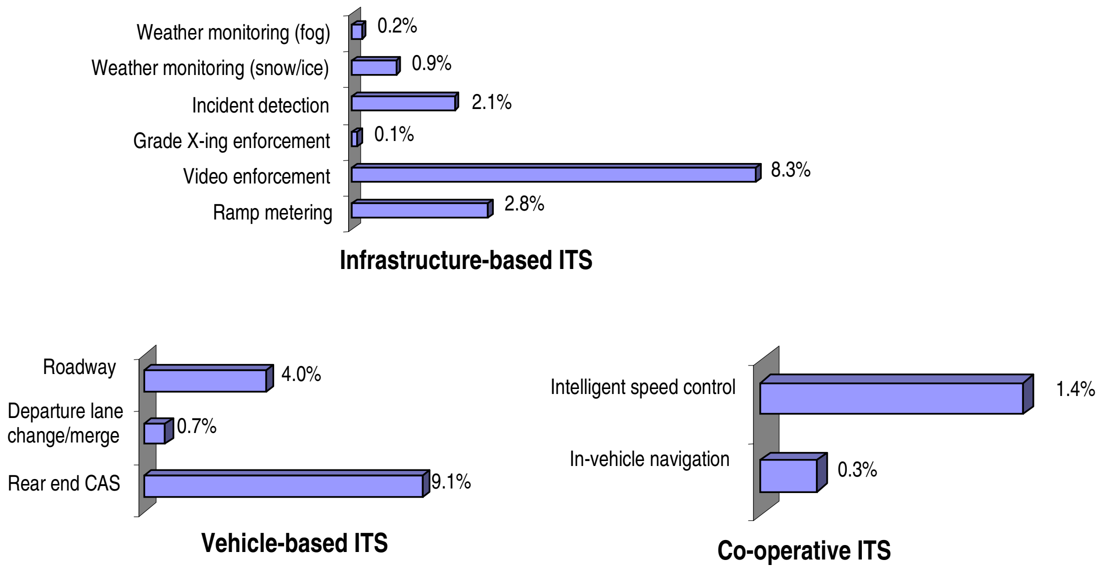
Based on the results of ITS safety evaluation data, McKeever (1998) reported safety benefits for fully deployed ITS systems as shown in Figures 4.1 and 4.2. System-wide estimates are those that anticipate the safety effects across the entire road transport system after full deployment of the technologies. In this light, if one considers the large number of total crashes occurring across a large road system, the benefits of even small percentage gains can be quite substantial.

Figure 4.1. System-wide fatal crash reduction by fully deployed ITS



The crash reductions that are shown are based on estimates from a working paper and may well vary from those shown. Furthermore, they are drawn only from US experience and the results could vary among countries.

Figure 4.2. System-wide injury crash reduction by fully deployed ITS



Benefit/cost information

The ITS Joint Program Office of United States DOT maintains a data base of cost and benefit information on ITS deployments. The Web site (www.benefitcost.its.dot.gov) has collected and categorised unit cost information as well as aggregated benefit information, some of which is used by the ITS Deployment Analysis System (IDAS) software (see Box 4.1). In general, these unit costs follow the IDAS equipment list. The cost estimates are categorised as capital, and operating and maintenance costs. The assumed life cycle for the type of equipment category is also listed. These can be thought of as non-recurring and recurring costs. Project costs are made up of many elements; equipment, facilities, communications, staff, etc. Because project costs can vary significantly, this data base portrays lows and highs of the cost elements.

Box 4.1. A pre-deployment safety analysis tool: IDAS

Developed by the Federal Highway Administration, the ITS Deployment Analysis System (IDAS) is the first computer software developed for ITS investment planning. It can currently predict relative costs and benefits for more than 60 types of ITS investments. However, the assumptions and calculations are not currently transparent for the user. Safety evaluation is part of its function.

IDAS uses the updated ITS benefit data collected from ITS implementation sites throughout the United States to generate reasonable estimation factors for ITS investment benefit. These factors then are employed into analysis to estimate benefit and cost information of ITS implementation. The accuracy of the results is dependent on the benefits and costs data. With more ITS implementation and more follow up studies being conducted, a good benefit/cost analysis at the planning stage can be achieved.

It should be noted that there may be significant cost savings to these unit cost figures through integration of ITS components. Therefore, good cost estimates may be more than simply adding up unit cost figures. It should also be noted that the annualised recurring costs of ITS are generally higher (in the order of 10% of capital costs) than are the operating and maintenance costs (approximately 3%) for bridges and roadways (PIARC, 2000).

The above equipment categories are mapped in the IDAS software to general programme areas where benefit data is reported. IDAS then is able to report on projected ITS project costs and compare these to the benefits of the ITS deployment. The general program areas are arterial management, freeway management, transit management, incident management, emergency management, electronic toll collection, electronic fare payment, highway rail intersection, and regional traveler information. Although this data base is useful and important for the use of the IDAS software, it does not map easily to projections specifically aimed at safety benefits.

PIARC (2000) provides some of the best information available on benefit/cost ratios for various ITS technologies (see Table 4.3 for a summary of the PIARC information). The reader should note that in this table, the B/C ratios are for stand-alone applications. B/C ratios would be generally higher when common ITS infrastructure is in place. In addition, some of the benefits of these technologies could primarily be other than safety – *i.e.* congestion relief, etc. – and are included here if they also have a collateral safety benefit.

Table 4.3. Benefit/cost ratios for selected technologies

Technology	Benefit/cost ratio
Incident detection	1.7 – 3.8
Speed control	2.9
Lane control	2.7
Ramp control	3.6
Intersection control	34.0
Emergency vehicle priority	4.8
Speed enforcement	4.1

Source: PIARC, 2000.

Carsten *et al.* (2001) examined various scenarios for the implementation of intelligent speed adaptation (ISA) in the United Kingdom. They considered all three possible ISA systems – *i.e.* advisory, driver select and mandatory – against the backdrop of both low and high GDP growth, among other things. All of the scenarios returned B/C ratios greater than 5. The range of B/Cs was 5 to nearly 17.

Estimated safety benefits

A wide range of evaluations and research estimations showing the potential benefits of various technologies have been documented in Tables 2.1 to 2.4 and Figures 4.1 and 4.2. The most conservative estimates of injury reductions and fatality reductions from these technologies are summarised in Table 4.4. These are system-wide estimations. Also shown are the maximum reductions that have been reported; however, these are not necessarily system-wide estimates or results.

Table 4.4. Estimated injury and fatality reductions from various technologies

Technology	Percentage injury reductions	Percentage fatality reductions	Maximum reduction reported
Weather monitoring	1.1	2	30 to 40% of all related crashes
Automated enforcement	8.3	4.4	50% of all related crashes
Ramp metering	2.8	2.3	2.8%
Collision avoidance (intersection, rear end, etc.)	13.8	10.3	17% overall and 50 to 80% for rear end CAS
Intelligent speed/ cruise control	1.4	0.7	5.9% of all crashes
Intelligent speed adaptation	15	18	Mandatory – 59% of fatal crashes

In some cases, these technologies will target the same accident type (*e.g.* speed cameras and ISA), therefore introducing both technologies will not necessarily produce a combined benefit. In other cases the technologies have complementary benefits (*e.g.* red light cameras and rear-end CAS) and the safety improvements of combining both systems may be better than the individual results show.

A number of other technologies have been described in this report which prevent or reduce primary causal factors of crashes and could improve road safety. Examples are alcohol locks – drinking and driving was a factor in 35% of all road fatalities in the United States in 2002 (FARS) and 28% in Australia in 1997 (Federal Office for Road Safety, 1999) – and drowsiness detection systems – fatigue is estimated to be a factor in 17% of crashes in Australia (Australian Transport Safety Bureau, 2002). However, estimates of system-wide benefits of these technologies are not yet available and therefore cannot be included in Table 4.4.

The conservative estimates in Table 4.4, coupled with further reductions from technologies that reduce or prevent other causal factors, would indicate reductions of the order of at least 40% in fatalities and 40% of recorded injuries. 125 000 people die on OECD roads every year. A reduction of 40% fatalities amounts to 47 000 lives saved.

Several countries calculate the cost of fatalities and injuries and these values are increasingly used in road traffic and safety planning. A number of countries avoid using fatality and injury costs; however, they implicitly assign values to the worth of saving life or preventing injury when they accept or reject road safety measures.

Injury crashes and property-damage-only crashes are also a large cost to society. Due to their far greater numbers, they significantly surpass the cost of fatalities. Table 4.5 shows the costs of crashes by injury category in Australia. The total cost of serious injury crashes amounted to nearly two and a half times the cost of all fatal crashes.

Table 4.5. Cost of crashes by injury category in Australia
(billions of AUD)

Fatal	2.92
Serious injury	7.15
Minor injury	2.47
Property damage only	2.44

Source: Bureau of Transport Economics (BTE), 2000.

Trawen *et al.* (2002) compared the costs of fatalities on roads in 11 OECD countries (Australia, Austria, Denmark, Finland, Netherlands, New Zealand, Norway, Sweden, Switzerland, United Kingdom, United States). In this paper, it was found that the average cost of a fatality is USD 1.56 million. Using this figure, the societal cost savings for 47 000 lives saved in OECD member countries would be about USD 73.3 billion annually. Based on Australian ratios of fatal costs to serious injury costs, a 40% reduction in injuries would save over USD 194 billion.

The total savings to OECD economies of all crashes (fatal, injury and property damage-only crashes) can conservatively be estimated to be greater than USD 267 billion per year.

These optimistic figures must be tempered, however, by the potential side effects or drawbacks that could result from implementation of new technologies. In particular, OECD member countries are urged to aggressively resist the unregulated proliferation of technologies that will further distract the driver or otherwise worsen road safety.

Furthermore, the estimates are based on the assumption of full deployment of the technologies in all OECD countries. Considerable obstacles in terms of public acceptance and political motivation will have to be overcome in many countries. These, and other implementation issues, are discussed further in the next chapter.

In spite of these concerns, the benefits described here provide a tremendous incentive to move as aggressively as possible with the technologies that offer positive safety benefits in OECD countries.

Conclusion

Chapters 2 to 4 show that there is an upside and a downside to the introduction of new technologies into the roadway environment. Whether these technologies are for entertainment, communication, information or safety, serious concern for the driver and their reaction and behaviour in the presence of these technologies must be considered throughout the development and deployment process.

The numbers presented here on safety benefits can only be estimates given the limited nature of available data on the safety effects of technologies that have been deployed only in a limited manner, if at all. Furthermore, though there may be some merit in arguments that the benefits of certain technologies are overestimated, it can also safely be said that there are further technologies that may improve safety that have not been included in this study. Ultimately, the lives saved could realistically be much higher if these existing technologies and others to be developed are deployed. In spite of this lack of data, this chapter has shown that there are tangible benefits to investments by the OECD countries in advanced technologies to improve safety.

References

Australian Transport Safety Bureau (2002), *Fatigue-related Crashes: An Analysis of Fatigue-related Crashes on Australian Roads Using an Operational Definition of Fatigue*, OR 23.

Besseling, H. and A. van Boxtel (2001), *Intelligent Speed Adaptation: Results of the Dutch ISA Tilburg Trial*, Ministry of Transport, Directorate General of Public Works and Water Management, Transport Research Centre, Rotterdam.

Blincoe L., A. Seay, E. Zaloshnja, T. Miller, E. Romano, S. Luchter and R. Spicer (2002), *The Economic Impact of Motor Vehicle Crashes*, NHTSA, Washington, DC. www.nhtsa.dot.gov/people/economic/EconImpact2000/index.htm

Bureau of Transport Economics (2000), *Road Crash Costs in Australia,* No. 102, Canberra.

Carsten, O., M. Fowkes and F. Tate (2001), *Implementing Intelligent Speed Adaptation in the United Kingdom: Recommendations of the EVSC Project*, Institute of Transport Studies, University of Leeds, Leeds.

Elvik, R., A.B. Mysen and T. Vaa (1997), *The Traffic Safety Handbook, Third Edition*, The Institute of Transport Economics, Oslo.

ETSC (European Transport Safety Council) (1998), "Telematics and Intelligent Transport Applications for Road Safety", November, http://www.etsc.be

European Commission (2000), "Telematics Applications Programme – Transport Area Results (4th Framework Programme)".
www.cordis.lu/telematics/tap_transport/research/10.html

ITS Joint Program Office of the US Department of Transportation, *Data Base of Cost and Benefit Information on ITS Deployments.* www.benefitcost.its.dot.gov

National Police Agency of Japan (1998), *Car Phone Related Traffic Accidents During the First Half of 1998*, Handout presented at ITS America Safety and Human Factors Committee Meeting, Dublin, OH, July 28, 1999.

Nouvier, J. (2003), "Towards Renewing the Enforcement System in France", Smart Moving Conference, April, Birmingham.

Nouvier, J. (2002), "Telematics and Road Safety: the French Approach", ITS World Congress, October, Chicago.

Nouvier, J., M. Aron and M. Marchi (2002), "La télématique au service de la maîtrise des vitesses"*, Revue générale des routes et aérodromes*, Paris.

OECD (1997a), *Road Safety Principles and Models*, OECD, Paris.

OECD (1997b), *Performance Indicators for the Road Sector,* OECD, Paris.

PIARC (2000), *ITS Handbook 2000,* Committee on Intelligent Transport, PIARC, Paris.

Proper, A.T. and M.D. Cheslow, (1998) *ITS Benefits: Continuing Successes and Operational Test Results*, FHWA Report no. FHWA-JPO-98-002, Washington, DC

Proper, A. and R. Maccubbin (2000), *ITS Benefits: Data Needs Update 2000*, Prepared in connection with the ITS Benefits Data Needs Workshop, 12 July, Washington, DC.

Proper, A.T., R.P. Maccubbin and L.C. Goodwin (2001), "Intelligent Transportation Systems Benefits: 2001 Update". www.benefitcost.its.dot.gov/its/benecost.nsf/ByLink/DBDocs

Saka, A. and R. Glassco (2001), *Modeling Traffic Safety Benefits of Intelligent Transportation System Technologies at Truck Inspection Facilities*, Transportation Research Record No. 1779, Transportation Research Board, Washington, DC.

Stutts, J.C., D. Reinfurt, L. Staplin, and E.A. Rodgman (2001), *The Role of Driver Distraction in Traffic Crashes*, AAA Foundation for Traffic Safety, Washington DC. www.aaafoundation.org/pdf/distraction.pdf

SWOV Institute for Road Safety Research (2000), *The Use of In-Car Information Systems That Are Not Relevant to the Driving Task*, SWOV, Leidschendam.

Trawen, A., P. Maraste and U. Persson, 2002, "International Comparison of Costs of a Fatal Casualty of Road Accidents in 1990 and 1999", *Accident Analysis and Prevention,* 34 (2002), pp. 323-332, Pergamon.

Chapter 5

OVERARCHING ISSUES

Abstract. This chapter discusses the issues that need to be addressed to promote the introduction of new safety technologies and limit the potential for the development of unsafe technologies. These include government objectives, human factors, social acceptance and education, standardisation, regulation, legal issues, data collection and use and implementation issues.

Introduction

Motorised road transport has been developing for more than a century. During this time, precedents and procedures have built up either through experience or legislation, based on the technology present at the time. With the arrival of affordable electronics and computer technologies, a major advance in control and information is offered to road transport that could result in major benefits both in safety and efficiency. However this promise of benefits must be measured against the perceptions of the user and the evolving traffic, technological, legal and regulatory environments. Positive measures may need to be taken to ensure that the full benefits of new technologies are realised and possible disbenefits are minimised. This may result in a need for changes in current practices, *e.g.* in traffic laws and the education of road users.

This chapter addresses the following issues that can arise with the introduction of any new transportation technology:

- Competing *visions* of the eventual form of the transportation system.
- The need to address *human factors* issues surrounding the operation of systems providing new functions, to avoid dangerous distractions from the driving task.
- The need to *educate* the public concerning the benefits and costs of new systems to obtain *social acceptance*, particularly if the effects on safety are unclear.
- The need for technical product *standards* to enable new systems to be produced economically, to function reliably when integrated into larger systems, and to facilitate communication and co-operation between vehicles and infrastructure.
- The need for new laws and *regulations* based on sound research findings to allow, limit, require or forbid the deployment or use of a new technology while allowing older technologies to continue to be used safely without forcing their premature and costly replacement.
- *Legal* issues such as liability and enabling legislation.

- The automated collection, within vehicles themselves and by traffic systems, of *data* on vehicle use and incidents, and the related issues of data ownership, storage and privacy.
- *Implementation* considerations such as the interactions, beneficial or otherwise, between new technologies and pre-existing systems.

Aligning national transportation visions

Intelligent transportation systems are costly to develop and introduce, and will be potentially used by millions of road users worldwide. Differing national mobility or safety priorities need to be identified and aligned, preferably through international discussion and agreement. Commonality of national and regional visions will facilitate the deployment of systems built to standardised specifications. It will also encourage competition that will lead to performance improvements and cost reductions.

There are significant differences in the national characteristics of the road safety problem. Examples are seatbelt wearing rates, alcohol use, the proportion of crashes involving pedestrians and cyclists, differences in sizes of vehicles and the speed of traffic. These differences in safety priorities would likely encourage different priorities for implementation of systems across countries.

For example, pedestrian collisions are relatively more numerous in Europe and Japan than in North America. Consequently, there is a higher priority for the development of pedestrian warning systems in Europe and Japan. North American interest in pedestrian safety might increase if systems relevant to the problem, such as night vision, could be supplied at low cost and with a broader purpose. This example indicates how international alignment of national visions for intelligent transport systems (ITS), despite significant differences in national safety profiles, could create opportunities for benefits beyond what a national ITS plan conceived in isolation would provide.

There is a need to balance international standardisation and national differences. Maintaining distinct national visions at a technical systems level parallel to similar international efforts may be counterproductive, *e.g.* by restricting the operation of vehicles that travel across national borders. Thus, assumptions of unique differences between national conditions need to be objectively assessed.

The global viewpoint of the major vehicle manufacturers is a positive influence for standardisation that produces rational economic solutions. However, government participation is also necessary to ensure that all sectors of the travelling public benefit from new technologies. A regulatory framework is needed that results in consistent and safe performance of all road vehicles equipped with new technologies and facilitates the rapid deployment of beneficial technologies without disadvantaging users of vehicles lacking such systems.

The following are examples of barriers to efficient deployment of ITS systems that may exist in different countries to varying degrees:

- Lack of social pressure and political priorities to improve safety.
- Lack of mass media/public attention on road safety.
- Different perceptions of risk.
- Lack of digital maps.

- Lack of appropriate geographic information systems (GIS) tools and applications platforms.
- Differences in the liability ascribed to manufacturers and users in the event of a collision.
- Lack of harmonised standards for construction of vehicles or traffic control systems.
- Industry resistance to systems perceived as unpopular or unexciting, one such example being intelligent speed adaptation (ISA).
- Incomplete or inaccurate data on collisions and their costs to support decisions on new regulations and infrastructure investments.

The alignment of broad national road safety policies or visions is a precursor to successful ITS deployment at the national, regional or global level. National differences in deployment patterns and schedules should not result in incompatible systems. Alignment of national road safety visions should broaden the deployment of compatible safety systems and push down costs. If global consensus cannot be reached, then regional consensus must be accepted as an interim goal. Non-restrictive performance standards and an adaptable system architecture are essential parts of the vision.

Human factors*

The introduction of new technology is causing comprehensive changes in road traffic and transportation. How future traffic, especially driving behaviour and the role of road users, will be influenced cannot be fully predicted. Introducing new components (ITS) to the traditional driver-vehicle-environment interaction leads to increased complexity of the road traffic system (Rumar, 1990). From a human factors perspective, it is reasonable to believe that the driving task will gradually change along with the implementation of new technology. Certain driver tasks will be carried out by technical support systems, while others may be modified and new tasks added.

Experience in other areas (*e.g.* aviation and process industry) shows that the implementation of advanced technology has the potential to change both the task structure and the allocation of tasks between the human and the technical system. From the traditional view that human related factors are frequently the cause of crashes, it would be logical to replace as many manual tasks as possible with automatic functions. However, available research suggests that this is not necessarily the solution. Human operators are very much needed in the control loop in the case of a high degree of automation (Wickens, 1992; Endsley and Kiris, 1995). When introducing new technology, the role of the operator is usually transformed from mainly manual to more supervisory control. The demand on human cognition is usually increased while the demand on human action is reduced (Wickens, 1992). The impact of driver behaviour may become more rather than less important (critical) in future "high technology" traffic. The fact that the driver "only" has to monitor without having to perform manual activities places the driver "out of the loop". This can lead to a diminished situation awareness and a complete reliance on the ITS device (even when it fails). Furthermore, less (or no)

* Nilsson *et al*., 2001.

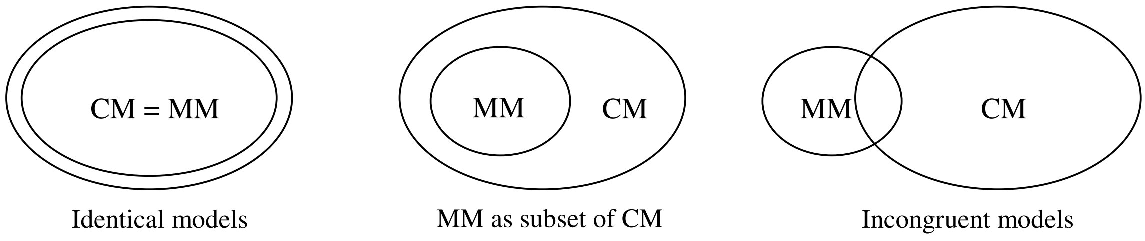
practice in manual tasks lowers the task performance. Both sorts of deterioration may have a negative impact on the ability of the driver to take over when technology fails.

To reach the intended positive effects and a successful use of new technology in road traffic, a number of human factors issues have to be considered. Crucial issues are:

- Drivers' experienced need and utility of information technology (IT)-based support systems (usability).
- Design of the human-machine interface/interaction (HMI).
- Users' acceptance of IT-based support systems.
- Users' comprehension of the functionality of support systems (predictability).
- Expectations of other drivers (predictability).
- Ability of support systems to provide similar support (general consistency).
- Influence of the support systems on the performance of specific driving tasks (controllability).
- General effects of ITS on driving behaviour including behavioural adaptation (impact) (Grayson, 1996).

Ideally the drivers' picture (mental model, MM) of an ITS should correspond to the technical description (conceptual model, CM) of the same system (Kopf *et al.*, 1999). This is not always the case, however. For example, during the introduction of ABS, drivers were used to reacting to lateral instability by having to steer using an old mental model. With ABS that is not necessary, so the mental model is changed. Drivers who had the old mental model had to change it. Drivers who have driven only with ABS will not have the experience and may experience reverse learning. This may be already be happening where vehicles are being sold without systems that used to be standard. Drivers may be caught unaware by the lack of a system they are used to. Waern (1990) has distinguished three constellations regarding the relationship between the conceptual and mental models (Figure 5.1).

Figure 5.1. Three constellations that can be distinguished as regards the relationship of conceptual and mental models



Source: Waern, 1990.

The left case in Figure 5.1 shows the ideal situation; CM and MM correspond. Only random unsystematic errors, which cannot be foreseen, are to be expected. In the middle case the user has some, but not full, knowledge of the system (*e.g.* the user is aware of only half of the functions of a navigation system). Certain functions remain unknown to the user or are quickly forgotten. The typical user is more willing to carry out complicated but known operations than to learn unknown but more effective solutions. The right case shows a situation with systematic differences between CM and MM. Such incongruities normally result in longer (re-)learning times and may occasionally cause serious operating errors of the "wrong, but has always worked" category (Becker and Cieler, 1997).

ITS systems can change a driver's outwardly observable behaviour, different from that displayed by unassisted drivers under the same circumstances. The modified behaviour can be difficult to predict for other road users, which must be considered less safe. This is especially relevant when relatively few drivers use ITS so that the modified behaviour is rare and has not yet been learned by the majority of drivers (ETSC, 1999).

If drivers can freely equip their vehicles with more than one ITS application, a number of different problems can arise as a result of lack of co-ordination. These problems include (ETSC, 1999):

- The placement of multiple displays, making the observation task unacceptably more complex.
- Simultaneous messages, with all possible mixtures of modes (visual, auditory, tactile) that arrest attention and demand extra time to sort out.
- Conflicting instructions or even conflicting actions.

To overcome these problems, the ADVISORS report (2001) advises to aim ADAS (advanced driver assistance systems) solutions at sets of problems instead of separate ADAS solutions for separate problems.

From a human/user centred perspective it is important to guarantee that the users/drivers can cope with the new task demands imposed by new technology. Four principles have to be considered when developing IT-based support systems, both in-vehicle and infrastructure-based, to be implemented in the traffic system (Kopf *et al.*, 1999).

Comprehensibility: The principle demands that the amount of information provided by the system does not overtax the user's capacity to process it.

Predictability: The principle demands that the user's mental model should preferably be identical to the manufacturer's technical model. The difference between potential users with regard to their prior knowledge has also to be taken into consideration.

Controllability: The principle means that the controllability of a system can be measured against individual human performance in the sense of skills learned and the speed of action and reaction.

Potential for misuse: The principle demands that the probability of behaviour detrimental to safety should be minimised.

The ADVISORS report (2001) suggests that supportive ADAS may often be preferable over ADAS that replaces human action. Supportive ADAS can help maintain or improve situational awareness by extending the possibilities of perception, so enhancing predictive behavioural strategies, or by assisting a skill-based routine. Although corrective autonomously acting ADAS can be effective, errors are already manifest and both time for correction and the sort of correction are usually limited. This raises the possibility that the correction is too simple to be valid in all situations (*e.g.* with ABS) and that merely a shift to other problems is obtained. One reason is that the driver is effectively removed from the control chain for a period of time and has to pick up immediately after the corrective actions. Another reason is that the automatically performed action may be alien to the expectations of surrounding road users and therefore may cause confusion and ensuing difficulties. Moreover, taking over skilled actions may eventually eliminate those skills in the driver, which may cause problems when changing to a non-equipped vehicle or in case of system malfunction.

Education and social acceptance

New challenges

There are several claims and concerns resulting from the arrival of the new technology.

- It is feared that drivers may lose skills they previously had. This is only a danger if those skills are still required (*e.g.* the use of the hand crank to start an engine is an obsolete skill). Drivers who have only driven vehicles equipped with ABS may not be aware of the technique of modulating brake pedal force to maintain control on slippery roads. Old skills that may still be useful on occasion may no longer be taught. Certain drivers cannot operate manual transmissions. Most of the danger in loss of skill is during transition from one technology to another.
- It is feared that drivers may come to overly depend on a new technology. Drivers may expect the new technology to do more than it is designed to do. They may not be alert to the situations that are outside the performance envelope of the technology and so may not be ready to take manual control in these circumstances.
- Drivers may not take full advantage of the new technology. This phenomenon is evident with other technologies (*e.g.* video recorders, computers, washing machines) that offer facilities which are rarely used or too complicated to remember. However, in vehicles, these facilities could enhance safety, and failure to take advantage of them will reduce the safety potential and could, in certain circumstances, increase the road death and injury toll.
- Drivers may misuse or abuse the new technology. The technology could be designed for one purpose but used for another that may result in danger.
- Drivers may be confused or distracted by the new technology. The attention allocated to the new technology may leave insufficient mental capacity for essential safety and observational tasks. Recent research on cell phone use by drivers has highlighted this problem.
- Drivers' past experiences may result in incorrect understanding of the new technology.
- Drivers may consider the imposition of some systems as an infringement of their liberty such as was initially felt with the introduction of compulsory motorcycle helmet wearing, seatbelt wearing, and alcohol breath testing.

It is necessary to monitor the transition to new technologies and make that transition as logical as possible. To be readily accepted by drivers, systems need to be usable with a minimum of training and familiarization. The performance of different brands of the same technology should not be so dissimilar that a driver moving from one vehicle to another is likely to be confused. The operating characteristics of early versions of new systems may vary significantly as manufacturers have different ideas about desirable performance and design parameters. Standards may be evolving rapidly and may allow a broad range of performance to accommodate systems based on different competing technologies. Such flexibility is acceptable when there is no basis, including safety, for ruling out any of the alternatives.

For example, the ISO standard on adaptive cruise control (ISO, 2002) specifies several levels of performance according to the minimum radius of the curve on which the system will track a preceding vehicle. The standard also classifies systems according to whether they are used with or without manual clutch controls, and whether or not the ACC activates the brakes. Over time, experience may lead to fewer variants or a more uniform range of performance. This in turn should allow drivers to adapt more easily to different vehicles, thus enhancing the potential achievable benefits of new technologies.

Over-expectation is a serious risk. Currently, manufacturers are claiming that the latest advanced driver assistance systems are only comfort systems and not safety systems. It is likely that the driver will expect that these systems have safety advantages and not be prepared when the system ignores a safety risk or returns control to the driver in an emergency.

The expected safety benefits of ABS have not been fully realised. The lack of driver experience on the proper use of the system may explain why drivers cannot take full advantage of the safety benefit (Harless and Hoffer, 2002).

Abuse of new technologies is also a serious threat. As an example, if adaptive cruise control results in drivers following each other too closely, then risk might actually increase.

The problems of confusion and overcomplicated interfaces are not new phenomena, but are amplified by the increased flexibility of digital technology.

Driver distraction must be minimised both by the location of the technology and by limiting access only to that which is essential for driving.

The past experiences of drivers must be taken into account in the design of new technologies. Currently, brake lights are well understood by drivers. Activated brake lights normally mean that a vehicle is slowing down, is maintaining a constant speed on a descent, or is stopped. However, yaw control systems that apply the brakes on selected wheels to maintain directional control do not activate the brake lights because to do so could confuse the drivers behind.

Drivers' sensitivities to the imposition of any compulsion must be recognised and they must be convinced of the benefits to ensure willing rather than resentful compliance.

Privacy issues

Information generated by new technologies could be used for purposes other than that needed for the primary driving task. This is likely to raise privacy concerns in a number of OECD countries. Privacy issues have been dealt with in other areas in society, *e.g.* information on credit card transactions and the ability to use cellular phone networks to track the movements of a person. The perceived advantages of mobile phones and credit cards have outweighed privacy concerns. Public perception of new technologies that could potentially monitor their activities must be treated sensitively.

Public education and awareness

The common popular perception of ITS is automatic tolls and surveillance cameras, which demand nothing in terms of driver behaviour and exert no direct control. ITS systems affecting safety and mobility will require drivers to acquire new knowledge in order to realise potential benefits. Education, for example on the merits of seatbelts and avoiding drinking and driving, has been a central technique in improving road safety.

New technologies are being promoted as enhancing drivers' abilities to pursue their travel preferences and choices of cost, time, mode, trip duration, etc. A negative possibility – that technology will move people further away from their natural capabilities in traffic – also has to be considered. Failure of an ITS system – such as a lane-keeping or a headway control system at a level of performance that is unsustainable by the driver without ITS support – with inclement weather conditions on a motorway would instantly create a demand for a level of driving performance (reaction time, vision) that humans do not inherently possess. The public will need to become informed not only about what the new technologies do, but also about their positive and negative effects on overall travel risk. Above all, manufacturers must take typical human performance limits into account in designing ITS systems to ensure that system malfunction does not place undue demands upon drivers in various traffic situations.

Acceptance

The need to improve road transport efficiency and safety is well accepted, but the methods and costs of doing so are often subject to heated debate. Governments will have to decide where new technologies fit in their priorities and assess public willingness to pay. There is a need for clear information on the costs and benefits of new transportation technologies compared to other major budget items that facilitate or control public behaviour. The public needs to appreciate that a new technology fulfils a useful purpose and that they can realise a personal benefit before the technology can be expected to gain wide acceptance.

Approaches

It is impossible to assess the effect of new technology by the standard techniques of measuring fatality and injury statistics. There are two responses to the opportunities created by new technologies. One is to wait until there is statistical evidence and then respond. The other is to use scientific methods to predict the likely results and actively manage the deployment of the new systems that can be shown to be effective.

Individual decisions are being considered to respond to the evidence or expected risk. For example, some countries are intent on banning the use of hand-held cell phones in moving vehicles, and some are considering banning the use of cell phones altogether. UNECE is considering expanding the set of circumstances for the illumination of brake lights. However, these examples are the tip of an iceberg of issues surrounding new technologies.

Just as ITS offers too many options to test simply, it is also offering too many options to be introduced without driver training. For the general public, this training could be limited to ensuring the direct safety benefits are realised and the obvious faults avoided. For professional drivers, the training could be extended to maximise these benefits. Training may not be necessary for systems that improve comfort or convenience. However, the decision on what constitutes comfort should not be left to the manufacturer;

an assessment of how the driver will use the technology may be a better measure of the potential safety or danger of its introduction.

Training can also attempt to address concerns about loss of driving skills. Where this is not possible, concerns can be addressed by either limiting the implementation of such deskilling technology or limiting the deskilled person to equipment that does not require that skill. The licensing system in some countries already reflects this, as drivers can be issued with licenses that restrict them to automatic transmission vehicles only.

Untrained drivers, infrastructure ITS, and equipped/non-equipped vehicles can all be controlled by specific driving licence clauses. For example, a non-equipped car may not be allowed on a road with ITS infrastructure, but such a car would be licensed to travel on "non-ITS" roads. Untrained drivers may not be allowed on certain equipped roads and/or in certain equipped vehicles, depending on the equipment.

Where there are convincing predictions that compulsory use of some systems would improve safety, the driver must be convinced of the benefit to ensure optimal compliance. An example of a successful implementation of this policy in many OECD countries was the approach to the wearing of seatbelts. First, vehicles were constructed with seatbelt anchorage points, the fact was advertised and drivers were encouraged to voluntarily fit belts by advertising showing the benefits of wearing seatbelts. The next step was when vehicles were constructed with seatbelts. Again, advertising was used to encourage the use of seatbelts including using personalities liked by the public. Not until the usage of seatbelts had exceeded a certain level (60% in the United Kingdom) did governments move to introduce compulsory wearing. Even then there were objections although the majority had already accepted the measure and the task of enforcement was reduced. The introduction of compulsory breath testing was not so readily accepted. It has taken many years to change the now-accepted moral stance that drinking and driving are incompatible. This was also achieved by publicity and education.

Standardisation

Formal standards for system design, data sharing and system functionality are important in minimising product costs as well as for the efficient and cost-effective implementation and successful cross-border implementation of new technology in traffic systems. Standards based on regional agreements or broad international agreements are related to the regulatory environments of the participating partners.

Guidelines (European Commission, 1998) and recommendations (European Commission, 2000) on safe and efficient in-vehicle information and communication systems have recently been presented as a "European Statement of Principles on Human Machine Interface". A similar publication has been released in North America – AAAM Statement of Principles (2002). The European statement includes sections on scope, existing provisions, overall design principles, installation principles, information presentation principles, principles on interaction with displays and controls, system behaviour principles, and principles on information about the system. A corresponding statement for *assisting* systems is expected soon. In addition, several working groups are concerned with the development of HMI standards for different design features relating to ITS systems. Visual information presentation, dialogue management, and audible signals are among the issues for which standards are currently considered. Other initiatives for the optimisation of new technology HMI are the Safety Checklist (Stevens *et al.*, 1999), which is directed toward system producers and currently under revision, the Swedish

SafeTE project, working with a consumer directed checklist, and the IHRA-ITS initiative (Noy, 1999).

Almost all standards organisations are active in this area with some co-ordination between such organisations (such as the shared working groups of the International Standards Organisation ISO and the European equivalent, CEN). The United States Department of Transportation's ITS programme is developing approximately 90 standards, using several standards organisations and co-ordinating them through ISO Working Group 204. These standards address a wide range of issues including data definition, message sets and protocols for data sharing between devices and transportation centres.

Standardisation initiatives may also be undertaken outside the scope of official standards organisations through direct industry co-operation. Such initiatives can be aimed at creating early consensus among system developers, implementers and regulators in order to co-ordinate research where the technology is not yet in commercial use. An example of such an activity is the Crash Avoidance Metrics Partnership (CAMP, 1997) established by Ford and General Motors to define and develop functional definitions, operating characteristics, performance measures and evaluation procedures for crash avoidance systems. Because of its pre-competitive nature, the work is partly supported by the United States government under its Intelligent Vehicle Initiative (IVI) programme.

There are advantages and disadvantages to introducing standards. The disadvantages of having no standard is incompatibility between systems, interference with other systems, lack of recognition by customers or purchasers, the need to comply with incompatible requirements in different regions, and ultimately higher implementation and maintenance costs. From a public sector point of view, this is an important consideration from both a safety and investment perspective.

Advantages of introducing standards are products and systems that can easily share information, operate in a uniform and predictable manner, are modular in design to facilitate expansion, and that may be cheaper in the long run. Other advantages may be the exclusion of unsafe systems, the avoidance of interface difficulties between systems, the opening of markets based on mutual recognition or adoption of technical standards.

The introduction of standards can also create difficulties, such as the slowness of creating such a standard, the need to compromise to attain a common performance requirement, and the premature nature of ITS making any standard a potential barrier to progress or stifling manufacturer innovation to develop competitive advantage.

Even though it is theoretically possible to design a system in complete isolation, the inevitable interaction of (and possible interference between) systems plus the need for transparency and the need to ensure that the protocols used are to an acceptable level means that the development and use of recognised standards is highly recommended. Standards can range from guidelines to detailed industry practices, and can become the basis of national or regional regulation.

In software there are several standards and guidelines, such as the MISRA (Motor Industry Software Reliability Association) guidelines that are promoted as a technique to ensure good software design. There are also several protocols, such as CAN and VAN, that are claimed to ensure safe communication between on-vehicle systems. Wireless communication protocols such as Bluetooth or DSRC (dedicated short-range communications) are also becoming available and are emerging as standards. Individual ITS systems have emerging standards such as the ISO specification for adaptive cruise control (ACC) (ISO, 2002).

In addition to standard protocols, there may be advantages to creating a complete architecture for groups of systems or related systems (Jesty, 2000). National architectures have been adopted in Canada, Japan and the United States that create a standard framework and define the interfaces that might be possible for standards development. This is particularly relevant for infrastructure/vehicle co-operative systems.

Standardisation of operation is important for safety and efficiency of various transportation systems. For example, traffic control signal sequence and colours have long been standardised. In the United States, signage has been standardised in the Manual of Uniform Traffic Control Devices (MUTCD).

The development of standards in a rapidly changing technology environment such as ITS is challenging. Reconciling different technical approaches, public and private sector concurrence, timing in the technology life cycle, and testing and certification all are factors in the adoption and implementation of standards.

Other broad issues include: software version updates, cost, retrofitting and tolerance of earlier "legacy" versions; participation by jurisdictions is important to ensure that local, regional and national needs are taken into account; and use of open-ended approaches to standards development to allow additional functions to be incorporated in the future.

Standards should be developed on regional – and if possible global – basis to avoid difficulties of harmonising national standards.

Regulations

Effects of new technologies on safety of traditional systems

Before the recent surge in affordable electronics, the only ITS that was generally available in road vehicles was antilock braking (ABS). With this exception, each vehicle system – be it braking, steering, suspension, seatbelts, etc. – could be practicably considered in isolation. Of course this was a simplification, but any interaction could be taken into consideration when testing and was therefore deemed unnecessary to regulate.

The arrival of ITS confirms that the safety of the system needs more consideration. The precedent set by ABS has helped in analysing this new situation.

ITS allows many permutations and combinations of action and result. This makes it difficult to definitively say that an ITS system is safe. In addition, different systems can interact. For example, the suspension system and the braking system may be linked and act to control a vehicle that is in danger of going out of control on a bend. Interacting systems need to be designed to ensure that the interaction does not reduce the safety of either system. Any failure in one system should not reduce the safety in the other. The road users (driver or other road users) should not be surprised by the interaction. This means that these complex systems need to be designed to ensure that the software, hardware and system interaction all result in an optimisation of the safety benefits and a minimisation of the disadvantages.

Vehicle construction regulations

Regulation of the construction (manufacture) of road vehicles within OECD countries varies both in the content and also in the method of enforcement. For example, the regime in North America is self-certification. In the United States, the Federal Motor Vehicle Safety Standards contain the road vehicle construction requirements. In Canada, Canada Motor Vehicle Safety Standards serve the same purpose. In the European Union and signatories to the United Nations Economic Commission for Europe (UNECE) 1958 Agreement, the regime is Type Approval. The EU usually uses directives to specify performance requirements. The UNECE uses regulations to specify performance requirements.

Self-certification requires the manufacturer to retain records of compliance and be prepared to prove to the regulatory authority that the system complies with any regulation should that authority decide to do conformance of production checks. Self-certification allows the manufacturer to enter a new vehicle in a market without prior approval. Type approval requires the manufacturer to offer the system for approval before production. Conformance of production checks are also an integral part of type approval.

The principle of both self-certification and type approval regulatory regimes is to remove trade barriers by agreeing to accept systems, from any source, that meet the prescribed safety performance requirements.

ITS either need to fit into the current regulatory schemes, or special measures need to be taken to take account of the arrival of ITS.

Before the arrival of ITS, it was possible to consider each system in isolation and safety performance indicators were reasonably simple to specify. Using UNECE Regulation No. 13 (the Braking Regulation) as an example, braking system safety is checked both by calculation and physical tests of the stopping distance, residual braking (in the case of a system failure), and stability requirements. With the arrival of the first ITS system, ABS, this performance check became more complicated to a degree. In addition to the extra calculations and physical performance tests introduced to check the safety of ABS, such as stability on split friction surfaces, the regulation included the requirement that "...the manufacturer shall provide the technical service with an analysis of potential failures...and their effects...." This extra requirement recognised that it was impossible to physically check all the possible failures on the finished vehicle and that the thought processes of the designer needed to be interrogated.

The recent arrival of other ITS resulted in a further development in the Braking Regulation. For example, electronic braking systems (EBS) and adaptive cruise control (ACC) required differing approaches. EBS could be thought of as a further refinement of the original braking system. The primary purpose of ACC was to assist speed control, but used braking to help in that control. Since the UNECE regulatory authorities recognised that these situations – one a development of a primary function, the other a secondary use of another system – would occur frequently with the development of ITS, it was decided that the ACC/braking regulation case should form a precedent for how to deal with ITS in regulations.

The solution proposed is the addition of a general annex to an existing UNECE regulation, and specific requirements to be added to the regulation itself. The first use of this annex, known as the Complex Electronics Annex, is as Annex 18 of the Braking Regulation. The next use is planned to be Annex 6 of the Steering Regulation, where it is necessitated by steer-by-wire technology, which transmits directions from the steering wheel to the steering gear electronically rather than by a mechanical connection. In both these examples, the arrival of ITS is a further refinement of the original system.

Currently in the UNECE there is no “ACC Regulation”. In this case there is no check of the fundamental safety of the ACC, but the Complex Electronics Annex would assure the safety of the system with which it interfaces is verified. If ACC used the brakes to control the speed, if a vehicle were fitted with ACC, the braking approval would need to be amended. Using the procedure in the Complex Electronic Annex and the specific requirements in the Braking Regulation, the effect of the addition of ACC would need to be shown not to compromise the safety of the braking system.

The next question is what should be done with ITS systems for which no regulations exist.

The simplest answer is to do nothing, but the disadvantage is that systems may be unsafe and, in different states and regions, they would be subject to different treatment and need to comply with incompatible requirements. The advantages of doing nothing include the freedom of manufacturers to do what they want when they want.

The alternative is to comply with a regulation. The disadvantages of this would be the slowness of creating such a regulation, the need to compromise to attain a common performance requirement, and the premature nature of ITS making any regulation a possible barrier to progress. The advantages of the existence of a regulation could be the banning of unsafe systems and the opening up of markets.

A recent development in the EU has made resolution of this question important. European whole vehicle type approval has been introduced. This allows a vehicle to be sold freely in any of the 15 member states without the fear of barriers to trade of national type approval. Currently, whole vehicle type approval only applies to cars and motorcycles, but it is planned to extend it to all classes of road vehicles. With this system, all 15 member states have agreed to the comprehensive list of system approvals that will constitute vehicle approval. The Framework Directive controls this process and each system is contained in a separate directive. One of the possible problems that might occur with this approach has been recognised. If there is not a relevant directive for a novel system, how may a manufacturer fit such a system? In these situations a manufacturer may petition a committee to allow the manufacture of that vehicle with that system claiming that it is too still novel to be recognised in an existing directive.

In the UNECE, only system approval is recognised so the resolution of regulatory treatment of ITS is not so urgent. However, it has been recognised that some acknowledgement of the existence of a novel system may be worthwhile. This would allow individual signatories to the 1958 agreement to allow novel systems in their national list of systems. Working Party 29 of UNECE is currently considering how to address this.

ITS systems are obvious candidates for consideration in these processes.

Countries throughout Europe (not just those 15 states in the EU) and many outside such as Australia, China, Japan and South Africa are signatories to the 1958 Agreement, and consequently Working Party 29 of UNECE has been renamed the World Harmonisation Forum. In addition, the signing of another agreement (the 1998 Agreement) has expanded those involved to include other regions such as the United States and led to the principle of introducing global technical regulations, which will result in one world specification for any system.

Approaches

A start has been made on addressing the impact of the arrival of ITS on technical standards and regulations. An increasing number of standards are being discussed and the introduction of regulation for systems that do not lend themselves easily to simple safety checks is being considered. Several organisations from ISO and CEN – through groupings of interested parties such as ITS America and ERTICO – to high-level policy groups such as the EU High Level Group on Safety/ITS are considering how standards can be used to assure that the best advantage can be taken of the arrival of ITS.

Assisted by the existence of standards, the introduction of regulations on a regional and global basis could result in common safety specifications which would also have the legal status to pre-empt contradictory laws at the national level.

The development of standards for interactive vehicle-highway systems that communicate across jurisdictional boundaries will require the establishment of new collaborative arrangements involving experts in road infrastructure, communications and vehicle engineering who traditionally have not needed to work together formally.

Legal issues

Liability

This is one of the most contentious and politically sensitive aspects. The arrival on the scene of new technologies, especially ITS systems that can "think", commonly known as *adaptive systems*, has raised the following questions:

- Should the user expect to trust the adaptive system at all times?
- What happens when a problem with the system, or a misunderstanding by the user of what to expect from the system, leads to injury?

A related aspect is the perception that adaptive systems may reduce the freedom of the user.

ITS such as ACC that perform functions normally done by drivers in the past, and systems such as intersection collision warning systems that interact to accomplish control or warning functions, will create new potential for liability concerns. Recognizing this, manufacturers of vehicles equipped with ACC systems make it clear that ACC is intended for driver convenience and make no claims that it reduces the risk of collision.

Manufacturers of new technologies and authorities who implement them need to be aware of the changing nature of laws allowing compensation for personal injury (tort law), including product liability and consumer protection laws. Countries that were influenced by the former British Empire follow a procedure of legal precedence. Japan has a similar system. A project to harmonise tort law in Europe has been underway for several years (European Group on Tort Law). American product liability law has resulted in the strongest penalties, but liability settlements in other countries are increasing.

Current situation

Five recent initiatives in Europe and one by ISO have indicated the current attitudes to the question of who is liable if there is an incident when adaptive systems are being used. These are the EU-sponsored project RESPONSE, the amendment to the UNECE regulation on speed controllers, the ERTICO working group SpeedAlert, the United Kingdom project on ISA, and the ISO standard on ACC.

- RESPONSE (Kopf *et al.,* 1999) was an EU project investigating *Vehicle Automation, Driver Responsibility, Provider Responsibility, Legal and Institutional Consequences*. One of the unique aspects of this project was the involvement of lawyers from several EU countries. The project did not complete all the work it intended (a RESPONSE II project is planned) but did arrive at the conclusion that…*systems remain "unproblematic" from the legal and the user's viewpoint only as long as they can be controlled and/or overruled by the driver at any time. However, problems regarding licensing and (product) liability are likely to occur with assistance system which cannot be overruled by the driver or which intervene beyond human psychometric performance limits (*e.g. *anti-collision systems).*
- UNECE Regulation 89 concerning speed limitation devices originally contained the specification for the maximum (fixed) speed limiters used currently in the EU for heavy commercial vehicles and interurban buses. This has now been amended to address devices that allow the driver to adjust the control speed to any value. At present the specification does not allow braking intervention for any vehicle other than a "car" but does allow the information on the current speed limit to come from any source (including telematic means).
- The SpeedAlert working group in ERTICO (a European organisation that brings together both industry and government authorities to discuss telematics progress and to conduct ITS development projects) will examine ways of informing the driver of the current speed limit. The terms of reference of this group limit study to systems where only information is offered to the driver.
- The UK government is sponsoring a project on intelligent speed adaptation that will include analysis of any expected legal problem that may be raised by the introduction of ISA. An earlier research project (at that time called External Vehicle Speed Control) could find no fundamental problem with the driver being kept within the legal speed limit.
- An ISO Standard (2002) on adaptive cruise control offers specifications for many combinations and permutations of ACC. However, all these systems are considered "comfort" systems and not safety systems or control systems.

Construction vs. use laws

The regulation of vehicle construction and vehicle use (driving and operation) is often carried out by different levels of authority. For example, the EU controls the construction standards of cars, whereas use is regulated at the individual national level. UNECE regulations also take precedence over national use laws. Similarly in Australia, Canada and the United States, the federal governments control the construction of vehicles and the states and provinces control most of the use laws. Positive decisions at a regional level normally result in discussions of local vehicle use requirements and the consequential removal of any contradictory law at the state level.

The ability of vehicle construction regulations *de facto* to control vehicle use is not a new situation. Previous examples of such situations include the introduction of automatic seatbelts and then the introduction of airbags by the US federal government. However, the increased ability of adaptive, automatic, telematic technologies to take over some aspects of vehicle control from the driver may mean that inaction by states results in a loss of sovereignty and control of the coherence of their particular road safety laws. Examples that are currently testing this area are the construction of vehicles with automatic illumination of their lights which are at odds with national use laws.

Enabling legislation and other government initiatives

The expectation that all progress should be left to manufacturers may be putting too much of a burden on them. They have limited ability to do large co-ordination tasks. They do excellent work in the standard setting area but that mainly concentrates on commonisation and intercommunication of and between systems. In addition, manufacturers may have no interest in introducing systems that appear to have no commercial demand, such as electronic vehicle identification, black box data recorders, and intelligent speed adaptation.

Without enabling initiatives from governments, many developments may be beyond the resources of individual manufacturers or even associations. More importantly in the present context, the possible safety benefits may never be realised. Such initiatives may include regulations to make systems mandatory, agreements on frequency bands, the introduction of communications systems and position location systems, the conversion of data to suit digital methods, and the agreement on a common architecture. Governments could undertake some of this at the bidding of industry, but some initiatives could also be speculative. Such enabling technology initiatives can be at the vehicle level and/or, in the case of infrastructure-based systems, at the state, regional, or global level.

Box 5.1. Enhanced digital maps

The United States has initiated the Enhanced Digital Map (EDMap) project. EDMap is sponsored by the United States Department of Transportation as part of the Intelligent Vehicle Initiative (IVI), a programme that is conducting research and field operational tests of vehicle-based technologies that can enable safer driving. The objective of EDMap is to develop and evaluate a range of digital map database enhancements that will enable or improve the performance of driver assistance systems under development or consideration by US automakers. The partners in the EDMap project include automotive manufacturers DaimlerChrysler Research and Technology North America, Inc., Ford Motor Company, General Motors Corporation, Toyota Technical Center USA, Inc., and map supplier Navigation Technologies Corporation.

The EDMap project began with the identification of 61 safety-related applications – from near term to long term – that would benefit from, or be enabled by, map database improvements. For each application, functional descriptions and requirements were developed. The list of requirements was used to define a group of map-derived information – termed mapplets – that support each application. Examples of mapplets include road geometry, road curvature, super elevation, lane width, number of lanes, intersection locations, traffic signal and stop sign locations, speed limits, and the location of no passing zones. Mapplets are combined with other vehicle sensor data, such as vehicle speed or road surface condition, to define an application system. A set of analysis categories was then developed to compare the potential safety benefits of each application system.

Box 5.1. Enhanced digital maps *(continued)*

The preliminary selection of applications to be further developed under the EDMap project includes curve speed warning, stop sign warning, forward collision warning, traffic signal warning, lane departure warning, curve speed control and lane following assistant. These applications will be used to drive development and refinement of detailed map accuracy and attribute requirements.

Two test areas have been identified where the applications can be demonstrated and evaluated. The EDMap demonstrations will occur in early 2004, and the results of the evaluation will be documented in a final report. The final report will provide an assessment of the types of map-enabled or enhanced safety applications that could be commercially feasible in the near, mid and longer term, given the expected developments in mapping technology, and advances in positioning and communications systems.

Discussion

All these initiatives show a sensitivity to the arrival of both "thinking" systems, especially systems that can limit the total number of alternative actions that a driver is able to take in given circumstances, and systems that effectively overrule local laws. There is another aspect that may be hidden behind these concerns. It is possible that manufacturers may consider that some systems, *e.g.* speed management, may make their products less attractive. They may want only to promote systems that apparently add to the pleasure of driving or appear to give a marketing advantage, and may as a secondary outcome reduce traffic congestion and improve safety. However, they may be less interested in other systems whose primary aim is to reduce congestion and improve safety, and may quote legal and product liability obstacles to the introduction of such systems.

It is interesting that neither the arrival of ABS nor the imposition of maximum speed limiters (on commercial vehicles) raised these questions in the past. There may be considerable scope to influence demand for safety systems by promoting the commercial advantages for fleet operators (both light and heavy vehicles). ISA is a prime example of a safety system that promises substantial economic savings through reduced crash costs, maintenance costs and fuel costs. Further work needs to be done in this area.

It may be necessary for governments to investigate and even mandate systems that manufacturers appear to have no intention of developing if they consider that such systems may be beneficial to safety.

It may be necessary for governments to introduce enabling measures especially if it is thought that without such measures the introduction of desired systems (whether for safety, congestion, or commercial efficiency reasons) may be delayed or never happen.

It may be necessary for governments to anticipate any threats to their local laws posed by the arrival of new technology. The fora already exist for such discussion, but active (rather than reactive) thought may be necessary and may require individual state laws to be amended for the greater good that new technology may offer the region or world.

Data collection, storage, access and ownership

New technologies, especially adaptive systems, generate and require data to make decisions. Once stored, the data can be retrieved and used for further improvements. It can also be used for diagnosis of collisions and incidents, and even evidence in a court of law. Consideration of how to handle access to such data such data are discussed here.

Examples of sources and uses of data

Examples of data collected by adaptive systems include acceleration, speed, brake pressure, tyre pressure, wheel rotation, distance to nearest object, and which auxiliary systems are engaged or activated. Such data can also be used to diagnose system deviations from the expected and alert either the driver or a maintenance organisation, or even to monitor the (in)competence of the driver.

These data could be used to detect the state of the vehicle immediately before and during a traffic conflict or collision. This would allow both a better understanding of the circumstances but, maybe more controversially, could also be used to apportion responsibility for the incident.

Data from sensors that identify both the vehicle and its location – by reference to global positioning system (GPS) satellites – are necessary inputs for navigation, logistics and collision prediction systems. These data could also be used for road pricing, to track the progress of individual vehicles to monitor traffic congestion or to monitor environmental performance. Equally, these data could be used to track individuals and in evidence in court cases not immediately related to the driving task.

Beyond data from in-vehicle sensors, data collected by the police through their survey and interrogation of collision sites and the people involved are invaluable as social statistical data. Numerous types of data are also collected through remote sensing systems by government organisations, road operators, commercial fleets and vehicle makers for such diverse purposes as traffic planning, monitoring driver performance, logistics, and monitoring vehicle usage and maintenance.

Approaches

Many data are already collected, for example, by police investigating collisions, through remote sensing systems by government organisations, commercial fleet operators and vehicle manufacturers. Application of information technologies would only improve the availability and accuracy of the data.

The use of privacy protection methods (such as separating the information gathering from the data dissemination) should be maximised. The availability of good quality data is the key to effective analysis and good policy-making. While privacy concerns are important, access to this data for safety research and network optimisation would have enormous public benefit.

Implementation considerations

Test history

New technology applications considered here cannot be fully assessed by tests of reliability, accuracy, resistance to interference or other such engineering measures, although they are an essential starting point. Indeed, proper operation of a system itself reveals almost nothing about its performance in application. The driver, vehicular traffic and the system itself combine to create a complex and varying operating system, the output of which is the safe transport of people and cargo.

Robust simulation followed by operational tests of new technologies installed in vehicles and infrastructure, including the public as drivers, are therefore needed to create a proper understanding of the effects of a new technology – or several technologies in combination –on transportation safety and efficiency. The largest examples of field assessments are those undertaken by the United States National Department of Transportation. Field operational tests are being done on a broad range of new vehicle technologies including adaptive cruise control, forward collision and roadway departure warning systems.

Order of implementation

Continual rapid technological advances make strategic planning for ITS implementation a particular challenge. Systems that are not currently economic or cost-beneficial may become competitive in the near future. Decision makers need to be aware of likely commercialisation time frames for promising systems that may be advantageous in comparison with available systems, or provide unique capabilities.

Some systems are prerequisites for others. ABS, for example, had to be developed to an advanced state of performance before adaptive cruise control and yaw stability control systems became practical.

Co-ordination

Many ITS systems transmit information between the vehicle and the infrastructure, or sense obstacles and features of the road environment. Communication and co-ordination among infrastructure operators, vehicle manufacturers, communications network providers and regulators will be required to ensure operability and reliability of such co-operative systems. Consultative mechanisms will need to be established between organisations, *e.g.* traffic control authorities and vehicle manufacturers, that may not have had direct contact before and that will now be providing separate components of the same system, such as intersection collision warning. Standardisation organisations may need to work together to establish compatible standards for infrastructure and vehicle-based equipment. Motor vehicle safety and communications authorities will need to co-ordinate their regulatory activities to ensure, for example, that the appropriate frequency spectrum is allocated for communications components of vehicle-based systems, and that the ITS equipment (whether mandated or simply allowed) meets radio interference and radiation hazard regulations.

It is a particular challenge to plan deployment of interactive systems so that they are immediately usable within a geographic area by a significant number of vehicles and users. In-vehicle collision warning systems that communicate with traffic control systems, for example, will be of limited use if the infrastructure has not been installed.

Government incentives may be needed to expand the networks throughout a region or country.

Need for uniform operating conditions

Systems need to be fault-tolerant. Failure should have minimum impact on mobility and safety. All systems require some degree of uniformity in operating conditions to function reliably.

For example, lateral guidance systems for vehicles are being developed that optically sense painted lines or other road features. However, many roads do not have painted lines, lines may be discontinuous or non-uniform, and lines are subject to degradation and damage. The critical implication is that the design of such features must be standardised, and road maintenance criteria and practices raised to a uniform level that assures system operability throughout national and regional road networks. Perhaps more importantly, systems must be designed so that the driver is warned when operational criteria are not met, in this case when automatic lateral guidance can no longer be maintained due to the absence of painted lines.

Advanced technologies as replacements for traditional measures

Some new technologies are analogous of more traditional safety measures. As the application of new technologies spreads, it may become feasible to consider removing, or at least no longer maintain, more traditional systems with the same purpose. For example, over time, physical rumble strips along roadway verges may become superfluous depending on how reliably an in-vehicle system can warn a driver of incipient lane departure and how quickly the new technology spreads through the fleet. Potential cost savings in traditional areas may improve the cost-benefit outlook for some new technologies.

On the other hand, if new technologies that duplicate the function of traditional measures are not made mandatory, then some proportion of new vehicles will quite likely remain un-equipped, if for no other reason than to minimise costs. In that case, the traditional safety measures will need to remain in place and maintained as long as they continue to serve a useful purpose.

Regardless of the capabilities of new technologies, some current infrastructure should not be replaced. Navigation systems can malfunction and may never become ubiquitous, so traditional direction and location signs will very likely always be needed.

Box 5.2. Deployment in commercial fleets

Commercial fleets are the most pragmatic and dynamic types of road system users. They will quickly adopt new technologies that can be shown to be commercially advantageous.

Logistics management systems to control vehicle deployment, monitor trip progress, and automate customs formalities are expanding rapidly. International commercial vehicle traffic is of such a high volume that a regional or continental system can be taken for granted.

Many commercial vehicles are equipped with communications links to support logistics and maintenance monitoring functions. Safety and traffic functions could be added that would make them useful probe vehicles for providing data to other drivers and traffic authorities. New economic models would be needed to reimburse transportation firms for data that are input to a national system and used for the general good. One model might involve reimbursement of private individuals or corporations for traffic and weather data they provide to services that integrate and broadcast the information.

Conclusions

The arrival of new technology, especially technology that allows adaptive control and communication with other systems, brings with it considerations that need to be resolved at supranational and regional levels. Previously, systems could be considered in isolation and be checked for basic safety in basic ways. All this has changed. One alternative is to allow uncontrolled deployment of new technology trusting to product liability controls to ensure products (primarily produced by manufacturers to sell vehicles) are safe. Another alternative is to try to influence deployment by promoting technology that promises improved road safety. This could minimise the effects of inappropriate technology and educate the driver to take full advantage of the expanding capabilities of affordable electronics, but risks stifling invention by introducing inflexible regulation based on insufficient proof.

On the other hand, a potential good exists in collecting information through the use of new road safety technologies and providing better access to it. By collecting different types of data on a comprehensive basis and integrating them into useful databases, various policies can become more effective. The efficient storage, search and retrieval of data, and access to databases, that have resulted from advances in information technologies fosters the emergence of various new applications. Collecting information about potentially dangerous road locations, or providing information about dangerous road conditions to road users can also create benefits. More emphasis on better institutions for better exploitation of this data is also essential.

References

ADVISORS (2001), *Problem Identification, User Needs and Inventory of ADAS*. Deliverable D1/2.1 V4. DGTREN GRD1 2000-10047.

American Alliance of Automobile Manufacturers (AAAM) (2002), "Statement of Principles, Criteria and Verification Procedures on Driver Interactions with Advanced In-Vehicle Information and Communication Systems, Version 2.0", Driver Focus-Telematics Working Group, www.autoalliance.org

Becker, S. and S. Cieler (1997), "Die Mensch–Maschine-Schnittstelle bei Fahrzeug-informationssystemen". *Vortrag anläßlich des Seminars "Fahrerinformations-systeme*", Essen, Haus der Technik, 25-26 September.

CAMP (Crash Avoidance Metrics Partnership) (1997), *Development and Validation of Functional Definitions and Evaluation Procedures for Collision Warning/Avoidance Systems: First Annual Report*, NHTSA Co-operative Agreement Programme no. DTNH22-95-R-07301.

Endsley, M.R. and E.O. Kiris (1995), "The Out-of-the-Loop Performance Problem and Level of Control in Automation", *Human Factors,* 37 (2), pp. 381-394.

ETSC (European Transport Safety Council) (1999), *Intelligent Transport Systems and Road Safety*, ETSC, Brussels.

European Commission (1998), *European Statement of Principles on Human Machine Interface for In-Vehicle Information and Communication Systems (Expansion of the Principles)*, Task Force HMI, European Commission, DG XIII, 9 November.

European Commission (2000), *Commission Recommendation of 21 December 1999 on Safe and Efficient In-vehicle Information and Communication Systems.*

Farradyne, P.B, Inc., *City of San Diego Photo Enforcement System Review: Final Report,* City of San Diego Police Department (California, USA).

Grayson, G.B. (1996), *Behavioural Adaptation: A Review of the Literature*. TRL Report 254, Crowthorne, England.

Harless, D and Hoffer G (2002), "The Antilock Braking System: A Drinking Driver Problem?", Accident Analysis and Prevention, 34, pp. 333-341.

ISO (International Standards Organisation) (2002), "Transport Information and Control Systems – Adaptive Cruise Control Systems – Performance Requirements and Test Procedures", ISO 15622:2002.

Jesty, P.H. (2000), *What Is a System Architecture?,* European ITS Framework Architecture, European Communities, 2000.www.frame-online.net/Presentations/What%20is%20a%20System%20Architecture2.PDF

Kopf, M., S. Becker, P. Burns, J. Dahlman, E. Dilger, T. Johanning, L. Lindahl, L. Nilsson, J. Schwarz and K. Svensson (1999), "Advanced Driver Assistance Systems: System Safety and Driver Performance", Deliverable No. D4.1, RESPONSE Project (TR4022), European Commission DG XIII.

Nilsson, L., L. Harms and B. Peters (2001), "The Effect of Road Transport Telematics", in P.-E. Barjonet (ed.), *Traffic Psychology Today*, Kluwer Academic Publishers, Boston, pp. 265- 285.

Noy, Y.J. (1999), *ITS Safety Test & Evaluation. International Harmonized Research Activities (IHRA): Intelligent Transport*. Workshop held 14-15 April 1999, Washington, DC. Report Transport Canada, Road Safety, Ergonomics Division.

OECD (2002), *Safety on Roads – What's the Vision*, OECD, Paris.

Rumar, K. (1990), "Driver Requirements and Road Traffic Informatics", *Transportation,* 17, pp. 215-229, The Netherlands.

Stevens, A., A. Board, P. Allen and A. Quimby (1999), "A Safety Checklist for the Assessment of In-Vehicle Information Systems: A User's Manual", TRL, Project Report PA3536/99.

United Nations Economic Commission for Europe (UNECE) (1993), Regulation 89, "Uniform Provisions Concerning the Approval of (I) Vehicles With Regard to Limitation of Their Maximum Speed, (II) Vehicles with Regard to Speed Limiting Devices of an Approved Type and (III) Speed Limitation Devices", New York. http://www.unece.org/trans/main/wp29/wp29regs/r089e_1.pdf

Waern, Y. (1990), "On the Dynamics of Mental Models", in D. Ackermann and M.J. Tauber (eds.), *Mental Models and Human-Computer Interaction,* 1, pp. 73-93. Elsevier, Amsterdam.

Wickens, C.D. (1992). *Engineering Psychology and Human Performance* (2nd edition, Harper Collins, New York.

Annex A

GLOSSARY OF ABBREVIATIONS

ACC	Adaptive Cruise Control
ADA(S)	Advanced Driver Assistance (Systems)
AHS	Advanced Cruise-Assist Highway Systems
CERTU	*Centre d'études sur les réseaux, les transports, l'urbanisme et les constructions publiques* (French research centre)
DMS	Dynamic Message Sign
EDR	Electronic Data Recorder (black box)
EU	European Union
GDP	Gross Domestic Product
GPS	Global Positioning System
HMI	Human-Machine Interface
IIHS	Insurance Institute for Highway Safety
ISA	Intelligent Speed Adaptation
ISO	International Standards Organisation
ITE	Institute of Transportation Engineers
ITS	Intelligent Transport Systems
NHTSA	National Highway Traffic Safety Administration (United States)
OBU	On-board Unit
OECD	Organisation for Economic Co-operation and Development
PIARC	World Road Association
RTR	Road Transport and Intermodal Linkages Research Programme (of the OECD)
UNECE	United Nations Economic Commission for Europe
VMS	Variable Message Sign

Annex B

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