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ROAD SAFETY IMPROVEMENT BY APPLYING POLICIES AND TECHNOLOGY

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ABSTRACT

Now a day's road traffic fatalities as well as injuries have become global crises. Road safety is a major concern for society and individuals. Every year more than 1.2 million people die on the world's road accident and about 50 million are injured. In order to address this major health crisis the UN has declared 2011-2020 as the decade of action for road safety. In the present context the need for making proper policies and better utilization of advanced technologies rendering for the improvement of road safety are the foremost task.

The thesis principally organizes to focus on both of the policies and technologies related to improvement of road safety. The road safety problem characteristics and the prevalent conditions in road safety are initially noticed by analyzing the accident trends of different regions (Europe, USA, and Asia).The new policies adopting in different corners of the world are also described along with its safety benefits against accident causation. Long term planning is very crucial as some countries (Norway, Sweden) have been benefiting applying their safety program such as vision zero. Having a better policy the contemporary technologies may serve the purpose of fulfilling the target of safety improvement taken by many countries. Both of vehicles and infrastructures could be integrated to get better benefit from enabling technologies. ITS plays an important role to safeguard that purpose. Implications addressing to reduce the probability of happening the crash event (active measures) and also consequences (passive measures) of ITS are well explained. Policies will have no effect on road safety unless they are implemented. The implementation considerations of both the policies and novel technologies are also suggested.

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ABBREVIATIONS

AAAM: American Alliance of Automobile Manufacturers
ABS: Anti-lock brakes
ACC: Adaptive Cruise Control
ADAS: Advanced Driver Assistance System
AFS: Active Front Steering
APTS: Advanced Public Transport System
ARP: Active Rollover Protection
ARTS: Advanced Rural Transportation Systems
ATIS: Advanced Traveller Information Systems
ATMS: Advanced Traffic Management Systems
AVI: Automatic Vehicle Identification
AVL: Automatic Vehicle Location
AWD: Advanced Warning Device
CAD: Computer-Aided Dispatch
CAPS: Combined Active and Passive Systems
CCTV: Closed-Circuit Television
CVO: Commercial Vehicle Operations
DRL: Daytime Running Lights
ESC: Electronic Stability Control
EU: European Union
FHWA: Federal Highway Administration
FARS: Fatality Analysis Reporting
GDP: Gross Domestic Product
GNP: Gross National Product
GPS: Global Positioning System
GRSP: Global Road Safety Partnership
GSRRS: Global Status Report on Road Safety
HDD: Heads-Down Display
HIC: High Income Countries
HMI: Human Machine Interface
HUD: Heads-Up Display
IIHS: Insurance Institute of Highway Safety
IHRA: International Harmonized Research Activities
IRTAD: International Road Traffic and Accident Databases
ISA: Intelligent Transport Systems
ISO: International Standards Organization
ITS: Intelligent Transport Systems
IVIS: In-vehicle Information System
LIC: Low Income Countries
MIC: Middle Income Countries
NHTSA: National Highway Traffic Safety Administration
OCED: Organization for Economic Co-operation and Development
PDA: Personal Digital Assistant
SUV: Sport Utility Vehicle
UNECE: United Nations Economic Commission for Europe
VMS: Variable Message Sign
VRU: Vulnerable Road Users
WHO: World Health Organization

CHAPER 1

INTRODUCTION

1.1 BACKGROUND

Drive towards human safety is one of the major social movements of the new millennium. Causality on road is a phenomenon that occurs quite frequently in small increments and unfortunately, we as members of the society are needed to be conscious. These incidents lead to enormous emotional and economic consequences, imposing high economic and social costs to the society. These costs are in the shape of loss of earning capacity, damage to physical assets, loss of wellbeing, and expenditure on medical care.

Universal data on the road accidents provides us with extremely useful information to assess and evaluate the nature and dimension of the problem from hosts of angles. It also provides us opportunity to explore various practical options to mitigate the enormity of this grim and grave problem. According to Global Status Report on road safety, more than 1.2 million people die on the world's roads every year and as many as 50 million others are injured. Over 90% of the deaths occur in low-income and middle-income countries. About 70% of these deaths occur in developing countries. Taking into account recent decline in fatality rate, the study estimates that the road traffic injury will be placed on the 5^{th} by the year 2030. The World Bank also estimates that the road accidents cost approximately 1% to 3% of a country's gross domestic product (G.D.P).

Historically many of the measures in place to reduce road traffic deaths and injuries are aimed at protecting car occupants. Almost half of those killed each year around the world are pedestrians, motorcyclists, cyclists and passengers in public transport. The current figures of the road safety draw our attention to the need of all road users- including the most vulnerable groups. While policy decisions on road safety, those groups must be considered equally. Prevention is by far the better option. We need to introduce the knowledge and experience and many tools of improved technologies to make our transport systems safe and healthy.

1.2 OBJECTIVES OF THE STUDY:

Road Safety studies are indispensable tools of traffic management and to determine whether the corrective measures are needed or not and to measure effectiveness of particular accident preventive measures. The objectives of the study are:

- Look into the state of the art of policies and technologies prevalent in the literature.
- Demonstrate the road safety problem characteristics and the evaluation methodology of the safety measures.
- Current global and regional trend of road safety is investigated.
- Addressing the policies for the road safety.
- To find out the up to date technologies in road safety.
- Finally to detect the problems arises for introducing the policies and technologies and recommend the measures to overcome the problem.

1.3 SIGNIFICANCE OF THE STUDY:

For the further improvement options of prevailing road safety conditions relating to both of policies and technologies, it is obvious that the current knowledge and research around the world are conducive.

The feasibility and applicability of the proposed policies and technologies are also important which may vary according to the target considered. This study will provide the support tool to gather technical knowhow and nationwide policies for the improvement of road safety. This solution requires comprehensive action by a well-trained, committed, adequately financed, and organizationally integrated public sector.

1.4 ORGANIZATION OF THE THESIS:

Apart from this chapter the thesis has been divided into six chapters based on the research work carried out.

Chapter 2 reviews the literature relevant and related to the theme of study. This will help us to understand the safety problem elements involved in accidents. Chapter 3 explains the road safety problem characteristics and methodologies to evaluate the road safety. Chapter 4 represents global and regional perspectives of road safety. In this regard, the global status, European and US status are reported. Also some of the selected country profiles are explained. Chapter 5 explains the road safety policies around the world. Chapter 6 presents the improved technologies applications in road safety. Chapter 7 presents the problems coming out from the applications of those policies and novel technologies and the possible recommendations and remedies to minimize those problems.

The below figure 1.1 shows the flow chart of the organization of the thesis:

Introduction

↓

Literature Review

↓

Road Safety Problem Characteristics and Evaluation

↓

Global and Regional Perspective of Road Safety

↓

Policies in Road Safety

↓

Technologies in Road Safety

↓

Conclusions and Recommendations

Figure 1.1 Flow chart showing outline of the thesis

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

It has been experienced all over the world that the countries which are undergoing increasing and rapid motorization face proportionately higher number of road accidents. The rapid development and extension of the road network and the increase in number of motor vehicles have led to a substantial rise in levels of both passenger and freight movement. Concomitantly safety related issues have emerged. The number of road accidents and fatalities has been growing in recent years. As road accidents involve roads, motor vehicles as also the human being, the National Road Safety Policy needs to address on a holistic basis, issues covering road engineering, signage, vehicle design, and education of road users and enforcement of traffic safety measures. [1]

Road traffic injuries (RTIs) are a growing public health problem that must be addressed through evidence-based interventions including policy level changes such as the enactment of legislation to mandate specific behaviors and practices. Policy makers need to be engaged in a road safety research to ensure that road safety policies are grounded in scientific evidence. [2]

The basis of road safety policy at the national level rests on an extensive information system (covering accidents, risk exposure, speed, utilization of mobile phones) and on analyses of road risk (the risks attributable to alcohol, speed and the use of mobile phones).
This statistical information and these risk models are integrated in risk management tools such as monitoring, ranking and policing. Monitoring makes it possible to track the development of road safety, bench-marking to compare the performance of the country's different departments with each other, and policy making to refine the details of a policy.
The development of the governance of road risk is leading managers and decision-makers to perfect data-gathering procedures, standardize and simplify the analytical tools used, and broaden the range of risks covered. [3]

2.2 SOME IMPORTANT DEFINITIONS:

Road accident:

- Heinrich defined accident as an unplanned and uncontrolled event in which the action or reaction of an object, substance or person results in personal injury probability thereof.[4]
- A working definition of accident is given by Chapanis: an accident is an unexpected and undesirable event, which arises directly from a work situation that is from faulty equipment or inadequate performance of a person. There may or may not be personal injury, damage of equipment or property. [5]
- Haddon defined that an accident is an unexpected occurrence of physical damage to

animate inanimate structure. [16]

- According to the definition given by Tomecki, an accident is rare, random, multifactor event and always proceeded by a situation in which one or more road users fail to cope with their environment. [6]

Crash:

A vehicle striking anything is referred to as a crash. Some authors considered accident term is unsuitable for technical use. For example David Shinar used the term crash in his book "Traffic Safety and Human Behavior."

Traffic safety:

The term traffic safety is used widely by specialist and the public. Such use rarely generates serious misunderstanding even though there is no precise, let alone quantitative, definition of traffic safety. The general concept is the absence of unintended harm to living creatures or inanimate objects. Quantitative safety measures nearly always focus on the magnitudes of departures from a total absence of some type of harm, rather than directly on safety as such. Depending on the specific subject and on available data, many measures are used. [7]

Passenger, driver, occupants:

Any person in (or in the case of motorcycle, on) a vehicle is referred to as an occupant. Occupants are either driver or passengers. Different vehicles can various categories of occupants (passengers, drivers, flight crew, cabin crew, stowaways, hijackers etc).

Risk

In road traffic, risk is a function of four elements. The first is the exposure – the amount of movement or travel within the system by different users or a given population density. The second is the underlying probability of a crash, given a particular exposure. The third is the probability of injury, given a crash. The fourth element is the outcome of injury. [8]

Safety Evaluation

Evaluation of prevailing road safety conditions and the future improvement measures is the paramount to disseminate the actions taken as safety initiatives. In literature several methods are proposed by the researchers such as Meta-analysis, Cost-benefit analysis, HAZOP applications, Road safety performance indication (RSI's) etc.

2.3 WHY ACCIDENT OCCURS

Road accident is not the result of a single cause but the combination of several contributory factors which are associated with the road users, the vehicle and the road environment. The causes of accidents are:

- Reckless driving
- Non-roadworthy condition of vehicles;
- Vehicles over-loading & drug addiction of drivers;

- Lack of general public safety awareness;
- Improper road design & maintenance;
- Lack of traffic management measures;
- Inadequate traffic control devices (signs, marking, etc.)
- Adverse roadway & roadside environment
- Poor design of junction & road section
- Excessive speeding
- Overloading, dangerous overtaking
- Carelessness of road users
- Failure to obey mandatory traffic regulations
- Defects in vehicles & conflicting use of roads
- Low level of awareness of safety problems

A 1985 study by K. Rumar, using British and American crash reports as data, found that 57% of crashes were due solely to driver factors, 27% to combined roadway and driver factors, 6% to combined vehicle and driver factors, 3% solely to roadway factors, 3% to combined roadway, driver, and vehicle factors, 2% solely to vehicle factors and 1% to combined roadway and vehicle factors. [9]
According to W.H. Paul (1972), the accident loss factor is classified into nine categories which are given below: [10]

Designation ***Examples***

Pre-cash

1) Human………………. Driver fell asleep
2) Vehicle……………….Brake failure
3) Environment…………Slippery roadway surface

At-crash

4) Human………………..Seat belts improperly worn
5) Vehicle………………..Structural weakness of side of vehicle
6) Environment…………Unyielding sign post near pavement

Post-cash

7) Human……………….By-standers took improper first aid action
8) Vehicle………………Vehicle not equipped with a fire extinguisher
9) Environment………..Emergency telephone not available

2.4 ELEMENTS INVOLVED IN ACCIDENTS:

The circumstances leading to the occurrence of accidents are the complex interaction of a number of factors such as

- Road geometries
- Traffic characteristics
- Road user behavior
- Road environment
- Level of implementation of laws relating to road accidents.

2.5 SCIENCE AND POLICIES IN ROAD SAFETY:

Road safety research, in particular road safety evaluation research, is highly emerging task. This type of research is carried out mostly to help reduce the number of road accidents and the injuries resulting from them.

Both of science and policies involvement are significant in the field of road safety for rationalizing improvement measures. Politico, scientific researchers and the concerning safety organizations should step forward for better amelioration of the prevalent road safety problems. According to Elvik [11] for policy making three important issues will be judged by the policy makes that are normative, empirical knowledge and perspectives. A broader scientific analysis of each road safety improvement measures and their evaluation for applicability in every nation are also depend in some extant to the prevailing political environment. Also researchers should be encouraged to deploy their technical know-how in road safety. A bridge need to be drawn between political power and scientific power.

2.6 AN OVERVIEW OF ROAD SAFETY:

The first road fatality in the world happened on August 17, 1896. The Lady named Bridget Driscol was hit by a car of tremendous speed (reported to be 4 mph) according to the witness. The driver of the car was Arthur Edsell who had been driving for only 3 weeks. There were no driving tests or licenses existed at that time. He was also said to have been talking to the young lady passenger beside him. After a six-hour inquest, the jury returned a verdict of "Accidental Death". At the inquest, the Coroner said: "This must never happen again". [12]

The important issue is that in the course of the past 115 years highway traffic safety has come a long way. There is no panacea in traffic safety. Safety is a multi-dimensional issue, and crashes are the outcome of multiple variables that interact at a specific place and time. In the early stages of motorization, it did not take rigorous scientific research to achieve major improvements in traffic safety. Instead, early traffic-safety countermeasures were often based exclusively on common sense [13]. Since then, scientific research has gradually increased in importance as the basis for developing successful interventions. Common sense could be applied only for easy problems rather than the complex one. Fortunately, our understanding of the complexities involved in traffic safety has recently made major gains, and common sense can now be supplemented, to some degree, by valid technical analysis as well as holistic policy management.

2.6.1 Road Safety Improvement Approaches:

According to literature it has been seen that the approaches to improve road safety have varied over time and reflect the way researchers and society explain accidents and how they can be avoided [14].From the scientific literature it is quite difficult to identify a clear line of development of different approaches to road safety. Wegman [14] has summarized road safety characteristics during the past decades in the following table-1.

Period	*Characteristic*
1900-1920	Accident is a chance phenomenon
1920-1950	Accident caused by the accident-prone
1940-1960	Accidents are mono-causal
1950-1980	A combination of accidents fitting within a “system approach”
1980-2000	The person is the weak link; more behavioral influence
2000-Later on	- Better implementation of existing policies - “Sustainably Safe”; adapt the system to the human being

Table 2.1: Approaches of Road Safety during the past decades, Wegman (2002) [14]

In compendium the road safety improvement approaches are synthesized into three ways: the system approach, the road-user approach and the “vision zero” approach.

According to *the system approach* of road safety two issues are to be considered through problem identification: (1) the relationship between the source of the problem and the solution, and (2) the effects of changes in any component on the total system. In the system approach, the better understanding of driver behavior, driver sensory, cognitive, and motor skills and limitations, driver motives and driver attitudes is a key to improving highway safety. Inattention to the proper stimulus at the right time can be identified as a causal factor in fifty percent or more of all traffic crashes [15]. By understanding these aspects of the road user (including drivers, cyclists, and pedestrians) we can also improve our roads and vehicles intelligently. The role of vehicle and environmental improvements in this context is to compensate for drivers' shortcomings; as identified in crash analyses and in studies of driver behavior. As stated in a World Health Organization report, their role is to "accommodate and compensate for human vulnerability and fallibility”. [8]

A systems approach has been present 1950-1980, by Wegman (2002) [14]. This approach is mainly based on the work of William Haddon Jr. Haddon (1972) [16] proposes a matrix, the most quoted framework within which highway safety improvements can be addressed is also known as Haddon's Matrix. This simple yet comprehensive and exhaustive matrix addresses crash prevention and injury reduction from the perspectives of the driver, vehicle, and environment, relative to three time periods: pre-crash, crash, and post-crash. The cells in the matrix contain the potential safety interventions as illustrated in Table-2.

ORGANIZATIONAL STRUCTURES

POLICIES

NORMS / VALUES

PHASE	GOAL	FACTORS AFFECTING SYSTEM COMPONENT		
		Road User	Vehicle	Environment
Pre-Crash	Crash Prevention	Licensing, education, enforcement	Inspection of brakes, lights, tires, Crash avoidance systems, alerting systems	Road design and layout, high-friction pavement, speed calming, pedestrian separation, safety policy and goals
Crash	Injury prevention and reduction of injury severity	Use of restraints, impairment	Occupant restraints, air bags, crash absorption, safety glass, padded interiors	Crash absorption barriers, breakaway poles, elimination of roadside objects, hard shoulders
Post-Crash	Injury treatment, life preservation	Medical treatment and evacuation	Ease of extraction, fire prevention	Rescue facilities, evacuation lanes and recognized traffic control procedures in congestion, treatment procedures

CULTURE

Table 2.2: A modified Haddon Matrix of means of increasing safety in terms of crash prevention, injury prevention, and injury reduction in the broader context of the social environment.

The specific actions that can be taken within each cell have changed significantly since the matrix was first introduced by Haddon 35 years ago [16], but the general principles have remained quite the same. To illustrate, half a century ago nearly all efforts in crash prevention efforts would have focused on road user as the decision maker and controlling element in the roadway-user-vehicle system. Today, many driving functions that used to be exclusively human are relegated to or shared with the vehicle. These include speed control (with cruise control) and maintaining safe headways (with adaptive cruise control). Other traditional driver responsibilities are in advanced stages of shifting to the vehicle or the infrastructure, such as invehicle fatigue monitoring and alertness maintaining devices (with new lane position detection systems). The automation of enforcement - with speed cameras and red light cameras - is another area where the role of the human (in this case, the law enforcement officer) is being replaced by the infrastructure.

All of these changes occurred because of two significant evolutionary processes. The first is the introduction of intelligent transportation systems (ITS) in the form of interactive in-vehicle and infrastructure based systems that alert the driver to dangerous conditions and to the status of his or her own vehicle. The second is the expansion of the environment beyond the immediate roadway and its structures to include the prevailing culture, and even the impact of alternative modes of transportation and organizational climate within which safety is treated.

The traditional approach to road safety, *the road-user approach* (RUA), has been that the individual road-users utterly are responsible when crashes occur. Sabey and Taylor [17], claiming that road-user factors are the sole or contributory factors in approximately 95% of all road accidents. According to Wegman [14] international research groups still support the truth of these findings. One example that clearly shows the impact of those findings on road safety strategies is the Irish Government Strategy for Road Safety 1998-2002 quoted by Wegman [14]: Human action is a contributory factor in over 90% of road accidents. The principal emphasis of all road safety strategies must therefore be on improving road user behavior. This behavior needs to be informed, trained, and to be modified, so as to improve interaction between road users, to ensure consideration for others to reduce risk. In this way a culture of road use is created that is both precautionary and proactive in relation to road safety.

Dekker (2002) [18] further claims that such an approach is based on our reactions to failure and shares the following features:

- **Retrospective.** Reactions arise from our ability to look back on a sequence of events, of which we know the outcome;
- **Proximal.** They focus on those people who were closest in time and space to causing or potentially prevent the mishap;
- **Counterfactual.** They lay out in detail what these people could have done to prevent the mishap;
- **Judgmental.** They say what people should have done, or failed to do, to prevent the mishap.

Countermeasures have thus mostly been aimed at changing the behavior of the road-user in order to adapt him/her to the road transport system. The road safety work has up until now heavily been relying on steps such as regulating and surveillance of behavior, information and education in order to make the road-user to behave correctly so that accidents will not occur. Mackay and Tiwari [19] claim that the historical view of remedies is “that road users through training, supervision and retribution can cope with the demands of traditional highways without causing accidents”.

The *“Vision Zero”* approach to road safety is built around two axioms; the system must be adapted to the mental and physical conditions and limitations of the human being and the responsibility for road safety must be shared between the road-users and the designers and professional operators of the system.

The most ambitious goal of this type is the one declared by the Swedish government under the heading of "*Vision Zero"*. According to this approach, the goal of the government is to ensure that there are essentially no fatalities on the road. There are several implications from this statement: (1) Life is of paramount importance and cannot be traded off against other values such as pleasure or expediency (e.g., from speeding), (2) the responsibility for achieving this goal rests with the government (thus, faulting the driver is not an acceptable alternative), and (3) achieving this goal requires a systems-wide approach [20]. Although the approach is unique it seems to be proving itself in the sense that Sweden is one of the world's leaders in highway safety.

2.6.2 An Overview of Roadway and Environmental modification

The general approach in the design of safe roads is to minimize the potential for going off the road and the potential for conflicts: conflicts among cars, bicycles, motorcycles, and pedestrians. Improvement goal may be achieved by separating motorized vehicles from pedestrians (with overpasses, underpasses, and pedestrian-only streets), from bicycles (by providing cyclists with special lanes), and from each other (by constructing divided highways).

One obvious way of eliminating many such conflicts is to replace narrow two lane roads with divided highways with wide median strips or barriers between opposing traffic lanes. Replacing a rural arterial road by high-speed divided highway reduces fatality risk (relative to total distance traveled) by 45% while significantly cutting travel time. Replacing signalized intersections with modern roundabouts increases safety and under most conditions also improves traffic flow. Replacing intersections with overpasses and underpasses eliminates collisions with cross traffic and improves traffic flow. Providing passengers with bridges and underground crossings reduces jay walking and pedestrian injuries while it increases traffic flow. All of these solutions are intuitively obvious, but also expensive. But there are other, less obvious, environmental enhancements that can assist drivers in avoiding crashes, and they are considered below.

Perceptual modifications: affecting drivers' perception of the roadway

In early studies conducted on crash data on rural curves in Ohio we noticed that the physical parameters of curvature have less to do with crash statistics at curves than the drivers' visual perspective of these curves [21], and changes in the delineation system in the curves and immediately ahead of them, that affected the drivers' perceptions of the curve and the road leading into the curve, were effective in reducing driver speeds as they entered the curve [22]. For example, by painting a sequence of lines perpendicular to the road with decreasing space between adjacent lines it is possible to give drivers an enhanced sense of speed, which they then reduce to maintain their 'desired' speed [22]. Other modifications such as Painting a herring-bone pattern that is supposed to induce a perception of road narrowing has also been shown to reduce drivers' speed [22] and variability in their lane position [23]. Perceptual modifications are more effective than instructional signs (such as speed advisory signs), because most drivers prefer to trust their direct sensory impressions than instructional and warning signs. Despite repeated demonstrations of the effectiveness of perceptual modifications in studies conducted in Australia, England, Japan, Sweden, and the U.S. [24], the approach has not gained wide appeal; perhaps because it implies 'tricking' the drivers' perceptions. Another problem with many modem high-speed roads is that they relieve the driver of so much of the driving task that their monotony actually induces fatigue and tends to induce what some have labeled "highway hypnosis" - driving without awareness (DWA) that is due to a tendency to become drowsy and fall asleep. There is some scientific basis for this phenomenon. Cerezuela [25] showed that drowsiness as measured by changes in EEG was greater after driving for prolonged periods on motorways than on conventional roads. To counter this and other reasons for exceeding the lane boundaries, rumble strips along the shoulder markers and along the median striping on 2-lane rural roads have been proposed, and in some locations installed. Charlton (2007) [23] found that rumble strips on the center lines and edge lines before curves reduced drivers' entry speeds, and Persaud [26] demonstrated that such rumble stripes in the median marker of two-lane rural roads significantly reduce crashes, especially head-on collisions with opposing traffic.

Positive guidance and self-organizing roads

For the improvement of veridical perceptions of the road, and to enable drivers to make correct control and guidance decisions quickly, The U.S. Federal Highway Administration proposed a set of rules for a design concept called "positive guidance": placing and designing roadway features in a way that maximizes the likelihood that drivers will respond with appropriate speed and route selection [27]. According to Dewar [28] “positive guidance is provided when the information is presented unequivocally, unambiguously and with sufficient conspicuity to allow the driver to detect a hazard in a roadway environment that may be visually cluttered, recognize the hazard or its threat potential, select an appropriate speed and path, and initiate and complete the required maneuver safely". In positive guidance, the information provided should conform to the following rules:

- Primacy - Information on signs should be placed according to its importance to the driver, and in the case of possible information overload, less important information should be deleted altogether.
- Spreading - When the total content is requires too many words, the information should be spread over several successive signs.
- Coding - Information should be coded according to ergonomic principles and conform to existing standards, driver expectations, and population stereotypes.
- Redundancy - There should be some redundant information, to ensure that in case one source is missed by the driver the other is not.
- Expectancy - All guidance and navigation information should conform to the drivers' expectancies (e.g., exits from right lanes).

A complementary approach to positive guidance that was developed in Europe is that of 'self-organizing roads'. The basic concept here is that the roadway itself should provide the drivers with all the necessary cues concerning speed and steering. It has been shown that treatments consistent with that philosophy - such as road narrowing, introduction of curves and roundabouts, and conspicuous speed bumps - are more effective at speed reduction than speed control through automated enforcement [29].

An interesting application of the self-organizing roads concept is the ‘2+1 road’s to prevent risky passing of slow-moving vehicles. The 2+1 roads are 3-lane road segments in which every several kilometers the road will have two lanes in one direction and a single lane in the other direction. These designs are common in some European countries such as Denmark, Germany, Finland and Sweden (but quite rare in the U.S. where nearly all major high-speed roads are at least two lanes in each direction). Signs along the 2+1 roads inform drivers of the distance to the next two-lane passing segment. By designing the passing segments fairly close to each other, this system encourages drivers to be patient and stay behind slow moving vehicles rather than risk passing in the presence of on-coming traffic. The approach has proven itself and drivers tend to be very responsive to this design. It reduces risky passing behaviors, crashes and fatalities, while increasing traffic flow. In Germany, the crash rates on 2+1 roads are 36 percent lower than on conventional two-lane highways; in Finland 2+1 roads are estimated to have crash rates that are 22-46 percent lower than conventional two-lane highways; and Sweden has experienced a reduction of over 50 percent in fatal and injury accidents with the implementation of 2+1 roads with cable barriers along the median (2+1 roads without cable barriers were less effective) [30].

In fact, there are situations where naturalistic perception of the road environment and communications with other road users are more effective and safer than dictating behavior through traffic control devices. Persaud [26] finding that the replacement of traffic signals with multi-way stop signs in one-way streets in Philadelphia PA, resulted in a 24 percent decrease in collisions. In this case intersection crossings based on drivers' own decisions proved safer than relinquishing the role of decision to traffic lights. Taking the same concept to extreme, a few small towns in Europe (Drachten in the Netherlands, Ejby in Denmark, Ipswich in England, and Ostende in Belgium) have begun to eliminate all traffic signs and signals and instead require drivers to assume all the responsibility for traffic management. Though the results of these experiments are still uncertain, the towns' people seem to support it [31].

Traffic calming

In 2001, the first 28 Slow Cities were certified, the majority being located in northern Italy, particularly in Tuscany and Umbria. The list has since grown to include cities in Europe and Brazil, for example. While the movement strictly applies to cities of 50,000 people or less, many of the principles of Slow Cities can be applied in any city. Part of the Slow Cities charter encourages citizens to ‘‘promote the use of technologies to improve the quality of the environment and the urban fabric” [32]. An important principle of slow cities is that they promote a more human, less frenetic way of life. Slow Cities are not just, however, about a fast city slowed down; they are about challenging the dominance of speed, accepting the view that it is OK to be slow [33]. This challenge to the dominance of speed is important for road safety in multiple ways. First, if this is applied to urban speed limits and average driving speeds, there are immediate and clear road safety benefits, as speed is clearly a significant factor in traffic accidents. Secondly, if the slow cities movement can encourage people to use local public spaces, then one impact of this is reduced traffic levels, as well as more careful driving from psychological traffic calming [34].

Scope of measure	Physical/ environmental ('Technique') E	Social/cultural ('Ethos') C
L Local (street or neighbourhood)	LE Local area traffic management	LC Neighbourhood speed watch
	Low-speed street design	Community action to oppose extraneous traffic
	Speed control devices	*Walking school bus*
I Intermediate (traffic corridor, regional road)	IE Lower speed zones	IC Voluntary behaviour change
	Shopping precincts with pedestrian focus	Mode choice (walk, cycle, bus) and reduced use of car travel – *TravelSmart*
	Bicycle lanes	
M Macro (city-wide)	ME Travel demand management (TDM)	MC Cultural change
	Changing urban form and structure	Loss of choice e.g. *peak oil and climate change* policies leading to behavioural changes such as reduction in car travel, lower driving speeds etc.
	Total system measures e.g. fares policy	

Table 2.3: A framework for classifying traffic calming measures (The ''Darwin Matrix'') (Brindle, 1991) [35]

Brindle) [35] proposed ''Darwin Matrix'' used for classifying various forms of ''traffic calming'' is shown in Table 3. This model is useful in providing specific meanings for a not well-defined term. Thus, it identifies three levels of traffic calming (labelled L for local; I for intermediate; and M for macro or city-wide). Such actions may involve the familiar physical traffic control and design treatments (''E'' for engineering or environmental), and social and cultural changes (''C'' for culture).

Traffic calming with roundabouts is the most effective means of slowing drivers, especially through the use of single lane traffic roundabouts. Their effectiveness is greater in severe and fatal crashes than in non-injury and slight injury crashes. Retting [36] evaluation of the effects of replacing signals and stop signs with single lane roundabouts at 24 U.S. intersections is a good example with 76 percent decrease in injury crashes and 90 percent decrease in incapacitating injury and fatal crashes.

3-wayoffset and fused grid neighborhood patterns

The Dutch Sustainable Road Safety (SRS) Program has produced a number of innovative land use and transportation initiatives for vehicular road users as well as non-vehicular VRUs. Following from the Dutch initiatives, these new 3-way offset, and fused grid neighborhood patterns appear to not only have positive effects in encouraging mode split (i.e. increasing walking and bicycling, and transit),slowing traffic, and reducing energy consumption and GHG emissions; but also, to hold potential to improve road safety.

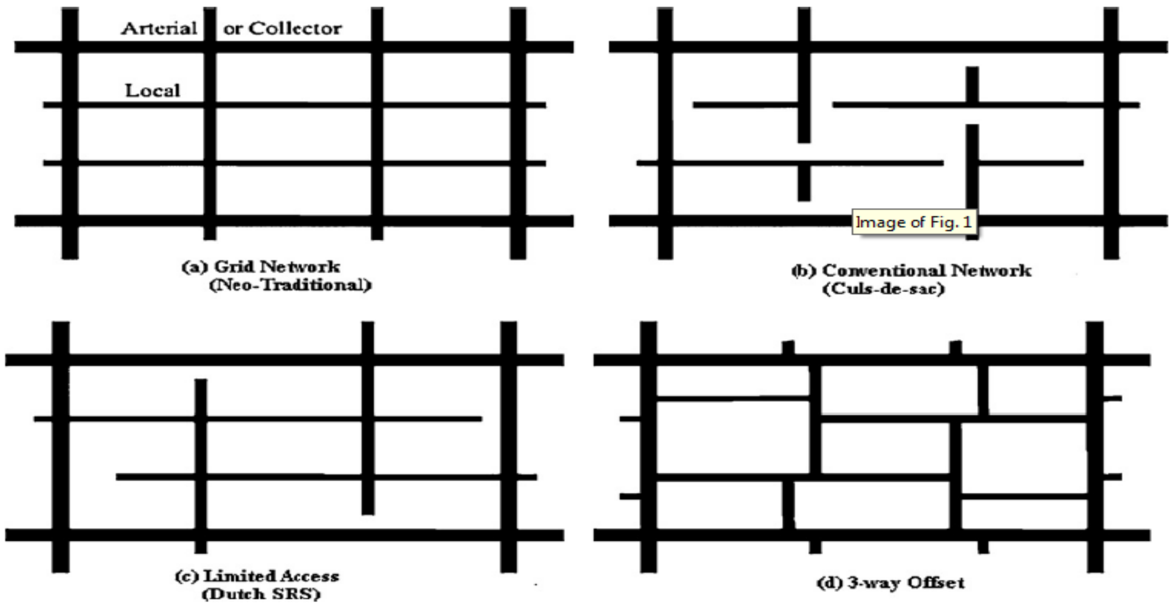


Figure 2.1: Neighborhood road network patterns [37].

The above figure suggested the new road network pattern supplement to the traditional grid network. The cul-de-sac road patterns are popular in residential area to limit through-traffic their accessibility for transit, utility, and emergency vehicles is significantly less than grid [38]. 3-way offset pattern addresses the road safety problem reducing high connectivity transforming the 4-way intersections to 3-way intersections [39]. The fused grid pattern is similar to 3-way offset and providing a safer accessible neighborhood layout that promotes balance between auto and non-auto travel modes shown in figure-2.

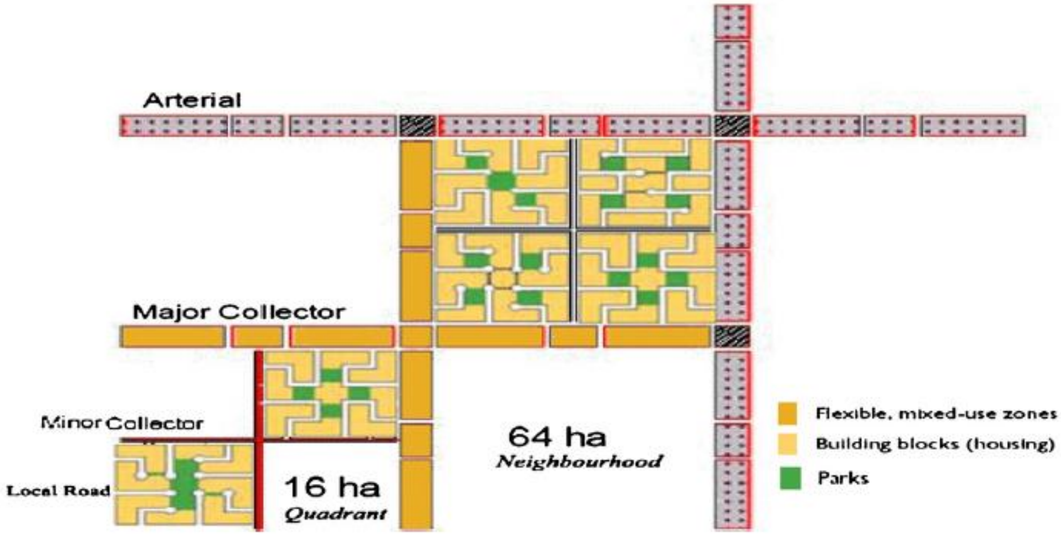


Figure 2.2: Fused grid neighborhood pattern (Frank and Hawkens, 2006) [40]

It is recommended that planners and engineers should carefully consider neighborhood land use and road patterns – the fused grid or 3-way offset patterns with promise to simultaneously facilitate community sustainability, increased VRU volumes and optimized road safety. Past, present and emerging research can be reasonably expected to lead to in the order of 30% less risk of VRU injuries and up to 60% fewer total collisions than traditional grid and conventional cul-de-sac neighborhood pattern. (Vicky Feng Wei, 2010) [41]

Enforcement as part of environmental traffic control

Enforcement can be part of the environmental approach to safety improvements in two respects: by including automated enforcement in the infrastructure, and by enforcing the proper design and maintenance required of the local authorities. Today's technology enables us to automate various aspects of traffic law enforcement. Red light cameras can detect, photograph, and record the license plate numbers of traffic light violators. Speed cameras can do the same for speed limit violators, and even headways between vehicles can be monitored and recorded - though not as reliably – to enforce safe headways [42]. Decina [43] concluded that both speed cameras and red light cameras not only reduce the frequencies of these violations, but are effective in injury reductions. The effects of speed cameras on speeds and crashes were evaluated in Australia, Canada, the Netherlands, New Zealand, the U.K., and the effects of red light cameras on crashes and injuries were evaluated in Australia, Canada, Hong Kong, the Netherlands, Singapore, U.K. and the U.S.The result showed that speed cameras are effective in speed and crash reduction, though better controlled evaluations are needed. Speed cameras are also effective, not so much in the reduction of crashes, as in the reduction of crash severities: by decreasing the number of side collisions with cross traffic at the expense of an increase in less severe rear end collisions [43].

Visual enhancement of roadway features

In the industrialist western countries, for example between 30 percent to 60 percent accidents fatalities occur during the hours of darkness despite the fact that the volume of traffic during this period is substantially lower than that of day-time hours. Three methods are used to increase legibility and visibility of signs, markings, and roadways: improving legibility and comprehension of signs through ergonomic design, increasing the ambient nighttime illumination (with street lighting and vehicle headlamps), and increasing the contrast of obstacles and sources of information (with choice of colors and by using retro-reflective or fluorescent materials. Kline and Fuchs [44] compared the visibility distance for signs comparing with the text, standard American symbols, or 'improved' symbols. The improved symbol signs retained the original general design (so that they remained familiar to the drivers) but maximized contour size, size of small details (gaps), and contour separation. The effects of these seemingly small changes were quite dramatic, especially for the older drivers. For drivers of all ages, standard symbol signs were identified from twice the distance as the text signs, and their 'improved' symbol signs were identified from an additional 50 percent farther by middle-aged and older drivers. The effects of contrast enhancement are controversial. Kallberg [45] evaluated the effects of delineation reflector posts in Finland where in 22 pairs of similar rural road segments one road was equipped with the reflectorized posts along the edge and one was not. He found that in the presence of reflectorized posts drivers increased their speed, and nighttime injury crashes increased by 40-60 percent. Before applying the improvement measure it’s important to foresee the feasibility of effectiveness.

Traffic signals management

Timing the signal phasing according to the ITE recommendations is safer than timing the phases so that they do not provide for adequate clearance of the intersections. This has been shown both in terms of the frequencies of drivers running the red lights [46], and in terms of injury crashes; especially with pedestrians and bicyclists [47].

Synchronization of the green cycle along travel routes is often used to improve traffic flow. However, they also have a safety benefit. In a study conducted in select Tel Aviv urban routes, it has found that drivers are much less likely to run the red lights when the timing of the signals along the route is synchronized with the traffic speed than when it is not. Furthermore, the likelihood of running red lights increased as congestion increased, traffic speed deviated more and more from the design speed, and the signal timing became less and less relevant to the drivers along the route [48].

2.6.3 An Overview of Vehicle Safety and Design for Safety

Periodic Motor Vehicle Inspections (PMVI's)

Vehicles have always had safety features. Over the years these features have both improved in their performance (e.g., tires) and in their variety (e.g., hazard warning systems). So it only seems rationale that one of the primary pre-requisites for safe driving be a safe vehicle, or at least one that performs according to the current safety standards. Analysis of insurance records also indicates that technical vehicle defects (prior to inspection) are associated with crash risk [49]. Thus, to verify that all the vehicles on the road meet these standards, many countries have periodic motor vehicle inspections (PMVI's), a proactive safety policy that is recommended by the World Health Organization [8].
There have, however, been two studies - both conducted in New Zealand - that suggest that PMVI's are effective. In New Zealand PMVI's are conducted every six months and defects are recorded in less than one percent of the vehicles [50]. White [50] examined the likelihood of a crash as a function of time since PMVI, and found - as he hypothesized – that crash probability increased with increasing time since the last PMVI. However, vehicle defects were noted in only 2.5 percent of vehicles less than 15 years old, and in approximately 5 percent of the vehicles that were 15 years old or older (of which there are not many vehicles).

In-vehicles intelligent systems

The automotive industry was rather late in embracing digital technology, but once it did, it embraced it with enthusiasm. Intelligent transportation systems (ITS) and vehicle telematics are now an integral part of all new vehicles, and the number of such features seems to be increasing in an exponential manner. These new systems, however, are of two types: safety systems and "infotainment" systems. While the former are designed to increase safety, the latter - as a byproduct - typically reduce it by increasing driver distraction and inattention. Hopefully the joint introduction of both results in a net gain for safety.

New and not-so-new ITS-based safety features typically involve the detection of hazards or hazardous situations, and in some instances also involve an intervention. Most of the systems are based on analyzing vehicle and roadway information, and thus circumvent the complex requirements of having to adjust to individual differences in driver behavior. Such systems include antilock braking systems (ABS), electronic stability control (ESC), hazard and fatigue detection, and adaptive cruise control. Other systems that are specifically designed to improve both safety and mobility include improved braking, tires, and lighting. Some devices originally designed to improve safety, such as ABS, can end up improving mobility more than safety. Night vision systems will certainly increase mobility (especially for older drivers) even if their effect on safety is uncertain. New 2007 cars have a variety of safety features [51] including adaptive cruise control coupled with hazard detection (e.g., Lexus LS 460) and even braking for mitigation of impending collisions (e.g., Ford S-MAX) that should reduce the frequencies of crashes due to the ubiquitous lapses in attention. Systems that detect the vehicle placement in the lane already assist drivers by both warning them when the vehicle moves in an uncontrolled fashion that may be indicative of fatigue (e.g., Volvo), or of lane departure (e.g., Citroen C6), and actually applying some steering torque to assure that the car remains centered in the lane (e.g., Honda Accord). Active head restraints that move the head rest forward in the event of a collision (e.g., Kia Sedona and Mercedes E-Class cars) should reduce neck injuries in forward collisions. Adaptive headlamps adjust lighting to the weather and driving conditions should improve visibility and nighttime obstacle detection (in the Mercedes E-Class). Flashing brake lights that are activated in emergency braking presumably reduce brake reaction times, and should therefore reduce rear-end collisions (in the Mercedes E-class cars). Assistive headway systems can now monitor headways to vehicle ahead and brake if the driver fails to do so when necessary (e.g., Nissan Infinity).

While the array of new safety systems is large and varied and the technological achievements are truly impressive, good evaluation studies of these systems' effectiveness are sorely lacking. The actual safety benefits of most systems that are being considered, and even some that are already implemented, are still unknown or based on very limited data. An attempt to provide a data-based evaluation of various in-vehicle safety technologies was made by the U.S. Federal Highway Administration [52] that compiled the evaluation research available as of the end of 2005. Table-4 provides a summary of the road safety improvements using in vehicle ITS.

Area	*System*	*Safety Benefit*
Collision Avoidance Systems	Obstacle Detection	A transport company in Canada reduced at-fault accidents by 34% in 1st year after installation of a radar-based collision warning system with forward-looking and side sensors to warn drivers of obstacles in blind spots. [53].
	Lane Change Assistance	A NHTSA study indicated a lane change 1 merge crash avoidance system would be

		effective in 37% of crashes. [54]
	Lane Departure Warning	A study conducted by NHTSA indicated a road-departure countermeasure system would be effective in 24% of crashes. [54]
	Forward Collision Warning	A NHTSA modeling study indicated collision warning systems would be effective in 42% of rear-end crash situations where the lead vehicle was decelerating, and effective in 75% of rear-end crashes where the lead vehicle was not moving. Overall, collision warning systems would be 51% effective. [54]
Driver Assistance Systems	Navigation / Route Guidance	Safety impacts of in-vehicle navigation systems were estimated using simulation models and field data collected from the Trav Tek project. Results indicated users could decrease their crash risk by up to 4%. [55].
	Adaptive Cruise Control	The performance of the system on ten cars in NHTSA study was compared to conventional cruise control and manually operated vehicles. Results indicated that vehicles with adaptive cruise control made the fewest number of risky lane changes in response to slower traffic. Manually operated vehicles, however, had the quickest average response time to lead vehicle brake lights. [56].
	Intelligent Speed Control	25 personal vehicles in Sweden were equipped with governors activated by beacons at city points-of-entry to limit inner city vehicle speeds to 50 km/h. The vast majority of participants preferred this adaptive speed control over other physical countermeasures such as speed humps, chicanes, or mini-roundabouts. [57].
Collision Notification Systems	Mayday Automated Collision Notification	The Puget Sound Help Me (PuSHMe) Mayday System allowed a driver to immediately contact a response center, transmit GPS coordinates, and request assistance. Survey of 77 users indicated 95% felt more secure if equipped with Mayday voice communications, and 70% felt more secure with Mayday text messaging [58].

	Advanced Automated Collision Notification	Impacts on incident notification were tracked for vehicles with and without ACN systems in urban and suburban areas of NY. Average notification time for vehicles with ACN was less than 1 minute with some notification times as long as 2 m. Average notification time without ACN was about 3 m, with some notification times as long as 9, 12,30, and 46 m. [59]

Table 2.4: Safety-oriented in-vehicle intelligent transportation systems (as of 2005; from Maccubbin et al., 2006).[52]

Center High-Mounted Stop Lamp (CHMSL): The CHMSL was introduced in the U.S. as a requirement for new cars in 1986. Studies that preceded its required installation demonstrated that this single central rear light reduced 'relevant' rear end crashes by 50 percent; or an estimated overall reduction in rear end collisions of 35 percent. A more recent evaluation of the CHMSL conducted in Israel, showed that without control for various confounding factors the CHMSL effectiveness in preventing police-reported rear end collisions appeared to be approximately 7 percent, but following adjustment for some potentially confounding variables more sensitive analyses showed that this reduction may be due to other potentially confounding factors that are unrelated to the CHMSL [60].

Anti-lock braking systems (ABS): Multiple crash analyses, employing various exposure measures against which the crash involvement of ABS-equipped vehicles was compared to the crash involvement of vehicles without ABS, have yielded fairly consistent results: ABS-equipped cars have fewer frontal impacts, especially on wet roads, but they have more run-off-the-road crashes, rollovers, collisions with fixed objects, and side impacts than non-ABS-equipped cars. Consequently, the net effect of the ABS on both crash reductions and fatalities has been essentially nil [61].

Electronic stability control (ESC): Farmer [62] found a 7 percent reduction in overall crash involvement of ESC equipped vehicles, a 34 percent reduction in fatal crashes, and a 41 percent reduction in single vehicle crashes. Dang [63] found a 35 percent reduction in single vehicle passenger car crashes and a 30 percent reduction in fatal crashes. The results obtained in studies in the U.S. [62], in Sweden and in Japan [64] were all quite positive. The U.S. National Highway Traffic Safety Administration estimates that once ESC is available on most vehicles it should result in 30 percent reductions of all U.S. single vehicle crashes and a savings of close to 10,000 lives annually [65].

2.7 AN OVERVIEW OF POLICIES OF ROAD SAFETY

Policy on Road Safety covering both preventive and post-accident aspects of Road Safety encompassing initiatives of public policy as well as implementation aspects, as also the responsibilities of various stakeholders. [1]

Road safety policy analyses for Norway and Sweden have concluded that if the priorities given to different road safety measures were based strictly on cost–benefit analyses (CBAs), there would be a larger reduction in the number of fatalities and injuries than currently accomplished. [66]

Policies can apply as following factors to improve road safety: [71]

- Raising awareness about road safety issues
- Providing enabling legal, institutional and financial environment for road safety
- Road safety information database
- Safer road infrastructure
- Safer vehicles
- Safer drivers
- Safety for vulnerable road users
- Road traffic safety education and training
- Traffic enforcement
- Emergency medical services for road accidents
- Research for road safety

New Zealand’s first Transport Strategy, published in December 2002, set out the road safety targets (first announced in September 2002) and established the Government’s objective for a road safety outcome by 2010 that is among the best in the world.
The strategy outlined a vision of a transport system that is affordable, integrated, safe, responsive and sustainable to be realized by means of an integrated approach that is forward-looking, collaborative, accountable, and evidence-based to the following 5 objectives.

- assisting economic development
- assisting safety and personal security
- improving access and mobility
- protecting and promoting public health
- ensuring environmental sustainability.

The integration of these objectives is being established both in new changes in the organization and funding of transport which makes things more complicated for road safety but also brings many opportunities. Other countries, particularly in Europe, have also embarked upon similarly ambitious integrated transport strategies. [67]

The government of Norway has been taken the long-term ambitious goal for transport safety is that nobody should be killed or permanently injured in transport accidents, has been adopted as the basis for transport safety policy plan named “Vision Zero” which is similar as Sweden. The plan for the 2010–2019 terms is currently in the final stages of preparation. “Vision Zero” applies to all modes of transport. A set of more specific policy objectives, possibly a quantified road safety target, may be set in addition to Vision Zero, although at the time of writing a final decision about such objectives has not been taken.

As part of the input to the National Transport Plan for 2010– 2019, a comprehensive analysis of the main options for road safety policy was made. This analysis included a cost–benefit analysis of 45 road safety measures, of which 39 were found to give benefits greater than costs and 6 were found not to do so. The cost–benefit analysis was based on the assumption that each road safety measure is used as efficiently as it possibly can be. For road related road safety measures, in particular, efficient use implies that sites are selected for use of these measures strictly according to traffic volume. In practice, however, selection of sites for the use of road-related measures is based on a process of negotiations between the regional offices of the Public Roads Administration and municipalities. An attempt is made in these negotiations to ensure a geographical distribution of the safety measures that most of those involved regard as fair. The result tends to be that the safety measures are spread out among as many municipalities as possible, including municipalities in which traffic volume on national roads is very low. [68]

These analyses conclude that road safety could be improved substantially if policy priorities were based on cost–benefit analyses to a greater extent than they are today. The use of cost–benefit analysis to set priorities for road safety policy is controversial. At least two arguments are often made against the use of cost–benefit analyses to set priorities for road safety:

1. Cost–benefit analysis is based on the assumption that road safety ought to be provided only to the extent that there is a demand for it (i.e. willingness-to-pay for reduced risk). But, critics claim that one of the major problems of road safety policy is that there is no demand for road Safety. Hence, providing for road safety only to the extent that monetary benefits exceed costs will not result in a large improvement in safety. An OECD report (Organization for Economic co-operation and development, 1993), for example, is based on the assumption that road safety needs to be “marketed” otherwise there will be an insufficient demand for it.

2. It is unethical to reject proposals for improving safety simply because monetary benefits are believed to be smaller than monetary costs. [69]

The SUNflower approach attempts to answer the question what exactly caused road safety to improve in (SUN) countries. When specific beneficial aspects of measures, operational practices, or underlying concepts can be determined, what are the possibilities for transferring these aspects to another SUN country or other countries? A better insight into the relationship between the developments of traffic risks and road safety policies, programmes and measures in these countries might conceivably identify key actors, which could further improve the current road safety practice in each of the SUN countries, and in other countries.

The methodological approach is based on a road safety target hierarchy as shown in Fig. 3 and was adapted from the consultation document on the Road Safety Strategy 2010 of New Zealand

(LTSA, Land transport safety authority, 2000). In this approach a fundamental understanding is required of traffic safety processes at different levels in the hierarchy of causes and consequences that lead to casualties and costs for society. The main reference is the model that describes a target hierarchy of 'structure and culture' towards 'social costs'. [70]

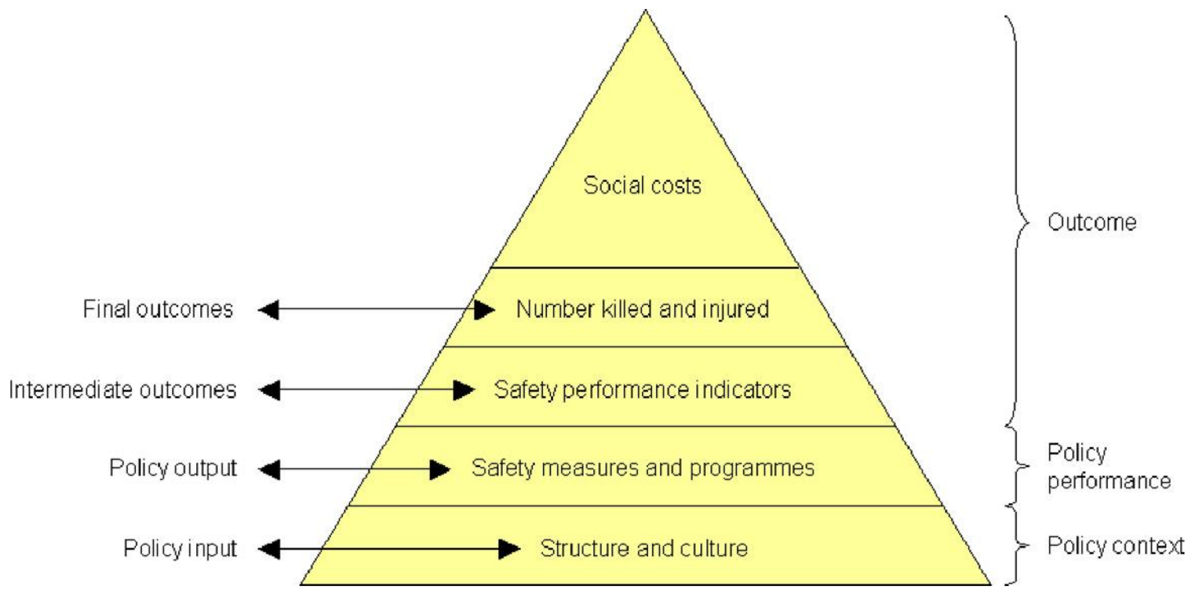


Figure 2.3: A target hierarchy for road safety.

In France at the end of 2001, about 35% of motorists were found to drive at 10 km/h more than the speed limit. This highlighted what was at stake as regards speeding in France and enabled us to understand why the country was so far behind other comparable European countries. In the light of these findings, traffic victims' associations called for tougher speed controls, which led the government to start testing automatic speed cameras in 2001–2002 and then to introduce them from 2003 onwards. The installation of 1400 fixed cameras and the deployment of 700 mobile cameras brought a substantial reduction in speed: the average speed declined by 10 km/h in 2008, with 10% of drivers driving at 10 km/h more than the speed limit. As a result, we observed a sharp fall in the number of deaths on the road – by 48% between 2001 and 2008. By this the powerful positive impact on policy of road safety in France addressing the control limit enforcement of speed is achieved. [3]

2.8 CONCLUSION:

A quick scan of road safety literature addressed the plethora of strategies and devices designed to increase traffic safety should make it obvious that road safety is a complex issue for which there is no panacea or 'magic bullet'. Many 'chefs' are involved in the delivery of safety, beginning with the government and safety oriented organizations, and ending with individual researchers designing and evaluating new safety products and strategies. Safety is maximized when all efforts are coordinated and safety systems are user-centered. Organization-wise, on a national basis, setting a difficult but achievable concrete goal for crash reduction is a key element in a crash countermeasure program.

Because crashes are caused by a variety of factors (that often have to occur together) safety improvements can only be achieved by multiple strategies - targeted at specific well defined problems. No single program can be optimal for all types of drivers, environments, and crashes. On the other hand, many programs, safety oriented behavioral management strategies, environmental design, and technological innovations have contributed to reductions in crash and injury rates very significantly over the past few decades.

There are many safety measures that have zero, or minimal, effects on mobility and other cherished values. Vehicle improvements in crashworthiness and passenger protection have increased safety at no cost to mobility or the pleasure of driving. Intelligent active crash prevention systems should also be effective crash countermeasures that do not reduce the 'fun of driving' as long as they remain invisible to the driver until appropriately activated in - relatively rare -imminent crash situations. Safer highway 'furniture' - such as break-away posts and signs, crash barriers, and rumble striping of lane delineators - should all reduce injuries and improve safety without affecting mobility and hopefully without behavioral adaptations.

Still we must accept the fact that life involves tradeoffs that force compromises. With today's systems many of these tradeoffs are very easy to accept. For example, modern seat belts are easy to use, quite comfortable and, as Evans [7] points out, the two seconds it takes a driver to fasten a safety belt increases the duration of a typical 15 minute trip by 0.2 percent; a totally insignificant reduction in mobility, but one of very consequential magnitude. Other tradeoffs encounter greater resistance. For example, vehicle, environmental, and driver management techniques for speed control all explicitly require drivers to reduce their speed, and if speed is a desired value in driving then by definition it must be compromised. Yet even in speed control some approaches are quite acceptable to most drivers (e.g., environmental traffic calming) while others are not so acceptable (e.g., speed enforcement). Empirical evidence from speed studies in various countries has shown that an increase of 1 km/h in mean traffic speed typically results in a 3% increase in incidence of injury crashes (or an increase of 4–5% for fatal crashes), and a decrease of 1 km/h in mean traffic speeds results in a 3% decrease in the incidence of injury crashes (or a decrease of 4–5% for fatal crashes) [72]

The challenge in the development and implementation of socially acceptable crash countermeasures is finding strategies that minimize the tradeoffs between safety and other driving-related values such as mobility and pleasure. This is where science, technology, and careful scientifically robust evaluations must come together. Many early safety countermeasures that are still with us could be viewed as based on common sense [13]. With limited technology and limited options, the introduction of safety 'systems' was slow and often intuitive. However, as safety regulations, vehicles, and roads became more complex, and technological innovations flourished, common sense countermeasures have given way to science-based, empirically-evaluated, and technology-based safety improvements. It is important that this trend continues; especially now with heightened public sensitivity to safety.

Advances in technology and science - including behavioral science of driver behavior – have provided us with many unconventional and new solutions to old problems such as vehicle control while braking, head-up displays to reduce visual in-vehicle distraction, and collapsible sign posts to reduce injury severity in crashes.

Finally, despite all the regulations, innovations in environmental design, vehicle crashworthiness and adaptive vehicle technologies, it is the driver who remains the most adaptive and controlling element in the traffic system. Therefore, engineering-based solutions to increasing safety will remain relatively ineffective unless they take into account all the potential effects on behavior adaptation in response to these changes. To be most effective, engineering solutions should be user - pedestrian, cyclist, and driver - centered. Regulated and enforced user-friendly solutions designed to address driver limitations in an increasingly dense and complex driving environment are our best hope for improving traffic safety.

CHAPTER 3

ROAD SAFETY PROBLEM CHARACTERISTICS AND EVALUATION

3.1 INTRODUCTION:

After the year of 1970, the highly motorized countries have been greatly improved road safety. It was the most impressive improvement has taken place in the Netherlands, where the number of road accident fatalities was reduced from 3264 in 1972 to 677 in 2008. This decline corresponds to a reduction of nearly 80%. Other countries that have succeeded in reducing the number of road accident fatalities by more than 50% from the peak level include France, Great Britain, and all the Nordic countries. Still, some road safety problems persist and seem to be almost impossible to solve. Thus, even if the total number of fatalities has been reduced by nearly 80% in the Netherlands, young drivers continue to have a considerably higher risk of accident involvement than middle aged drivers, and the injury rate for pedestrians, cyclists and riders of mopeds or motorcycles continues to be higher than the injury rate for car occupants. [73]

In worldwide road collisions are both a social and economical burden on societies. According to World Health Organization (2004) and United Nations (2007) reports on road safety, injuries due to road crashes are the 9th leading cause of death in the world. Projections indicate that road crashes will be the 5th leading cause of death by 2030 unless there is new commitment to prevention (WHO, 2009; UN, 2007). While it is understood that most of the road collisions leading to these morbid road safety records can be attributed to failures in at least one of the three road system components – driver, vehicle and road – a larger dynamic needs to be considered, namely that leading to our auto-dominated culture. [76]

3.2 DIMENSIONS OF ROAD SAFETY PROBLEMS:

The "right" way of defining a road safety problem does not exist anymore. A reasonable definition is that a road safety problem is any factor that contributes to the occurrence of accidents or the severity of injuries. The term road safety problem is broadly synonymous with the term risk factor, interpreted in a wide sense that includes traffic volume as a risk factor. [74]

The following nine dimensions of road safety problems are proposed. [74]

- Magnitude
- Severity
- Externality
- Inequity
- Complexity
- Spatial dispersion
- Temporal stability
- Perceived urgency
- Amenability to treatment

Definitions of dimensions of road safety problems shown in below table 3.1:

Dimension of problem	**Definition**
1. Magnitude	The size of the contribution a problem makes to the total number of accidents or killed or injured road users.
2. Severity	The gradient of the attributable risk associated with a problem with respect to levels of injury severity.
3. Externality	The fact that travel performed by one group of road users imposes an additional risk on other groups of road users.
4. Inequity	The size of the contribution to risk made by a lack of proportionality between the benefits of transport and the risk run.
5. Complexity	The extent to which the specific contributions of individual risk factors to the overall risk represented by a problem can be identified
6. Spatial dispersion	The degree to which an accident problem is concentrated geographically.
7. Temporal stability	Changes over time with respect to the magnitude of a road safety problem.
8. Perceived urgency	The strength of the support in the population for stronger action or regulations designed to solve a problem.
9.Amenability to treatment	The prospect of implementing effective safety treatments, i.e. treatments that will reduce a problem (in particular its magnitude).

Table 3.1: Definitions of dimensions of road safety problems [74]

Some important road safety problems have been known to exist for a long time. As shown in below: [73]

- The high accident rate of young drivers, in particular young male drivers, compared to the safest group of drivers.
- The high injury rate of pedestrians, cyclists and riders of two wheeled motor vehicles compared to car occupants.
- The high rate at which heavy vehicles cause injuries to other road users compared to the rate of injuries to occupants of these vehicles.
- The stability over time of differences in accident involvement rate between different types of vehicles and different types of traffic environment.
- The high proportion of motorists who exceed speed limits.

3.3 ROAD SAFETY EVALUATION

Road safety is usually defined and evaluated in terms of the recorded number of accidents or the number of killed or injured road users. The number of accidents or injured road users recorded during a certain period is the result of a complex process. There are two problems associated with the use of the recorded number of accidents to estimate safety: under-reporting of accidents and random variation in the recorded accident numbers. When evaluating safety measures, it is often better to use estimates of the expected, rather than the recorded, number of accidents by using the Empirical Bayes (EB) method, which also is described below.

3.3.1 Expected number of accidents

The expected number of accidents is the number of accidents (e.g. on a specific road or in a specific junction) that one can expect per time unit, based on known properties of the road or junction. It is the average number of accidents that will occur per unit of time in the long run, given that exposure and all risk factors remain constant.

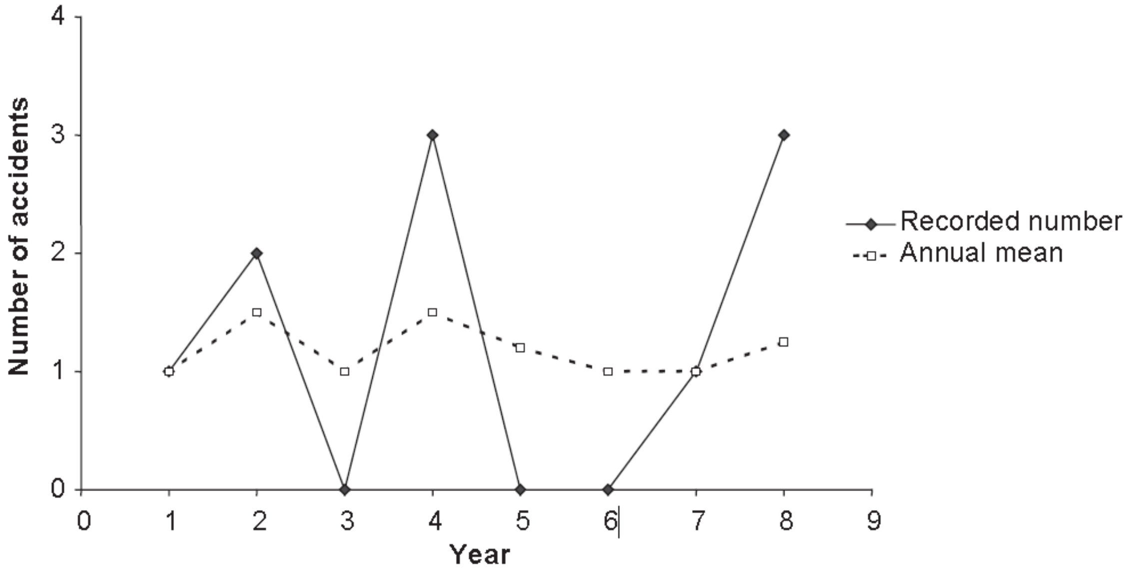


Figure 3.1: Illustration of the concept of the expected number of accidents

The meaning of the expected number of accidents can be clarified by means of an example. Figure 3.1 shows hypothetical numbers of accidents recorded in a junction during a period of eight years. The black dots represent the recorded number of accidents per year and the white dots show the moving average of the annual counts of accidents. In the first year, this is the same as the count of accidents for that year. In the second year, it is the average of the two first years; in the third year, it is the average of first three years, etc.

The expected no of road accident can alter due to Random and systematic variation in accident counts. Random variation in the number of accidents is variation in the recorded number of accidents around a given expected number of accidents. Two sets of factors generate systematic variation in the number of accidents [82]:

- The amount of traffic (exposure)
- Risk factors (factors that affect the probability of accidents at a given exposure): engineering factors and behavioral factors.

3.3.1.1 Expected number of accidents using Statistical method

Pure random variation in accidents is usually modeled by the Poisson probability law. According to the Poisson probability law, the variance of the count of accidents equals the mean. The smaller the size of the standard deviation, calculated as a percentage of the number of accidents, the greater the number is. For example, the standard deviation in 10 accidents is equal to about three accidents, i.e. 30%. The standard deviation in 100 accidents is equal to 10 accidents, i.e. to say 10%. A 95% confidence interval for random variation in the number of accidents can be obtained by multiplying the square root of the number of accidents by 1.96. For example, the 95% confidence interval for an expected number of accidents of 10 is

$$10 \pm 1.96 \times \sqrt{10} = 10 \pm 1.96 \times 3.16 = 10 \pm 6.2$$

The lower limit of the confidence interval is 3.8 and the upper limit is 16.2.

Multivariate statistical models, often Poisson regression models or negative binomial regression models are increasingly used to analyze factors that explain systematic variation of the number of accidents. The most common specification of these models is

$$\text{Expected number of accidents} = \alpha Q^{\beta} \exp^{\sum kx}$$

Where Q measures exposure, i.e. some variable describing traffic volume. Exp is the exponential function, i.e. the base of natural logarithms (e = 2.71828) raised to the sum of parameter estimates multiplied by the relevant values of the explanatory variables, representing risk factors (∑kx).

3.3.1.2 Expected number of accidents in before-and-after studies with the Empirical Bayes method

Results from before-and-after studies may be misleading when evaluation studies are based on the recorded number of accidents, especially when the recorded number is small, and when the study units selected had higher than normal recorded numbers of accidents in the before period. When a measure is implemented only for units with high numbers of accidents in the before-period, the number of accidents will most likely be smaller in the after period, even if the measure has no effect at all. This is referred to as the regression to the mean effect. Regression to the mean may be controlled by using the expected, instead of the recorded, number of accidents in the before-period. Since the expected number is never known exactly, it has to be estimated. By means of the EB method, the expected number of accidents (e.g. on a road section or at a junction) can be estimated as follows:

- It is estimated how many accidents would normally be expected in a unit with comparable properties (risk factors and exposure), based on a multivariate model of accident occurrence in a (preferably large) number of the same type of units, with varying properties. In addition to the normal expected number of accidents, the uncertainty of this estimate is calculated.

- It is estimated how many accidents would be expected for the actual unit, by combining the normal expected number of accidents (step 1) and the recorded number of accidents. The observed number of accidents is included in order to take into account specific unobserved risk factors (that are not included in the accident model in step 1). The expected number of accidents is assigned a statistical weight that corresponds to the uncertainty of this estimate and that can assume values between 0 and 1. The expected number of accidents for the specific unit is calculated as follows:

Expected number of accidents for the specific unit =
Expected number of accidents × Statistical weight
+ Observed number of accidents (1- Statistical weight)

- The observed number of accidents in the after period is compared to the expected number of accidents that has been estimated for the specific unit in the before period [82].

3.3.2 The use of accident rates to evaluate safety

In estimating accident rate, the traditional assumption is that the effects of traffic volume on the number of accidents can be removed and controlled for.

$$\text{Accident Rate} = \frac{\text{No of Accidents}}{\text{Traffic Volume}}$$

According to Hauer (1995) [83] the assumption is not correct. Most accident rates, which are defined per vehicle kilometer or per person kilometer, have a significant non-linearity, i.e. the assumption that the number of accidents is independent of the distance driven or the amount of travel does not hold. Figure 3.2 shows a very striking example of this, taken from a British study [12].

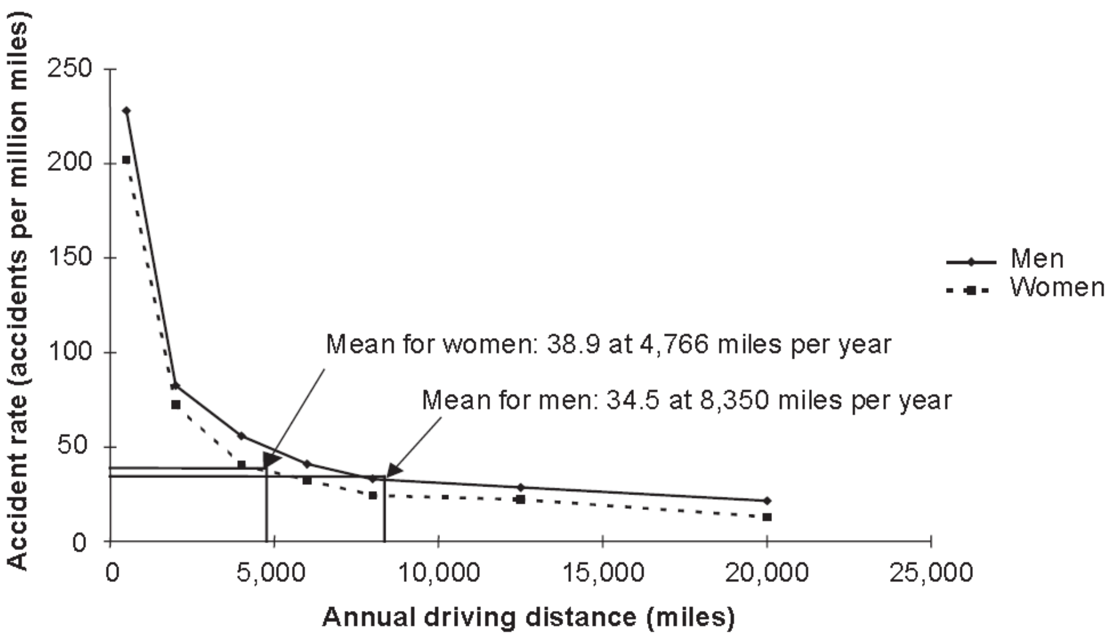


Figure 3.2: Relationship between annual driving distance and accident rate [84]

Accident rate declines sharply as annual driving distance increases. The mean accident rate for men is 0.345 and for women is 0.389. Women have a higher mean accident rate than men, despite the fact that their accident rate for any given annual mileage is lower than the accident

rate for men. If this fact were not known, one might erroneously conclude that women are poorer drivers than men.
The finding presented in Figure 3.2 is a case of Simpson's paradox, which may occur when data exhibiting strong non-linearity, or a strong interaction between two or more factors, are aggregated across categories of the non-linear function or the variables that interact. This can result in a fallacy of aggregation: in this case to an erroneous conclusion that the accident rate for women is higher than it is for men.

Non-linear relationships between traffic volume and accidents have also been found in most studies that have developed accident models for roads or junctions. In most studies, the percentage increase of the number of accidents is smaller than would be expected if there were a linear relationship, i.e. the number of accidents increases at a lower rate than traffic volume. Consequently, the effects of exposure on accidents are not adequately controlled by estimating accident rates and accident rates may have limited value as a measure of road safety. Road safety evaluation studies that use accident rate ratios as the dependent variable are of dubious validity unless the accident rate ratio applies to study units that have an identical amount of exposure and are otherwise identical with respect to at least major risk factors affecting the number of accidents.

Practically, all of the variations and non-linearity made the evaluation studies a bit of complex task for the organizations and practitioners to come up with realistic solutions. Some of the rational approaches of road safety evaluation are summarized below:

3.3.3 The use of meta-analysis for road safety evaluation:

Meta-analysis is essentially a systematic review of available estimates of effect of a particular intervention. According to Elvik (1999), Meta-analysis is a quantified synthesis of results of several studies that have evaluated the same road safety measure stated in the form of a weighted mean estimate of effect [85].

3.3.3.1 Main elements of meta-analysis

The study element of a meta-analysis deals with an estimate of effect. An estimate of effect has to be stated as a precise point estimate in order to be included in a meta-analysis. If a result is stated simply as: 'No statistically significant changes in the number of accidents were found', it cannot be included in a meta-analysis. Moreover, the standard error of an estimate of effect has to be known, at least if results are to be weighted according to their statistical precision. A single study can contain more than one result. In such cases, all results, or the most important results from studies with a very large number of results, have been included in the meta-analyses. Multiple results from the same study have been treated as statistically independent, although this assumption may not always be correct.

Study results can be summarized by means of meta-analysis if the studies

- provide at least one numerical estimate of the effect of a road safety measure, or provide information that can be used to derive such an estimate and

- state the number of accidents on which the estimate of effect is based or provide other information that allows the calculation of the statistical uncertainty of the effect estimate, such as the confidence interval.

Basics of the log odds method of meta-analysis:

In meta-analysis the log odds method has been applied throughout [86]. In this method, a weighted mean estimate of effect is calculated on the basis of the estimates of effect found. This method of meta-analysis was chosen because the odds ratio (OR) is the most commonly found estimate of effect in road safety evaluation studies. An example of how an OR is calculated is as follows: If a study finds that there were 75 accidents on road X before a measure was taken, and 23 accidents afterwards, whereas on a comparison road, there were 67 before the implementation of the measure on road X and 25 afterwards (no measure was implemented on the comparison road), the OR is (23/75)/ (25/67) = 0.307/0.373 =0.822. This result to an accident reduction of 17.8% (-1+0.822). In studies that employ multivariate techniques of analysis, effects are normally stated in terms of an OR that has been adjusted for confounding.

A summary effect is calculated as the weighted mean of the logarithms of the individual estimates of effect (ORs), when applying the log odds method of meta-analysis. Combining logarithms of ORs yields an unbiased estimate of the weighted mean effect of a set of studies. The steps in a log odds meta-analysis are

- calculation of estimates of effect,
- calculation of statistical weights and choice of the model of meta-analysis: Fixed effects when there is no systematic variation in the estimates of effect or random effects when there is systematic variation in the estimates of effect,
- calculation of summary estimates of effect, and
- confidence intervals: for each summary effect, a 95% confidence interval is calculated.

Calculation of estimates of effect:
In the Odd Ratios (ORs), estimates of effect are calculated. In the Table 3.1 some of the estimators of effect commonly found in road safety evaluation studies are listed. It is based on multivariate analyses, which have the statistical properties of ORs, are not as common, but have increasingly been used in recent studies. The different estimators of effect should not be mixed up. Producing summary estimates of effect in meta-analysis

Name of dependent variable	Formal definition
Odds	Uat/Ubt
Odds ratio (simple or adjusted)	(Uat/Ubt)/(Uac/Ubc)
Ratio of odds ratios	[(Uati/Ubti)/(Uaci/Ubci)]/[(Uatj/Ubtj)/(Uacj/Ubcj)]
Ratio of relative risk	[Uati/(Uati+Ubti)]{[Uatj/(Uatj+Ubtj)]
Accident rate ratio	(Ua/Ta)/(Ub/Tb)

U= number of accidents; T= traffic volume, exposure to risk; a=after, or with, some measure whose effect is evaluated; b=before, or without, some measure whose effect is evaluated; t= test group; c= comparison group; i= category I; j= category J.

Table 3.2: Commonly used estimators of effect in road safety evaluation studies [82]

based on studies that employ different estimators of effect can be misleading because both the statistical properties and the substantive interpretations of the various estimators differ. When other estimates of effect other than ORs are reported, ORs are calculated as far as possible based on the available information.

In literature, two methods available for combining estimates of effect in meta-analysis, the fixed effects model and the random effects model. The fixed effects model of analysis is based on the assumption that there is no systematic variation in effects in the set of studies considered, that is, all estimates of effect are samples of the same 'true' effect. When there is systematic variation, or heterogeneity, in the estimates of effect, the estimates cannot be regarded as representing the same 'true' effect. In this case, a random effects model is more adequate. In a random effects model, an account is taken of heterogeneity in the results and an underestimation of the uncertainty of the summary effect is avoided.

3.3.3.2 Application of meta-analysis in CAST project:

European Commission supports a targeted research project, Campaigns and Awareness-Raising Strategies in Traffic Safety (CAST) ran from 2006 to 2009 focusing on the development of three tools aiming to provide practical help for campaign practitioners [87]:

- a Manual for designing, implementing and evaluating road safety communication campaigns.
- an Evaluation tool aimed at helping users assessing the campaign's effectiveness; and
- a Reporting tool that provides clear guidelines for writing a complete and standardized campaign report.

The tool meta-analysis has been use to estimate the size of the effect that road safety campaigns have according to several outcome measures. The stages in meta-analysis of road safety campaign effects are given below:

Stage	**Description**
Study retrieval and extraction of data	Criteria are set in order to determine: 1. The outcome measure of interest; 2. Which campaign evaluation studies will be selected; 3. Data to be collected describing the content and delivery of the evaluated campaign.
Description of the sample of campaign effects	After retrieval, the set of campaign effects is described in order to better understand the sample being summarized. The campaigns evaluated can also be described using the data collected on content and delivery.

Calculation of overall effect	A simple statistical procedure is used to provide a weighted average of the group of individual effects, in which a weight is assigned to each effect according to its statistical reliability
Summary for whole group of effects and subgroups of effects.	The output of meta-analysis is a single summary effect, here in terms of percentage change in outcome measure coinciding with road safety campaigns. A confidence interval is provided with each summary effect. The summary effect can describe the whole group of retrieved effects, or only certain types of campaign (subgroups). The latter are defined according to the data collected on content and delivery.

Based on a conservative meta-analytical approach, the results summarize a database of 437 individual campaign effects and associated variables extracted from 228 different campaign evaluation studies, most reported within the last 30 years in 14 different countries. According to weighted average effects, calculated after accounting for publication bias, road safety campaign result in a 9% decrease in accident levels, a 25% increase in seatbelt use, a 16% reduction in speeding, a 37% increase in yielding behavior, and a 16% increase in risk comprehension. Since these overall estimates summarize effects of disparate campaigns, a brief consideration is also given to related work aiming to identify individual predictors of campaign success.

3.3.4 Application of cost-benefit analysis (CBA) and cost-effectiveness analysis (CEA) for road safety evaluation [88]:

Cost–benefit analysis (CBA) and cost-effective analysis have its roots in traditional, neoclassical welfare economics. Both are very effective tool for evaluating effectiveness of the interventions addressing improvement of road safety. When using these approaches, a project's effects are given a monetary value, which is inferred from consumer behavior in markets, as expressed by the consumers' willingness-to-pay.
In cost-benefit analysis (CBA) a variety of decision criteria exist to measure the efficiency of a project or policy measure. Mostly used are the net present value criterion and the benefit–cost ratio. The net present value (NPV) of a project is defined in formula

NPV = Present value of all benefits — Present value of all costs

All benefits are usually added to obtain the total benefits and expressed in monetary value. Social costs, increased travel expenses etc are considered as negative benefits and these are subtracted from the benefits. The cost term usually refers to the implementation costs (i.e. the budgetary cost) of a measure, expressed in terms of the opportunity cost from a social point of view. To facilitate the comparison of projects of different scale/scope, a benefit–cost ratio (BC ratio) can be estimated, as presented in formula

$$BC\ ratio = \frac{Present\ value\ of\ all\ benefits}{Present\ value\ of\ implementation\ costs}$$

When the NPV is positive, the BC ratio exceeds the value of 1.

On the other hand cost-effectiveness analysis (CEA) can be described as an analysis by which a measure or alternative (e.g. safety measure) is selected that can achieve a policy objective (e.g. increasing road safety) at the lowest budgetary cost possible. Alternatively, CEA may examine the effectiveness (e.g. a maximum reduction of accidents/risk) of a policy objective (e.g. increasing road safety) with a fixed amount of resources (e.g. an acceptable or maximum cost). The former approach corresponds to cost minimization, the latter to effect maximization. [89]
The CEA of a road safety measure can be defined as the number of fatalities, injuries or (injury) accidents prevented per unit cost of implementing the measure. By the CE ratio simply states the prevented fatalities per one million euro spent. Both CBA and CEA are methods of economic analysis that can be applied for the evaluation of public investment, where different projects (in road safety and other areas) are competing for scarce resources.

3.3.5 Application of Multi-criteria analysis (CBA) and cost-effectiveness analysis (CEA) for road safety evaluation [88]:

MCA can be defined as formal procedure (or a set of rules, i.e. an "institution") which allows comparing a number of actions (e.g. projects or policy measures, "alternatives" or "scenarios") in terms of specific criteria. By these criteria, the operationalization of the objectives and sub-objectives of decision makers and stakeholders participating in the decision making process are addressed.
It is especially useful for the evaluation of ITS, since this method makes it possible to structure complex decision problems according to their constituent parts (objectives, sub-objectives as measured by criteria) and to make comparisons among project alternatives, even when effects cannot be monetized fully, nor even quantified. It is usually possible to link specific stakeholders with specific criteria in the MCA and, by doing so, stakeholder management may be performed and effective implementation strategies may be defined.

The difference between CEA and MCA is that, in the former, the effectiveness is a one-dimensional concept, whereas in MCA it is conceived as a multiple dimensional one. This means that in MCA a number of objectives which are additional to the main objective may be taken into account. For instance, regarding the evaluation of ITS based road safety measures, it is possible to take into account effects on time savings, environmental effects, investment risk, implementation barriers, etc. next to the main objective (c.q. reducing the number of fatalities).
The objectives identified in the MCA may correspond to the objectives of specific stakeholders identified in the decision making process. Alternatively, it is possible to define objectives (and hence criteria) directly on the basis of stakeholder analysis.

The general procedure of MCA for the process-related steps to be followed the structure as shown in Fig. 3.3.

First, the nature of the problem is identified and analyzed. After this analysis, actions ("alternatives" or "scenarios") that may remedy the problem are formulated in the second step. In the third step, criteria are developed relevant to the evaluation of the actions to be studied. A criterion is a function that makes it possible to provide a score (quantitative or qualitative) for each action, measuring the contribution of that action to a relevant specific objective. By giving scores, a partial evaluation is performed (i.e. an evaluation in terms of one or more specific objectives as measured by criteria).

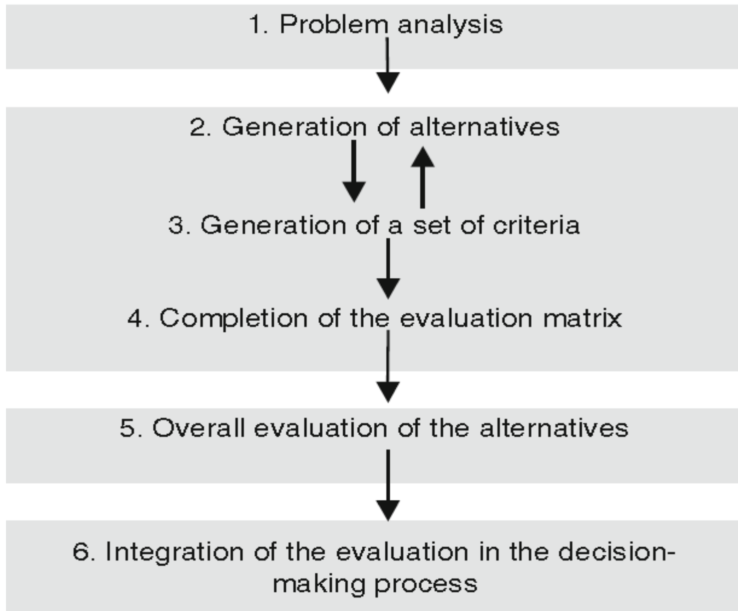


Figure 3.3: Process-related steps in Multi-Criteria approach (MCA)

For example, in the IN-SAFETY project, for the prioritization of innovative road safety measures, the IN-SAFETY project team sets three levels of criteria which are: users' criteria (driver comfort, full user cost , driver safety , travel time duration), society's criteria (network efficiency, environmental effect, socio-political acceptance, public expenditure etc) and manufacturers' criteria(investment risk, liability risk, technical feasibility etc) .

The fourth step consists of constructing and completing the evaluation matrix. This is a matrix where all the actions (a=a_1, a2…a_i….a_n) are evaluated in terms of all the criteria (g=g_1, g_2…g_i…g_m) as shown in Table 3.2.

	g_1	g_2	...	g_j	...	g_m
a_1	e_{11}	e_{12}	...	e_{1j}	...	e_{1m}
a_2	e_{21}	e_{22}	...	e_{2j}	...	e_{2m}
...	...	...	...	...	...	...
a_i	e_{i1}	e_{i2}	...	e_{ij}	...	e_{im}
...	...	...	...	...	...	...
a_n	e_{n1}	e_{n2}	...	e_{nj}	...	e_{nm}

Table 3.3: Evaluation matrix [88]

For example the actions of users' criteria could be in-car VMS dynamic speed limit, school bus ahead warning, in-car speed warning, in-car lane departure warning, overtaking assistance etc.

In the fifth step, the information in the evaluation matrix needs to be aggregated. An aggregation method is, therefore, needed in most cases to synthesize the conflicting information. Each aggregation method relies on specific assumptions regarding the comparability of the partial evaluations and the relations between criteria.
Criteria should be given explicit weights by policy makers in most cases. Analysts can introduce an interactive tool to help policy makers when reflecting on relative weights, but ultimately it is the decision makers themselves who must give the policy weights. Within each aggregation method, several MCA approaches can be used to aggregate the partial evaluations.
After aggregation, all the actions and measures are comparable in terms of common value and unit. Assessing the final evaluation value the priority could be set in case of road safety intervention. The higher value demands more importance than the lower one eventually.

3.3.6 The traditional HAZOP approach:

The new technologies have been introduced in traffic produces a range of unknown deviations in the desired traffic process. These developments require additional ex-ante assessment procedures for measures which will be implemented in the traffic system. The HAZOP (Hazard and operability analysis) methodology is applied to road traffic measures to provide scenarios based upon predicted deviations and problems with new, mainly in vehicle technologies. To make HAZOP applicable for road safety purposes analysis of the expectations of road users is added to the traditional approach. Some results are shown for speed reduction measures.

Actually the HAZOP technique has long been used in the chemical industry for assessing designs in recent years its area of application has increasingly been extended to other industries and technologies. In the Safety Science Group in Delft these applications have included road maintenance work, tunnel building and more recently driving. The HAZOP technique describes the approach which has been achieved in assessing the potential safety effect and effectiveness of both conventional road features, such as speed humps, and new technologies, such as intelligent speed adaptation (ISA). [77]

Lawley developed the method [78] which is designed to search for every conceivable process deviation and look backwards at possible causes and forwards at possible consequences. The reason for developing the method was the assumption that most problems are missed because of the system’s complexity rather than because of a lack of knowledge on the part of the design team. The main objective is to define safety (hazards) and operability problems. A secondary objective is to evaluate the possible consequences, which is done in a semi-quantitative manner. The approach is based on stimulating creativity and imagination through a structured brainstorm, in order to think of all possible manners in which hazards and operability problems can occur. This is done in a systematic way by a team of specialists with different training and experience in order to reduce the chances of missing any hazard and operability problems. In order to perform the method systematically process parameters (e.g. temperature and flow) and guide words (e.g. no, high and reverse) is used. A combination of a process parameter and a guide word (e.g. no flow) forms a potential deviation. For each deviation (cell of the matrix) the HAZOP team discusses the following questions. [84]

- Could the deviation occur?

- If so, how could it arise?
- What are the consequences of the deviation?
- Are the consequences hazardous or do they prevent efficient operation?
- If so, can we prevent the deviation (or protect against the consequences) by changing the design or method of operation?
- If so, does the size of the hazard or problem (that is, the severity of the consequences multiplied by the probability of occurrence) justify the extra expense?

The HAZOP studies have been used in the field (e.g., chemical process engineering, food process engineering, nuclear power and programmable electronic systems, [79, 80] has in common the investigation of a process that is delimited both in space and in the number of different operations. The road traffic system has much in common, but differs in some ways:

- It deals with a larger number of people who moreover not all have similar experiences or expectations in participating in the traffic process.
- The number of participants and the variety in these participants (car drivers, pedestrians, etc.) within the traffic process is variable in time and in space/location.
- Within the traffic process individual participants cannot be assumed to have the same goals as each other or as the authorities.

As a result of these differences the tasks of different participants are harder to describe in a generic process description. However, as the HAZOP approach seems to show great promise for the identification of test scenarios for ICT-based new technologies in traffic, such as:

- Traffic process
- Representation and visualization of the traffic process
- Basic assumption in the Traffic HAZOP
- Traffic parameters and guidewords

3.3.7 Evaluation Steps of a road safety campaign: [81]

Evaluation is a fundamental part of a campaign. Evaluation of the Road safety campaign consists six basic Steps. These are:

Step I: Getting Started.
To get started, practitioners should: (a) analyze the context, (b) identify and involve partners and stakeholders, (c) draft the budget, (d) gather the campaign participants at a kick-off meeting and finally (e) set up the campaign team.

Step II: Situation Analysis.
After precisely identified the problem, practitioners should analyze this problem in greater detail in order to define the specific objectives of the campaign. To do so, the following steps should be considered: (a) in-depth analysis of the problem and possible solutions, (b) segmenting the audience, (c) acting on main motivations and reaching the audience, (d) defining specific campaign objectives, and (e) gathering information from evaluations of past campaigns and other actions.

Step III: Designing the campaign and the evaluation.
In this stage, the design of the campaign itself starts. Practitioners deal with questions on how the road safety communication campaign should be done and on the ways its efficiency could be assessed. In summary:

- Develop the campaign strategy; this includes: (1) defining the strategy, (2) developing the message, (3) choosing the media and (4) developing and pretesting the message and slogans in their full context;
- Design the campaign evaluation by (1) defining the objectives of the evaluation, (2) choosing the evaluation design and sample, (3) defining methods and tools to collect data and (4) planning the evaluation. For this step it is advisable to consult this evaluation tool.

Step IV: Implementation of the before period evaluation and implementation of the Campaign.
Once launching the campaign, the measurement for the before period of the evaluation study needs to be implemented. The result of the before measurement shall be used as a baseline measurement for the other phases of the evaluation. This will also be the moment for practitioners to produce the actual campaign materials and launch the campaign. To complete this fourth step, the implementation of the campaign materials should be monitored carefully in order to deal with any problems that may arise.

Step V: Completing the evaluation and drawing clear conclusions.
At this step, the other scheduled evaluation measurements should be made and compared with the before measurements. In order to determine the effectiveness of the campaign, the collected data should be analyzed data. Regardless of whether there were positive or negative effects, all results should be reported.

Step VI: Writing a final report.
All important information should gather in the final report and feedback to provide the campaign partners, stakeholders, and the general public with an in-depth understanding of the campaign results. The improvement of future campaigns depends on the availability of rigorous and easy accessible campaign reports in order to learn from past campaigns.

In practice, the third step of campaign evaluation is mentioned. Three types of evaluation are distinguished in the manual namely: process, outcome and economic evaluation. This evaluation tool will help you trough the decisions that you need to make about the *outcome evaluation*. As it is advisable to carry out at least two measurements (one measurement before the campaign is implemented), you should start to think about and organize the evaluation right after the campaign design phase. In addition, during the ongoing campaign, the utility of measurements gathered and the need for an evaluation process to be continuous and parallel to the implementation of the road safety campaign.

In literature, researchers suggest a lot of approaches for the assessment and effectiveness evaluation of road safety intervention measures. Some of the approaches are describes above. All the approaches of road safety performance and their quality evaluation should comply with the theoretical judgment and the effect must satisfy two casual chains: engineering factors and behavioral factors. The extent of the evaluation studies in a theoretical aspect is discussed below.

3.3.8 Crash reduction factors and crash modification factors:

A crash reduction factor (CRF) is the percentage crash reduction that might be expected after implementing a given countermeasure at a specific site. For example, the installation of centerline rumble strips on a two-lane roadway can expect a 14% reduction in all crashes and a 55% percent reduction in head-on crashes.

Figure 3.4: Centerline rumble strips on two-lane roadway

Expected countermeasure effectiveness is also commonly expressed as a crash modification factor (CMF). A CMF is a multiplicative factor used to compute the expected number of crashes after implementing a given countermeasure at a specific site.

Both CRFs and CMFs are commonly used in the field of traffic safety and are related by a simple mathematical formula: CMF = 1 - (CRF/100). For example, if a particular countermeasure is expected to reduce the number of crashes by 23% (i.e., the CRF is 23), the CMF will be 1 - (23/100) = 0.77. On the other hand, if the treatment is expected to increase the number of crashes by 23% (i.e., the CRF is -23), the CMF will be = 1 - (-23/100) = 1.23.

3.3.9 Extent that theory account for the finding of road safety evaluation:

Road safety evaluation studies are designed to estimate the effects on accidents or injuries of one or more road safety measures. One of the major problems of road safety evaluation research is the fact that most of this research does not have a strong theoretical basis. In this respect, there is sharp contrast between road safety evaluation research and research in more theoretically mature disciplines [90].

Effectiveness of the most road safety measures influence the human behavior. Seat belts must be worn to protect from injury; headlights must be turned on in order to make the car more visible;

drivers must stop at red traffic signals for these to function as intended, and so on. It is, however, not always the case that human behavior needs to be influenced for a road safety measure to be effective. Road lighting, for example, does not require road users to change their behavior in any way. Guardrails and other energy absorbing structures fitted to roads or vehicles protect road users from injury, while not requiring that road users modify their behavior in any way.

From theoretical point of view, Leonard Evans (1985, 1991) [91] suggests the most lucid contribution that a road safety measure normally influences road safety by way of two causal chains: (1) the engineering effect, and (2) human behavioral feedback to engineering changes ("the behavioral effect"). A model based on these concepts is shown in Fig. 3.5.

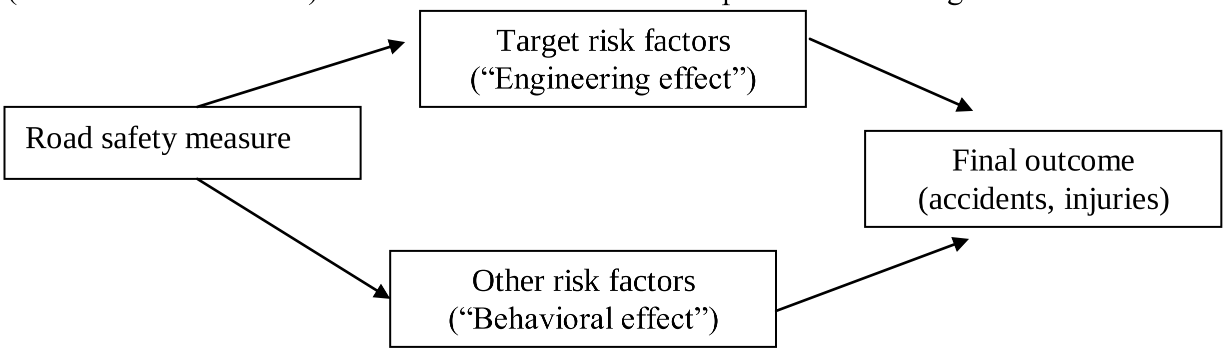


Figure 3.5: General model of the causal chain through which road safety measures influence road safety.

In Fig. 3.4, represent a typology of the basic risk factors for road accidents and injuries that are normally targeted for influence by means of road safety measures. This typology will serve as the basis for modeling the engineering effect of road safety measures. It is proposed that all these risk factors can be reduced to one or more of the following general types:

1. Kinetic energy
2. Friction
3. Visibility
4. Compatibility
5. Complexity
6. Predictability
7. Individual rationality
8. Individual vulnerability
9. System forgiveness

The basic hypothesis is that if one or more of the basic risk factors are favorably influenced (kinetic energy reduced, friction increased, and so on), then, one would expect road safety to improve. It is notoriously difficult to predict road user behavioral adaptation to road safety measures. What is needed to explain road user behavioural adaptation is a set of more specific, yet general hypotheses. Bjørnskau (1994) and Amundsen and Bjørnskau (2003) [92, 93] have proposed hypotheses designed to explain road user behavioral adaptation to road safety measures. The hypotheses identify the following factors as influencing road user behavioral adaptation:

1. How easily a measure is noticed

2. Antecedent behavioral adaptation to basic risk factors
3. Size of the engineering effect on generic risk factors
4. Whether or not a measure primarily reduces injury severity
5. The likely size of the material damage incurred in an accident
6. Whether or not additional utility can be gained

To assess the findings of road safety evaluation studies from a theoretical point of view, the following checklists are needed:

1. For any measure we need the checklist for the engineering effect of a road safety measure identifies a number of general mechanisms through which a road safety measure can influence accidents or injuries. If it is not possible to describe the engineering effect of a road safety measure in terms of these mechanisms, there is simply no reason to believe that it will have an effect. Any study claiming that the measure is effective would then be suspect.

2. The checklist for the behavioral effect if a road safety measure identifies conditions that influence the likelihood of behavioral adaptation. If, as an example, most of these conditions are present, and there is evidence of behavioral adaptation, one should not be surprised if the behavioral effect of a measure fully or partly offsets the engineering effect.

3. If a road safety measure can be expected to have a large engineering effect, and no behavioral effect, finding a large effect on accidents would conform to theoretical expectations.

The following table 3.3 shows the checklist for a measure, road lighting and their effects:

Engineering effect of road lighting		Behavioural effect of road lighting	
Generic risk factors	Effect of measure on generic risk factors	Factors eliciting behavioural adaptation	Effect of measure on factors eliciting behavioural adaptation
1: Kinetic energy	Not affected	1: Ease of noticing measure	Road lighting easily noticed
2: Friction	Not affected	2: Antecedent behavioural adaptation	Not adequate to eliminate the effect of darkness on accident rate
3: Visibility	Improved; size of improvement depends on quality of lighting	3: Size of engineering effect	Detection distances increase by how much depends on quality of lighting
4: Compatibility	Not affected	4: Affects probability of accidents or consequences of accidents	Both aspects of risk may be affected
5: Complexity	Not affected	5: Likely material loss in an accident	May be adversely affected by the presence of lighting poles
6: Predictability	Not affected	6: Prospects of gain in utility	Road lighting makes travel at night less strenuous (observation is easier)
7: Road user rationality	Observation becomes easier; fewer errors are likely to be made		
8: Road user vulnerability	Not affected		
9: Forgiveness	Adversely affected; lighting poles are a new hazard		

Table 3.4: Illustration of the use of the models of the engineering effect and behavioral effect as checklists to explain the effects of a road safety measure on accidents.

3.4 CONCLUSION:

Due to rapid globalization, the increasing demand of traffic flow leads the growing of incompatible vehicles and road users, high speed hybrid and electric sports cars, over speeding, users' non homogeneous biological factor, which made the road safety problem to be unsolved. Proper intervention measures concerning all the problem characteristics should be addressed to prevent the probability and consequences of the accidents.

Road safety Evaluation studies can better suggest us the effectiveness of the measures taken. Deployment of any permanent or temporary measures is needed to be assessed prior to the action taken. Randomness and deviation of traffic flows are to be considered for the expected number of accident calculation. To check the economic advantages of the alternative measures, the evaluation of CBA is suggestive. MCA are more rational for considering the entire sub-division safety indicators to assess qualitatively the road safety measures prioritization. The nine basic risk factors representing the engineering effect of a road safety measure, and the six factors influencing the likelihood of behavioral adaptation can be used as checklists in assessing whether or not the findings of road safety evaluation studies make sense from a theoretical point of view.

CHAPTER 4

GLOBAL AND REGIONAL PERSPECTIVE OF ROAD SAFETY

4.1 INTRODUCTION:

The public health priority in low and middle-income countries depends upon Road Safety development with unacceptable health losses and associated negative economic and social impacts being incurred on their road networks. The gap of road safety performance between poor and rich countries is widening, and this trend will continue unless new global, regional and country initiatives are taken to close it. [94]

Over 1.2 million people die each year on the world's roads, and between 20 and 50 million suffer non-fatal injuries. In most regions of the world this epidemic of road traffic injuries is still increasing. Over 90% of the world's fatalities on the roads occur in low-income and middle-income countries, which have only 48% of the world's vehicles.

In recent years there have been two major studies of causes of death worldwide which have been published in the 'Global Burden of Disease' (2004, World Health Organization, World Bank and Harvard University) and in the 'World Health Report – Making a Difference' (WHO 2009).These publications show that in 2004 road accidents as a cause of death or disability were by no means insignificant, lying in ninth place out of a total of over 100 separately identified causes. However, by the year 2030 forecasts suggest that as a cause of death, road accidents will move up to Fifth place. [95]

TOTAL 2004

RANK	LEADING CAUSE	%
1	Ischaemic heart disease	12.2
2	Cerebrovascular disease	9.7
3	Lower respiratory infections	7.0
4	Chronic obstructive pulmonary disease	5.1
5	Diarrhoeal diseases	3.6
6	HIV/AIDS	3.5
7	Tuberculosis	2.5
8	Trachea, bronchus, lung cancers	2.3
9	Road traffic injuries	2.2
10	Prematurity and low birth weight	2.0
11	Neonatal infections and other	1.9
12	Diabetes mellitus	1.9
13	Malaria	1.7
14	Hypertensive heart disease	1.7
15	Birth asphyxia and birth trauma	1.5
16	Self-inflicted injuries	1.4
17	Stomach cancer	1.4
18	Cirrhosis of the liver	1.3
19	Nephritis and nephrosis	1.3
20	Colon and rectum cancers	1.1

TOTAL 2030

RANK	LEADING CAUSE	%
1	Ischaemic heart disease	12.2
2	Cerebrovascular disease	9.7
3	Chronic obstructive pulmonary disease	7.0
4	Lower respiratory infections	5.1
5	Road traffic injuries	3.6
6	Trachea, bronchus, lung cancers	3.5
7	Diabetes mellitus	2.5
8	Hypertensive heart disease	2.3
9	Stomach cancer	2.2
10	HIV/AIDS	2.0
11	Nephritis and nephrosis	1.9
12	Self-inflicted injuries	1.9
13	Liver cancer	1.7
14	Colon and rectum cancer	1.7
15	Oesophagus cancer	1.5
16	Violence	1.4
17	Alzheimer and other dementias	1.4
18	Cirrhosis of the liver	1.3
19	Breast cancer	1.3
20	Tuberculosis	1.1

Table 4.1: Leading causes of death, 2004 and 2030 compared.
Source: World health statistics 2008 (http://www.who.int/whosis/whostat/2008/en/index.html)

Road safety problem becomes a global burden for society and individuals. No nations are fully satisfied with their present status and trend of road traffic fatalities and injuries. In the following passages we focus on the Global and Regional perspectives of Road safety.

4.2 GLOBAL PERSPECTIVE OF ROAD SAFETY:

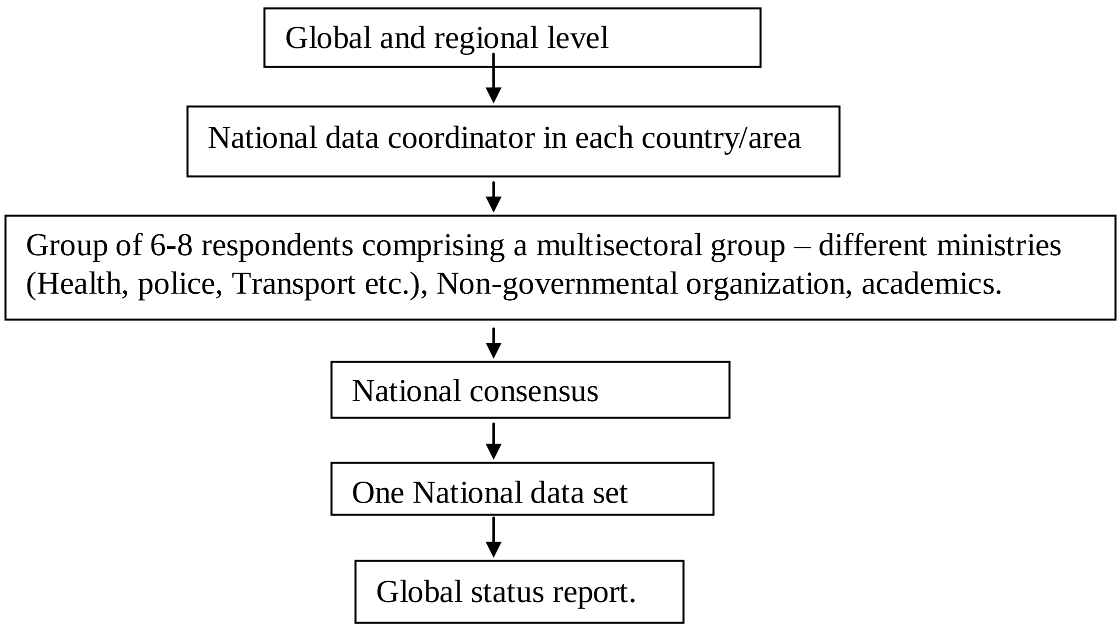
The problem of deaths and injury as a result of road accidents is now acknowledged to be a global phenomenon with authorities in virtually all countries of the world concerned about the growth in the number of people killed and seriously injured on their roads.
The growing awareness is reflected in the recent establishment of the Global Road Safety Partnership (GRSP) by the World Bank, the International Federation of the Red Cross and Red Crescent Societies, bilateral aid agencies and other interested parties under the framework of the World Bank's Business Partners for Development (BPD) Program.[96] A steering committee for GRSP is now in place with the aim of creating a global information network that aims to produce solid evidence of the positive impact of partnerships – both the development impact and the business benefits. Two important aspects of GRSP are the involvement of the private sector in funding road safety projects and the promotion of greater awareness of road safety worldwide. With the setting up of the GRSP it was considered important that a comprehensive summary of the global situation was made available to all involved in the problem of road accidents in developing and transitional nations. For example, using published statistics from countries throughout the world, TRL (Transport Research Laboratory) has in the past attempted to identify the number of people killed in road accidents world-wide and also on a regional basis. The last attempt to do this however used 1990 data and is now out of date [97]
The main sources of data used for this study were the International Road Traffic and Accident Database (IRTAD) annual report 2010, WHO (World Health Organization) publications, Fatality Analysis Reporting (FARS) of recent regional and country studies. IRTAD database has been maintained by BASt (The Federal Highway Research Institute, Germany) under the auspices of the OECD.

The data, provided by relevant national institutes, are constantly checked for consistency within countries and over years. IRTAD is a traffic accident analysis tool that stimulates international standard definitions and spurs improvements in data collection and comparison. For example, the number of fatalities is available in corrected form (30 day recording period). Member countries were repeatedly encouraged to adopt the 30-day limit for the definition of a fatality and most countries have now complied. The definition for a seriously injured person as "hospitalized" (non-fatal victims who are admitted to hospital as in-patients) is to some extent workable, but nationally different registration coverage of seriously injured persons is present. According to the *30-day definition* fatality count consider any person killed immediately or dying as a result of a road traffic injury accident within 30 days.

The IRTAD database is used as a prime source of international data required for annual reports and ad hoc studies at the aggregated level. The main advantage lies in the ease of quick reference. It allows the development of safety indicators and is used as an analytical tool for statistical comparisons and road safety policy formulations. It is the quickest way to achieving the goal of reliable, comparable and consistent traffic and fatality data for nearly all OECD countries. To be internationally representative on a global scale, IRTAD is open to all non-OECD member countries.

The Fatality Analysis Reporting System (FARS), which became operational in 1975, contains data on a census of fatal traffic crashes within the 50 States of US, the District of Columbia, and Puerto Rico. To be included in FARS, a crash must involve a motor vehicle traveling on a traffic way customarily open to the public, and must result in the death of an occupant of a vehicle or a non-occupant within 30 days of the crash.

In August 2007 WHO began to develop the global status report on road safety (GSRRS) to address this data gap and to assess road safety around the world. For the preparation of global status report the general methodological setup are given below: [95]



Data collection started in March 2008 and was completed in September 2008. The final data were collected from 178 participating countries and areas (176 WHO member states and 2 non-member areas).The countries are categorized according to the income level: High income countries (HIC), Middle income countries (MIC) and Low income countries (LIC). The income levels are given by World Bank (Atlas method) using gross national income per capita (GNI) for 2007 to categorize countries in to:

Low income = $ 900 or less
Middle income = $ 936 to $ 11455
High income = $ 11456 or more.

WHO REGION	NUMBER OF MEMBER STATES AND ASSOCIATE MEMBER STATES	COUNTRIES/AREAS PARTICIPATING	NON-PARTICIPATING MEMBER/ASSOCIATE MEMBER STATES AND % OF REGIONAL POPULATION
AFRICAN REGION	46	41 (0 HIC, 11 MIC, 30 LIC)	Algeria, Côte d'Ivoire, Equatorial Guinea, Gabon, Guinea (8.8%)
REGION OF THE AMERICAS	36	32 (31 Member and Associate Member States, 1 non-member area) (6 HIC,[c] 26 MIC)	Antigua & Barbuda, Dominica, Grenada, Haiti, St. Kitts & Nevis (1.1%)
SOUTH-EAST ASIA REGION	11	10 (0 HIC, 6 MIC, 4 LIC)	Democratic People's Republic of Korea (1.4%)
EASTERN MEDITERRANEAN REGION	21	20 (19 Member States, 1 non-member area) (5 HIC, 12 MIC, 3 LIC[c])	Djibouti, Somalia (1.7%)
EUROPEAN REGION	53	49 (25 HIC, 21 MIC, 3 LIC)	Andorra, Denmark, Luxembourg, Monaco (0.7%)
WESTERN PACIFIC REGION	28	26 (6 HIC, 15 MIC, 5 LIC)	Niue, Tokelau (< 1%)
GLOBAL	**195** Member and Associate Member States	**178** (176 Member and Associate Member States, 2 non-member areas) (42 HIC, 91 MIC, 45 LIC)	**19** (accounting for 1.7% of population of the 195 Member and Associate Member States)

Table 4.2: Participation in the survey, by WHO region and income group. (WHO 2009)

The total number of deaths reported in the global status report is approximately 660000 (using a 30 day definition), indicating vast under reporting. The total 30 day number for 178 countries included in this study is 1.23 million. Almost all data sources show that about three quarters of road traffic deaths are among men and that the highest impact is in the economically active age ranges. The road traffic death, population and registered motorized vehicles by income group are shown in pi-chart below:

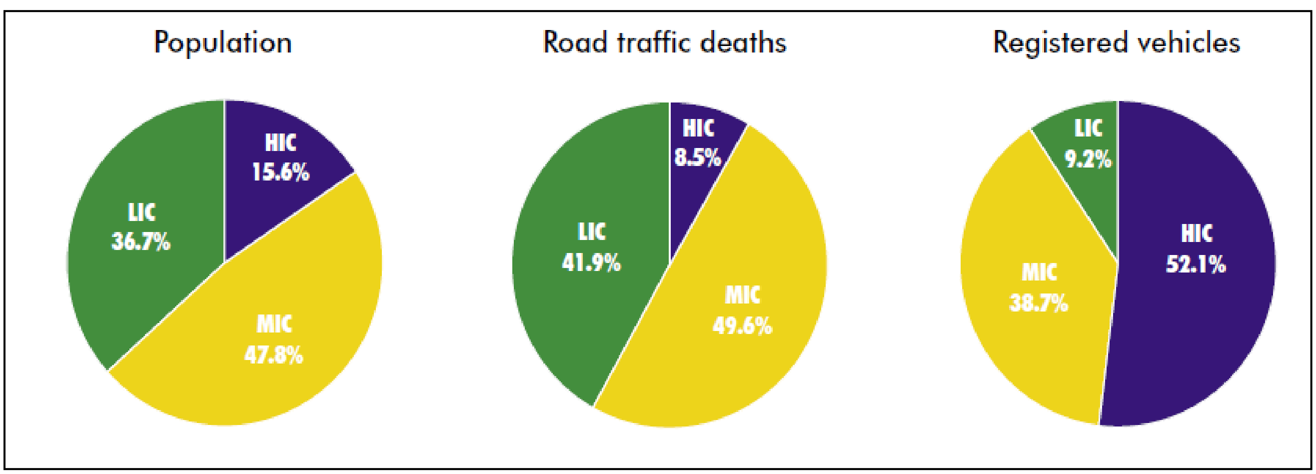


Figure 4.1: Population, road traffic deaths (30 day definition), and registered motorized vehicles, by income group. (WHO 2009)

Most of the world fatalities on the roads occur in low-income and middle-income countries, which have only 48% of worlds registered vehicle. Approximately 62% of reported road traffic deaths occur in ten countries which are India, China, The United States, The Russian federation, Brazil, Iran, Mexico, Indonesia, South Africa, and Egypt-account for 56% of world population.

Country	Population numbers for year 2007	GNI per capita for 2007 in US dollar	Income level	Number of registered vehicles	Reported number of traffic deaths	Estimated road traffic deaths rates per 100000 population
India	1169015509	950	Low	72718000	105725	16.8
China	1336317116	2360	Middle	145228994	96611	16.5
United states	305826246	46040	High	251422509	42642	13.9
Russia	142498532	7560	Middle	38695996	35972	25.2
Brazil	191790929	5910	Middle	49644025	35155	18.3
Iran	71208384	3470	Middle	17000000	22918	35.8
Mexico	106534880	8340	Middle	24970879	22103	20.7
Indonesia	231626978	1650	middle	63318522	16548	16.2
South Africa	48576763	5760	Middle	9237574	16113	33.2
Egypt	75497913	1580	Middle	4300000	15983	41.6

Table 4.3: The ten countries with highest number of road traffic deaths.(WHO 2009)

4.2.1 Fatalities per head of population and per Billion vehicle-kilometers: [98]

Relative progress in road safety depends somewhat on what one uses as a measure of exposure to risk (i.e., population, registered vehicles, distance travelled). There has been considerable debate in the past about which indicator is most appropriate as an indicator of exposure. Those in the health sector prefer the use of population as the denominator, since it permits comparisons with other causes of injury or with diseases. As the health and transport sectors increase their level of co-operation, fatalities per 100 000 populations are becoming more widely used. In the transport sector it has been common, where data are available, to use fatalities per distance travelled (e.g. fatalities per million vehicle-kilometers) as a principal measure, or fatalities per 10 000 vehicles. Fatalities over distance travelled have traditionally been favored by road transport authorities as it implicitly discounts fatality rates if travel is increased.

Fatalities per 100 000 population is the number of inhabitants is the denominator the most often used, as the figure is readily available in most countries. This rate expresses the mortality rate or an overall risk of being killed in traffic for the average citizen. It can be compared with other causes of death like heart disease, HIV/Aids, etc. It is a very useful indicator to compare risk in countries with the same level of motorization; it is, however, not at all adapted to comparing safety levels between industrialized countries and countries where the level of motorization is very low.

Fatalities per billion vehicle-kilometers (or fatalities per billion vehicle-miles is the most objective indicator to describe risk on the road network. However, only a limited number of countries collect data on distance travelled.

Fatalities per 10 000 registered vehicles is the rate can be seen as an alternative to the previous one, although it differs in that the annual distance travelled is unknown. This indicator can therefore only be used to compare the safety performance between countries with similar traffic and car use characteristics. It requires reliable statistics on the number of registered vehicles. In some countries, scrapped vehicles are not systematically removed from the registration database, undermining accuracy.

Ideally, it would be desirable to use all three indicators to make comparisons of performance between countries.

Table 4.4 and Figure 4.3 show the evolution of the mortality expressed in terms of deaths per 100 000 population since 1970. Table 4.4 also includes the evolution in risk expressed in terms of deaths per billion vehicle-kilometers. Figure 4.2 shows the risk of road deaths per 100 000 population in the year 2009.

Since 1990 remarkable progress has been made in all countries. For most countries risk has been reduced by more than 40%. Greatest improvements were recorded in Spain (-75%), Portugal (-72%), Switzerland (-68%) and Slovenia (-68%). In 2009, the death rate or the risk level per 100 000 population were the lowest found in the United Kingdom, the Netherlands and Sweden which all had rates below 4.0 (see Figure 4.2). While this rate is useful to compare the performance of countries with similar levels of development and motorization, it should not be used as a universal tool to rank all countries.

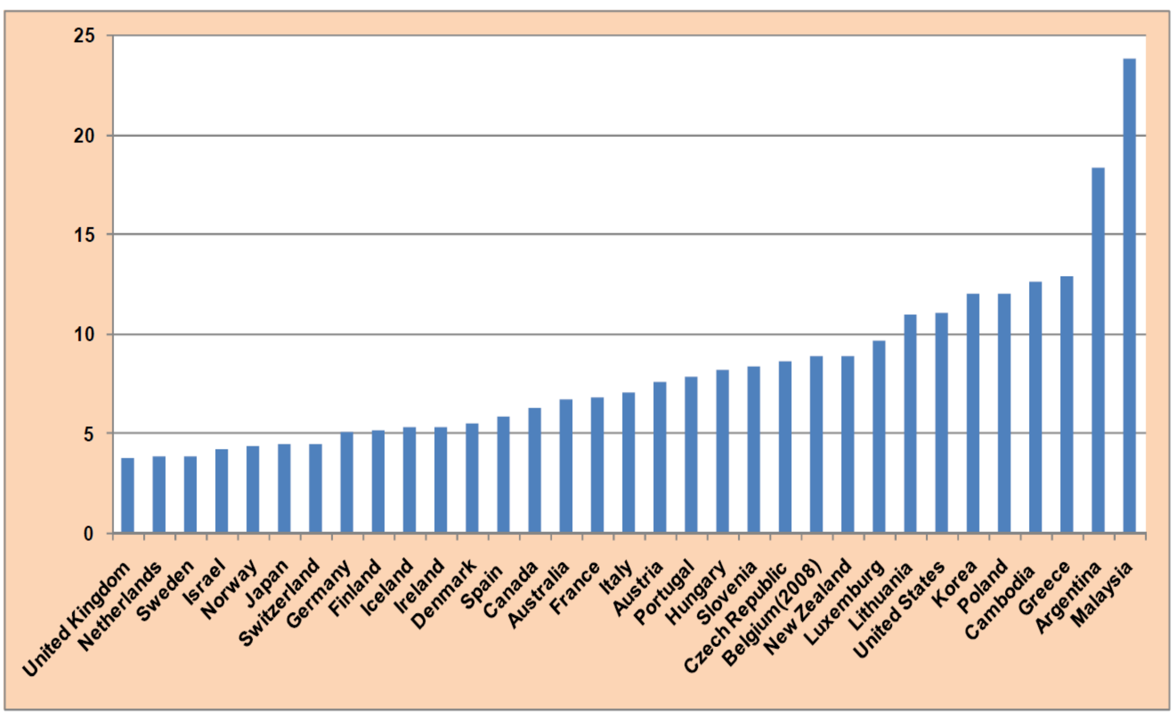


Figure 4.2: Risks of road fatalities per 100 000 populations in 2009. (IRTD 2010)

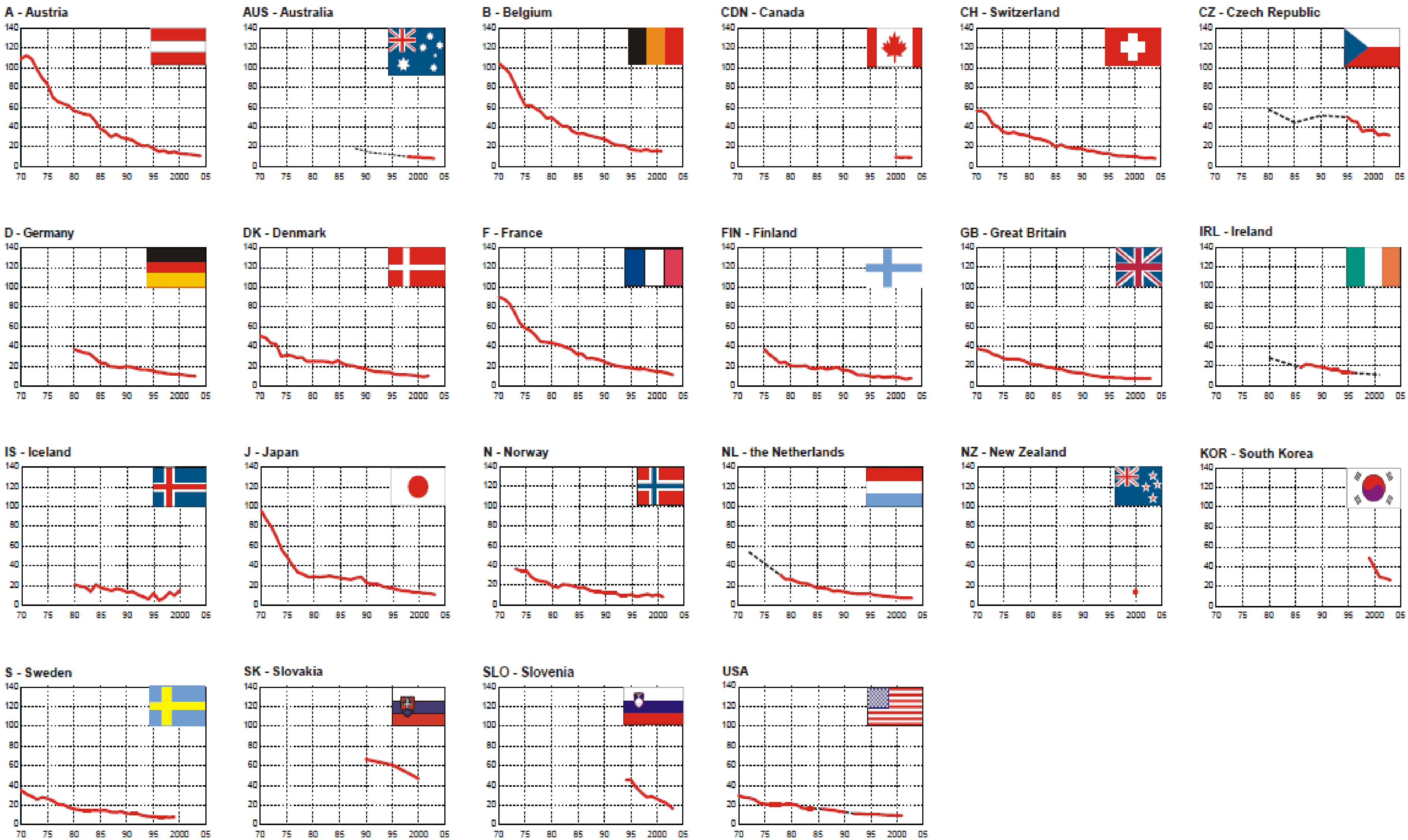


Figure 4.3: Traffic deaths per 100 000 populations 1970-2009.(IRTD 2010)

Country	Killed per 100 000 inhabitants					Killed per billion veh-km				
	1970	1980	1990	2000	2009	1970	1980	1990	2000	2009
Argentina					18.4					
Australia	30.4	22.3	13.7	9.5	6.8	49.3			9.3	6.7
Austria	34.5	26.5	20.3	12.2	7.6	109	56.2	27.9	13.2	9a
Belgium	31.8	24.3	19.9	14.4	8.9a	105	50.0	28.1	16.3	9.6a
Cambodia					12.6					
Canada[1]	23.8	22.7	14.9	9.5	6.3				9.3	6.3
Czech Republic	20.0	12.2	12.5	14.5	8.6		53.9	48.3	37	19.4 a
Denmark	24.6	13.5	12.4	9.3	5.5	51	25.0	17.3	10.7	8.2a
Finland	22.9	11.6	13.1	7.7	5.2		20.6	16.3	8.5	5.2
France	32.6	25.1	19.8	12.9	6.8	90	43.6	25.7	15.1	7.8
Germany	27.7	19.3	14.0	9.1	5.1		37.3	20.0	11.3	6.0
Greece	12.5	15	20.1	18.7	12.9					
Hungary	15.8	15.2	23.4	12	8.2					
Iceland	9.8	11	9.5	11.5	5.3		21.1	14.9	13.8	5.5
Ireland	18.3	16.6	13.6	11.0	5.3		28.4	19.2	12.6	4.9
Israel			8.67		4.2					6.4
Italy	20.5	16.4	12.6	12.2	7.1					
Japan	21.0	9.3	11.8	8.2	4.5	96	29.3	23.2	13.4	7.7
Korea		17.2	33.5	21.8	12				49.5	20.0
Lithuania					11					
Luxemburg		27.0	18.8	17.5	9.7					
Malaysia					23.8					17.7
Netherlands	24.6	14.2	9.2	6.8	3.9		26.7	14.2	9.1	5.6
New Zealand	23.0	18.9	21.4	12.1	8.9				12.4	9.6
Norway	14.6	8.9	7.8	7.6	4.4		19.3	12.0	10.5	5.4
Poland	10.6	16.8	19.2	16.3	12				12.4	9.1a
Portugal	18.6	27.7	28.3	18.1	7.9					
Slovenia	35.8	29.2	25.9	15.8	8.4	167	96.1	65.1	26.7	9.6
Spain		17.7	23.2	14.5	5.9					
Sweden	16.3	10.2	9.1	6.7	3.9	35	16.4	12.0	8.5	4.4
Switzerland	26.6	19.2	13.9	8.3	4.5	56.5	30.9	18.5	10.4	5.7
United Kingdom	14.0	11.0	9.4	6.1	3.8				7.4	4.6
United States	25.8	22.5	17.9	15.3	11.1	29.7	20.9	12.9	9.5	7.1

Table 4.4 Traffic deaths per 100 000 inhabitants / per billion veh-km 1970, 1980, 1990, 2000 and 2009.(IRTD 2010)

Data on risks expressed in terms of deaths per billion vehicle-kilometers are included in Table 4.4.Analysis in terms of fatalities over distance travelled is a very useful indicator to assess the risk of travelling on the road network. However, only a subset of IRTAD countries collects regular data on vehicle-kilometers. Based on this risk indicator, the situation has improved substantially between 1990 and 2008-2009. In 2008-09, the indicator ranged from 3.9 to 20.1, while in 1990 it ranged from 12 to 65. In almost all countries for which data are available, the risk has diminished by more than 50%. Slovenia is the country showing the biggest change with the risk divided by five (from 65 to 12). In 2009, the best performing countries recorded risk below 6 deaths per billion vehicle-kilometers (Iceland, Sweden, the United Kingdom, Switzerland and Ireland) (see Figure 4.4).

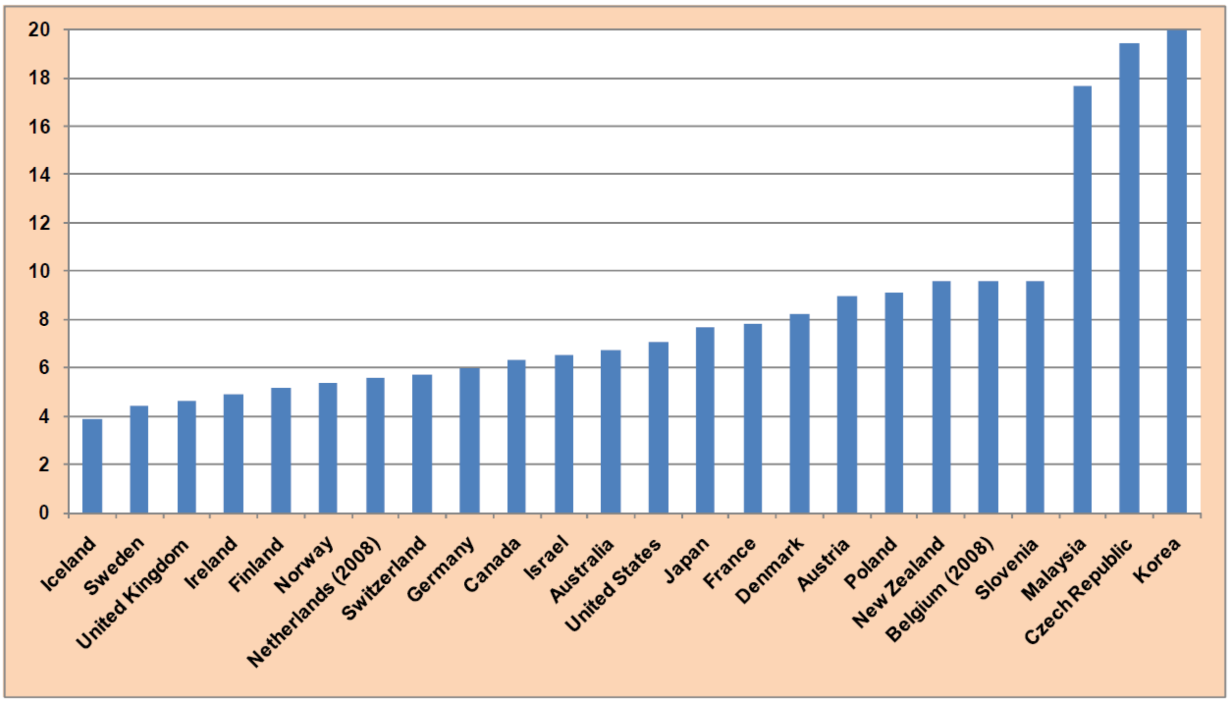


Figure 4.4: Risks of road fatalities per 100 000 populations in 2009 (IRTD 2010)

From a public health perspective and for the purpose of making comparison, the use of rates per 100 000 population is a more useful measure of the size of a problem than absolute number and also useful for assessing performance over time and for giving an indication of risks. The road traffic injury rates per 100 000 population within WHO region and by income group is shown in table 4.4 below:

WHO REGION	HIGH INCOME	MIDDLE INCOME	LOW INCOME	TOTAL
AFRICAN REGION	-	32.2	32.3	32.2
REGION OF THE AMERICAS	13.4	17.3	-	15.8

SOUTH-EAST ASIA REGION	-	16.7	16.5	16.6
EASTERN MEDITERRANEAN REGION	28.5	35.8	27.5	32.2
EUROPEAN REGION	7.9	19.3	12.2	13.4
WESTERN PACIFIC REGION	7.2	16.9	15.6	15.6
GLOBAL	**10.3**	**19.5**	**21.5**	**18.8**

Table 4.5: Road traffic injury fatality rates (per 100 000 population), by WHO region and income group. (WHO 2009)

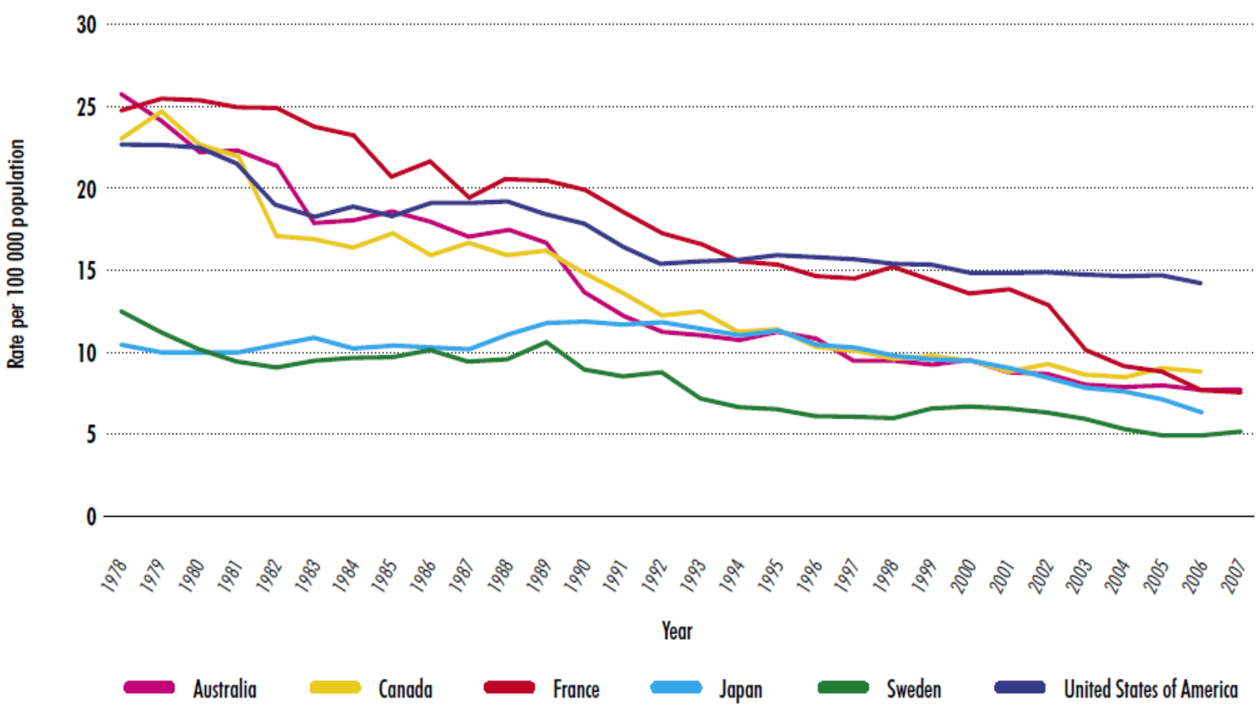


Figure 4.5: Trends in road traffic fatality rates in selected high-income countries. (WHO 2009)

The above figure 4.5 shows the trends in road fatality for some high-income countries. It represents a reduction of their road traffic fatality rates in recent decades. It is evident that although the highest rates are in low-income and middle–income countries, road traffic injuries remain very relevant to high income countries as well. A number of high income countries have road traffic injuries fatality rates well above the average for this income group. For instance, high income countries in the Eastern

Mediterranean region have a road traffic injury fatality rate of 28.5 per 100 000 population, which is well above the global average for countries in this broad income group.

4.2.2 Vulnerable road users:

Pedestrians, cyclists, and drivers of motorized two wheelers and their passengers account for almost half of global road traffic deaths. In most low income and middle income countries the majority of road users are vulnerable road users – pedestrians, cyclists, and those using motorized two or three wheelers. This group of road users does not have a protective "shell" around them and are therefore more at risk than those in vehicles. Public transport users may also be vulnerable road users, particularly where public transport vehicles are unsafe, overcrowded or unregulated. [95]

Vulnerable road user are at additional risk where their need have not been taken into consideration during the planning the land use or road construction. In many countries roads are planned and built to allow motor vehicles to travel faster while insufficient thought is given to the needs of pedestrians and cyclist, which means that these vulnerable road users face increasing risks in using and crossing the roads. [102, 103]

The global survey shows that pedestrians, cyclists, and rider of motorized two –wheelers and their passenger account for around 46% of global road traffic deaths. Vulnerable road user make up the highest reported proportion of total deaths in the south- East Asia and western pacific regions (Figure4.6). Within regions the proportion of deaths among vulnerable road users varies considerably.

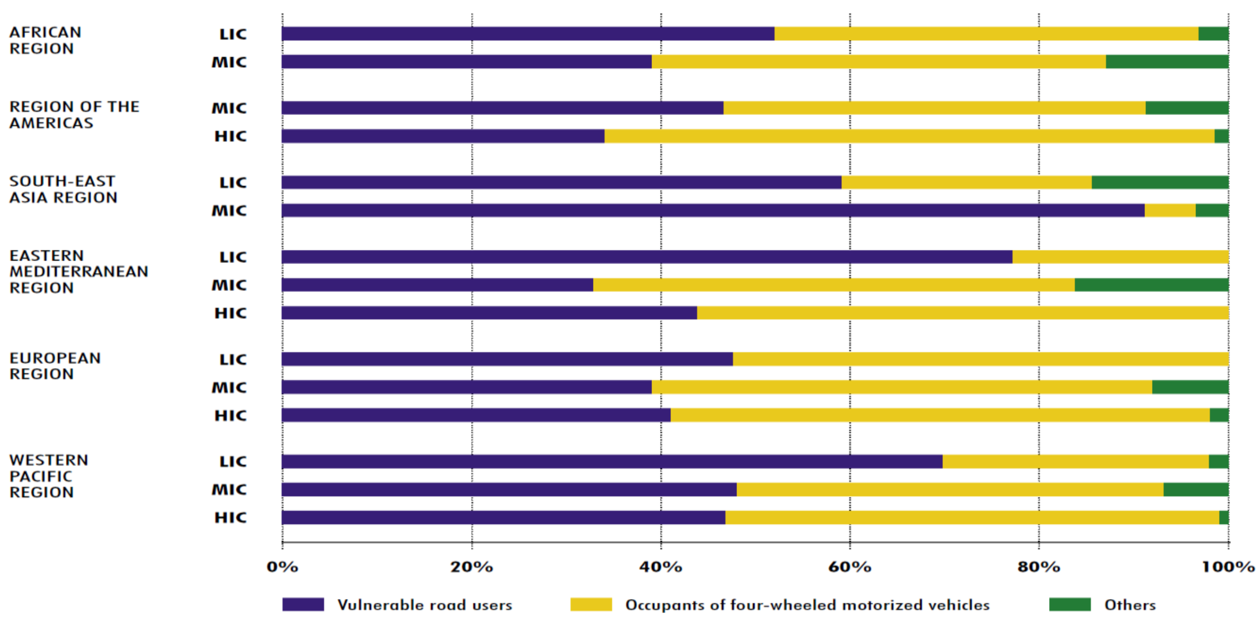


Figure 4.6: Reported deaths by type of road user (%), by WHO region and income group. [2]

4.2.3 Global view of drink driving and seat-belt wearing: [98]

Drink Driving:

Drink driving, speeding and non- wearing of seatbelts remain recurrent key issues in all countries. Table 4.5 summarizes the maximum blood alcohol content authorized in IRTAD countries together with an estimation of the share of alcohol related crashes.

Country	General BAC level	Differentiated BAC for young drivers, professional drivers
Argentina	0.5g/l	0.0 g/l professional drivers
Australia	0.5 g/l	0.0 g for novice drivers 0.2 g for professional drivers
Austria	0.5 g/l	0.1g/l moped riders < 20 y Novice and professional drivers
Belgium	0.5 g/l	
Cambodia	0.5 g/l	
Canada	0.8g/l	0.2 g/l in some provinces for professional drivers
Czech Republic	0.0 g/l	-l
Denmark	0.5g/l	-
Finland	0.5g/l	-
France	0.5g/l	0.2g/l (bus drivers)
Germany	0.5g/l	0.0 g/l (novice drivers)
Greece	0.5g/l	0.2g/l, professional drivers, motorcycles and moped riders
Hungary	0.0g/l (sanctions when BAC > 0.2g/l)	
Iceland		
Ireland	0.5g/l (implementation in 2011)	0.2g/l young drivers, professional drivers
Israel	0.5g/l	-
Italy	0.5g/l	0 g/l for novice and professional drivers since July 2010.
Japan	0.3g/l	
Korea	0.5g/l	-
Lithuania	0.4g/l	0.2g/ novice and professional drivers
Malaysia	0.0 g/l	
Netherlands	0.5g/l	0.2g/l novice drivers
New Zealand	0.8g/l	0.3 g/l drivers under 20 -
Norway	0.2g/l	
Poland	0.2 g/l	-
Portugal	0.5g/l	-
Slovenia	0.5g/l	-
Spain	0.5g/l	0.3g/l novice and professional drivers
Sweden	0.2 g/l	-
Switzerland	0.5g/l	-
United Kingdom	0.8 g/l	-
United States	0.8g/l	0.2 g/l for drivers < 21 0.4 g/l for professional drivers

Table 4.6: Maximum blood alcohol content in 2010. (IRTD 2010)

It shows that drink driving is responsible for between 10 and 32 % of fatal crashes. A number of factors make it difficult to compare the importance of drink driving between countries. The way accidents are classified as alcohol-related varies from country to country. Not all countries have the same legal blood alcohol content (BAC) limit and methodologies and protocols for checking the presence of alcohol in drivers involved in an injury crash differ. An alcohol related crash is usually defined in one of 2 ways:

• A crash where one of the drivers tests positively for any level of alcohol (even if below the legal limit) or
• A crash where one of the drivers has blood alcohol content above the legal limit.

Most IRTAD countries have a maximum permissible blood alcohol content of 0.05 g/dl. Lower limits are found in several countries, with a 0 limit in the Czech Republic, Hungary and Malaysia. A higher limit is found in the United Kingdom, New Zealand and the United States, where the legal limit is 0.08 g/dl. According to Global Status Report on Road Safety by WHO, the BAC limit by WHO regions are given in the figure 4.7. It shows mostly countries (86%) in the European region have BAC laws, in the other regions of the world most countries either do not have BAC limits or have limits that are above 0.05 g/dl.

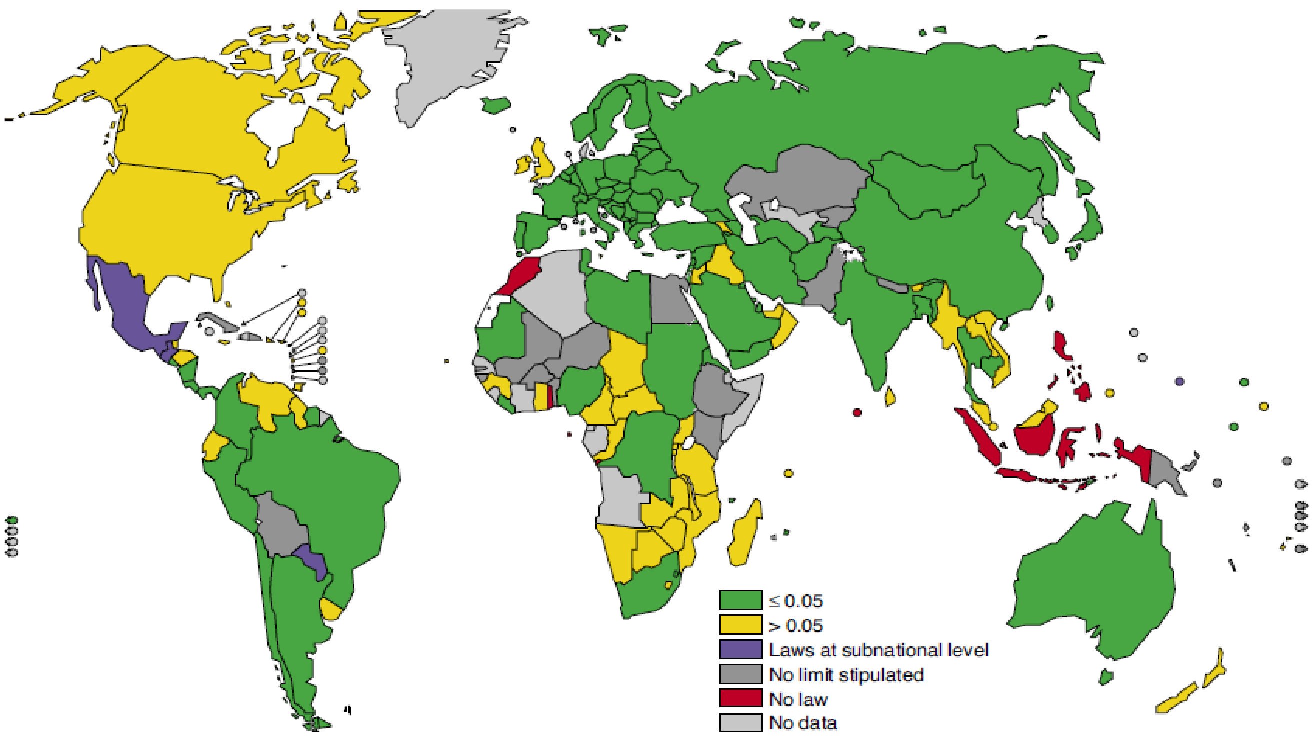


Figure 4.7: Blood alcohol concentration limits (g/dl) by country/area. (WHO 2009)

Seat-Belt Wearing:

Wearing a seat-belt reduces the risk of fatality among front seat passengers by 40-50%. Studies suggest that seat-belts can reduce fatalities among rear-seat car occupants by 25-75%. Mandatory seat-belt laws, their enforcement, and appropriate public awareness campaigns have been shown to be very effective in increasing rates of seat-belts wearing. [99], [100], [101].

Table 4.6 and figure 4.8 summarizes the situation regarding the seatbelt laws in IRTAD countries and provides estimation for the seatbelt wearing rate in 2009 or 2010. Seatbelt wearing is compulsory in front seats and rear seats in almost all IRTAD countries. In most of the countries, mandatory seatbelt laws for rear seats were introduced 10 to 15 years after the front seat law. In some countries, mandatory seatbelt laws in rear seats were introduced only very recently; for example in 2008 in Japan and in 2003 in Greece. The wearing rate in these countries is much lower than in countries where the law is older. In almost all countries, however, there is a significant difference in wearing rates between front seats and rear seats. Much effort can still be made in all countries to increase

wearing rates especially in rear seats, and a significant number of lives could be saved every year. Even in France, where the wearing rate is among the highest in IRTAD countries, it was estimated that, in 2007 if every passenger and driver had worn a seatbelt,) 397 lives could have been saved (around 9% of total fatalities).

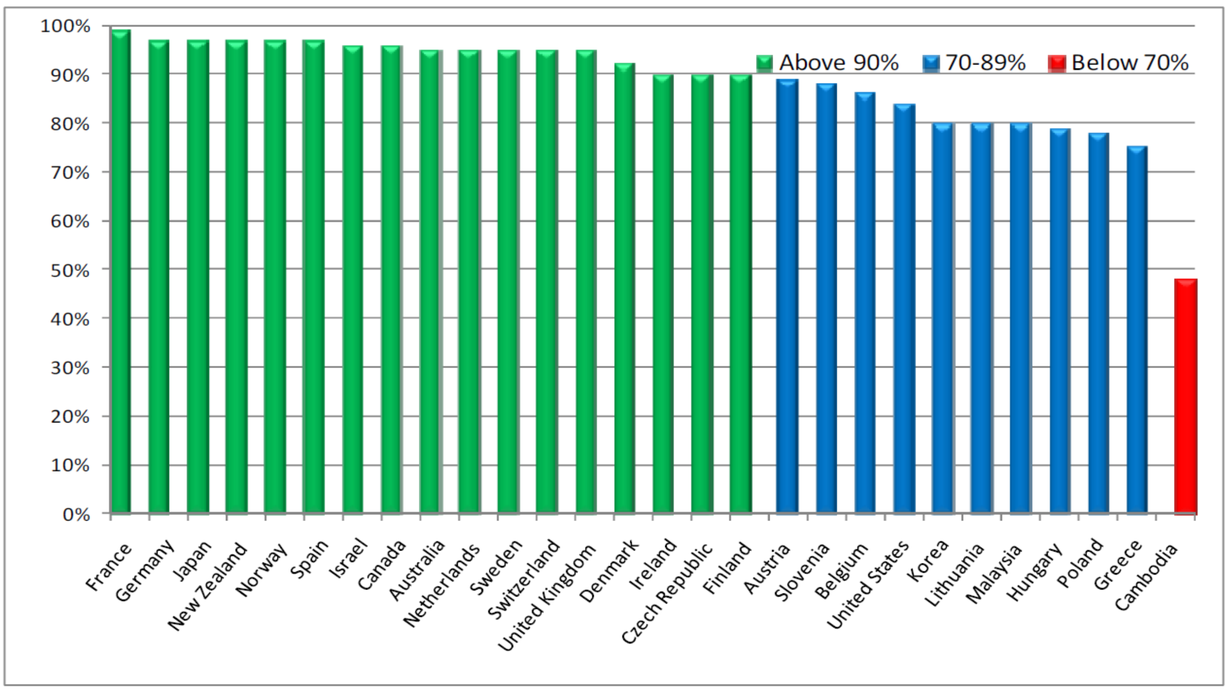


Figure 4.8: Blood alcohol concentration limits (g/dl) by country/area. (IRTD 2010)

Country	Front seats		Rear seats	
	Y/N date of application	Wearing rate	Y/N date of application	Wearing rate (adults)
Argentina	Yes, 1995	-	Yes, 1995	
Australia	Yes, 1970s	Around 95%	Yes	Around 80%
Austria	Yes	89%	Yes	65%
Belgium	Yes, 1975	86%	Yes, 1991	Unknown
Cambodia	Yes, 2007	48% drivers 25% passengers	No	unknown
Canada	Yes, 1976-1988	Around 96% (drivers)	Yes, 1976-1988	Unknown
Czech Republic	Yes, 1966	90% (2006)	Yes, 1965	68% (2006)
Denmark	Yes, 1970s	92% (drivers)	Yes, 1980s	71%
Finland	Yes, 1975	Around 90%	Yes, 1987	
France	Yes, 1973	95-99% (drivers)	Yes, 1990	78%
Germany	Yes, 1976	97%	Yes, 1984	96%
Greece	Yes, 1987	75%	Yes, 2003	23%
Hungary	Yes, 1976	79%	Yes, 1993 (outside built up areas), 2001 (inside built up areas)	50%
Iceland	Yes		Yes	
Ireland	Yes, 1979	90%	Yes, 1979	79%
Israel	Yes, 1975	96% (drivers) 91% (passengers)	Yes, 1995	69%
Italy	Yes, 1988	Around 65%	Yes, 1994	
Japan	Yes, 1985	97% (drivers) 91% (passengers)	Yes, 2008	34%
Korea	Yes, 1990	88% (drivers) 74% (passengers)	Yes on motorways, since 2008	12%
Lithuania	Yes		Yes	
Malaysia	Yes, 1978	80% (drivers) 70% (passengers)	Yes, 2009	10% (it was 40% in 2009)
Netherlands	Yes, 1975	95%	Yes, 1992	80%
New Zealand	Yes, 1972	95%	Yes, 1979	87%
Norway	Yes, 1975	97% (drivers) 89-94% (passengers)	Yes, 1985	
Poland	Yes, 1991	78%	Yes, 1991	47%
Portugal	Yes, 1978	87% (2004)	Yes, 1994	16% (2004)
Slovenia	Yes, 1977	88%	Yes, 1998	56%
Spain	Yes, 1974	88-97% (drivers)	Yes, 1992	
Sweden	Yes, 1975	96%	Yes, 1986	80%
Switzerland	Yes, 1981	89% (passengers) 88% (drivers)	Yes, 1994	74%
United Kingdom	Yes, 1983	95%	Yes, 1989 (children); 1991 (adults)	89%
United States	Primary law in 30 out of 50 states.	84%	Varies by State	70%

Table 4.7: Mandatory seatbelt wearing law and wearing rates in passenger cars (2009- 2010). (IRTD 2010)

According to WHO report(2009), only 38% low-income countries and 54% of middle-income countries requires seat-belts to be used in cars by both front-seat and rear-seat passengers. The following figure 4.9 represents the status of seat-belt laws in the whole world.

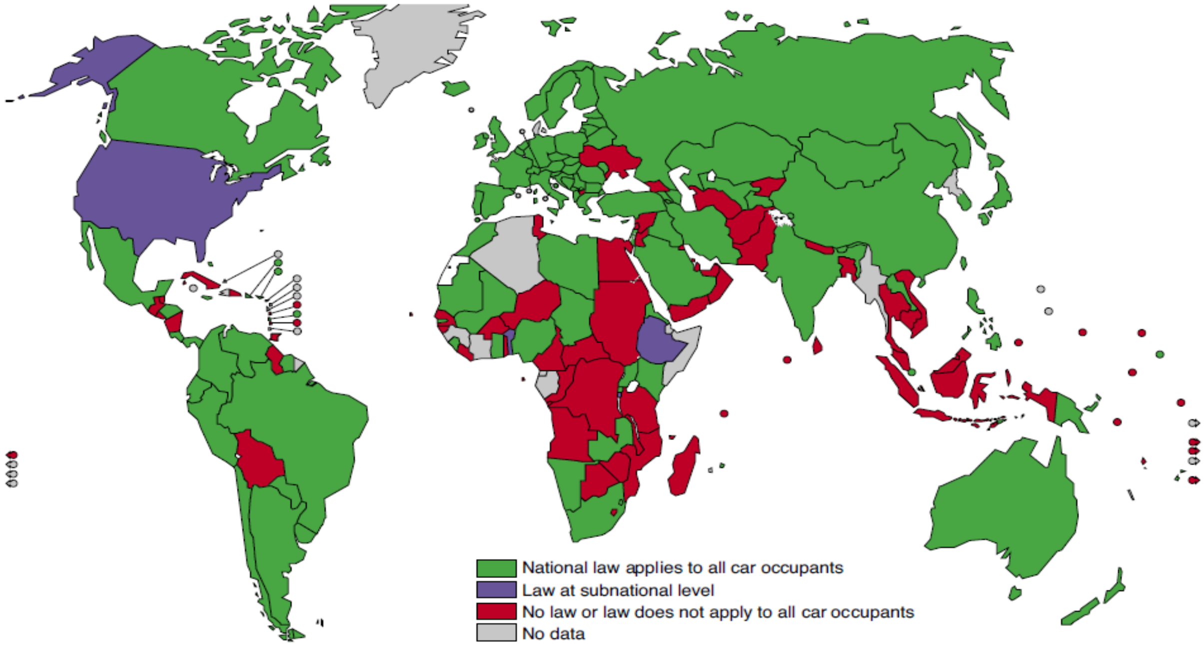


Figure 4.9: Seat-belt laws by country/area. (WHO 2009)

4.3 ROAD SAFETY IN EUROPEAN REGION:

According to report of WHO's Global Burden of Disease project 2004, the road traffic injuries are a major public health problem in the 53 countries of the WHO European Region and the annual death toll from road traffic injury is estimated to be 129 000. In addition, road crashes injure more than 2.4 million people each year. The problem is especially severe for people aged 5–29 years, for whom road traffic injuries are the leading cause of death (table 4.7). The care and rehabilitation cost are considerable, the social costs which have been estimated up to 3% of gross domestic product (GDP) [104,105].

Within the region the burden of road traffic injuries is unequal. Whereas mortality rates from road traffic injuries have declined overall in the Region, this is in stark contrast to the Commonwealth of Independent States (CIS[1]), which has the highest rates (Fig. 4.10). In the CIS, mortality rates peaked in the early 1990s and, after an initial fall, are climbing again. This differs from the European Union (EU), where rates are falling, making the gap even wider [106, 107]. Even the EU has great inequality, with the Nordic countries (Denmark, Finland, Iceland, Norway and Sweden) having far lower death rates than the Baltic countries (Estonia, Latvia and Lithuania) and those of southern Europe. The pedestrians, children, older people and young males are most at risk as car occupants or riders of motorized two-wheelers in the Region [104, 108, 109]. They are considered as vulnerable road users.

The European Union had an estimated 40000 road deaths in 2001 [110] and about a four-fold difference between the countries with the lowest and highest death rates per 100 000 population [111]. In the European Union, road crashes comprise 97% of all transport-related deaths and more than 93% of all transport-related crash costs and are the leading cause of death and hospital admissions for people under 50 years. The average mortality rates of Commonwealth of Independent States countries were almost three times higher than those of the Nordic countries (Denmark, Finland, Iceland, Norway and Sweden) (Figure 4.11). According to World report on road traffic injury prevention (2004), the global mortality rate is 18.8 per 100000 populations. For the European region the rate is 13.4.

1 CIS countries consisted of Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Republic of Moldova, Russian Federation, Tajikistan, Turkmenistan, Ukraine and Uzbekistan at the time the data were collected. (WHO 2010).

Rank	0–4 years	5–14 years	15–29 years	30–44 years	45–69 years	70+ years	Total
1	Perinatal causes 87 500	Road traffic injuries 4180	Road traffic injuries 39 300	Ischaemic heart disease 56 900	Ischaemic heart disease 679 400	Ischaemic heart disease 1 554 600	Ischaemic heart disease 2 295 600
2	Lower respiratory infections 34 500	Drowning 2430	Self-inflicted injuries 29 500	Self-inflicted injuries 41 000	Cerebrovascular disease 314 900	Cerebrovascular disease 1 020 200	Cerebrovascular disease 1 363 600
3	Diarrhoeal diseases 32 400	Lower respiratory infections 1930	Violence 14 900	Poisoning 33 600	Trachea, bronchus, lung cancer 190 900	Chronic obstructive pulmonary disease 176 300	Trachea, bronchus, lung cancer 370 700
4	Congenital anomalies 25 800	Leukaemia 1680	Poisoning 14 100	Road traffic injuries 33 200	Cirrhosis of the liver 112 400	Trachea, bronchus, lung cancer 168 900	Colon and rectum cancer 238 100
5	Meningitis 5360	Congenital anomalies 1390	HIV/AIDS 7010	Tuberculosis 28 900	Colon and rectum cancer 83 500	Colon and rectum cancer 148 300	Lower respiratory infections 234 700
6	Upper respiratory infections 3000	Self-inflicted injuries 1280	Tuberculosis 7000	Cirrhosis of the liver 27 400	Breast cancer 75 200	Lower respiratory infections 139 300	Chronic obstructive pulmonary disease 233 800
7	Drowning 2470	Lymphomas, multiple myeloma 700	Drowning 6570	Cerebrovascular disease 23 000	Stomach cancer 65 400	Hypertensive heart disease 130 700	Cirrhosis of the liver 184 900
8	Road traffic injuries 1740	Epilepsy 650	Ischaemic heart disease 4610	Violence 22 600	Self-inflicted injuries 57 500	Alzheimer and other types of dementia 128 400	Hypertensive heart disease 179 000
9	HIV/AIDS 1660	Violence 640	Cerebrovascular disease 4380	HIV/AIDS 13 700	Chronic obstructive pulmonary disease 54 600	Diabetes mellitus 106 700	Breast cancer 158 400
10	Endocrine disorders 1650	Cerebrovascular disease 590	Leukaemia 4250	Inflammatory heart diseases 10 700	Poisoning 52 300	Stomach cancer 82 000	Diabetes mellitus 155 400
11	Poisoning 1140	Endocrine disorders 590	Cirrhosis of the liver 3800	Breast cancer 10 300	Lower respiratory infections 46 800	Prostate cancer 77 100	Stomach cancer 155 100
12	Fire 1080	Poisoning 560	War and conflict 3700	Trachea, bronchus, lung cancer 10 200	Hypertensive heart disease 45 100	Breast cancer 72 500	Self-inflicted injuries 150 500
13	Leukaemia 970	Falls 530	Falls 3590	Lower respiratory infections 9400	Diabetes mellitus 42 800	Inflammatory heart diseases 68 600	Alzheimer and other types of dementia 137 400
14	Hepatitis B 950	War and conflict 470	Drug use disorders 3010	Drowning 9000	Inflammatory heart diseases 39 800	Nephritis and nephrosis 53 100	Road traffic injuries 129 100
15	Inflammatory heart diseases 780	Upper respiratory infections 430	Inflammatory heart diseases 2740	Falls 7900	Pancreas cancer 39 100	Pancreas cancer 51 600	Inflammatory heart diseases 122 900
16	Epilepsy 730	Fire 430	Lower respiratory infections 2730	Drug use disorders 7500	Road traffic injuries 36 500	Lymphomas, multiple myeloma 44 700	Poisoning 107 000
17	Violence 690	Meningitis 390	Epilepsy 2310	Stomach cancer 6800	Tuberculosis 33 600	Falls 44 600	Prostate cancer 97 300
18	Iron-deficiency anaemia 680	Nephritis and nephrosis 350	Nephritis and nephrosis 2200	Colon and rectum cancer 5500	Mouth and oropharynx cancer 33 300	Bladder cancer 43 100	Pancreas cancer 93 300
19	Falls 660	Inflammatory heart diseases 270	Congenital anomalies 2120	Fires 5300	Lymphomas, multiple myeloma 27 300	Cirrhosis of the liver 41 100	Perinatal causes 87 600
20	Hepatitis C 560	Diarrhoeal diseases 260	Lymphomas, multiple myeloma 2090	Alcohol use disorders 5200	Liver cancer 27 100	Liver cancer 35 500	Nephritis and nephrosis 80 300

Table 4.8: Number of deaths for leading causes by age group in the WHO European Region, 2004

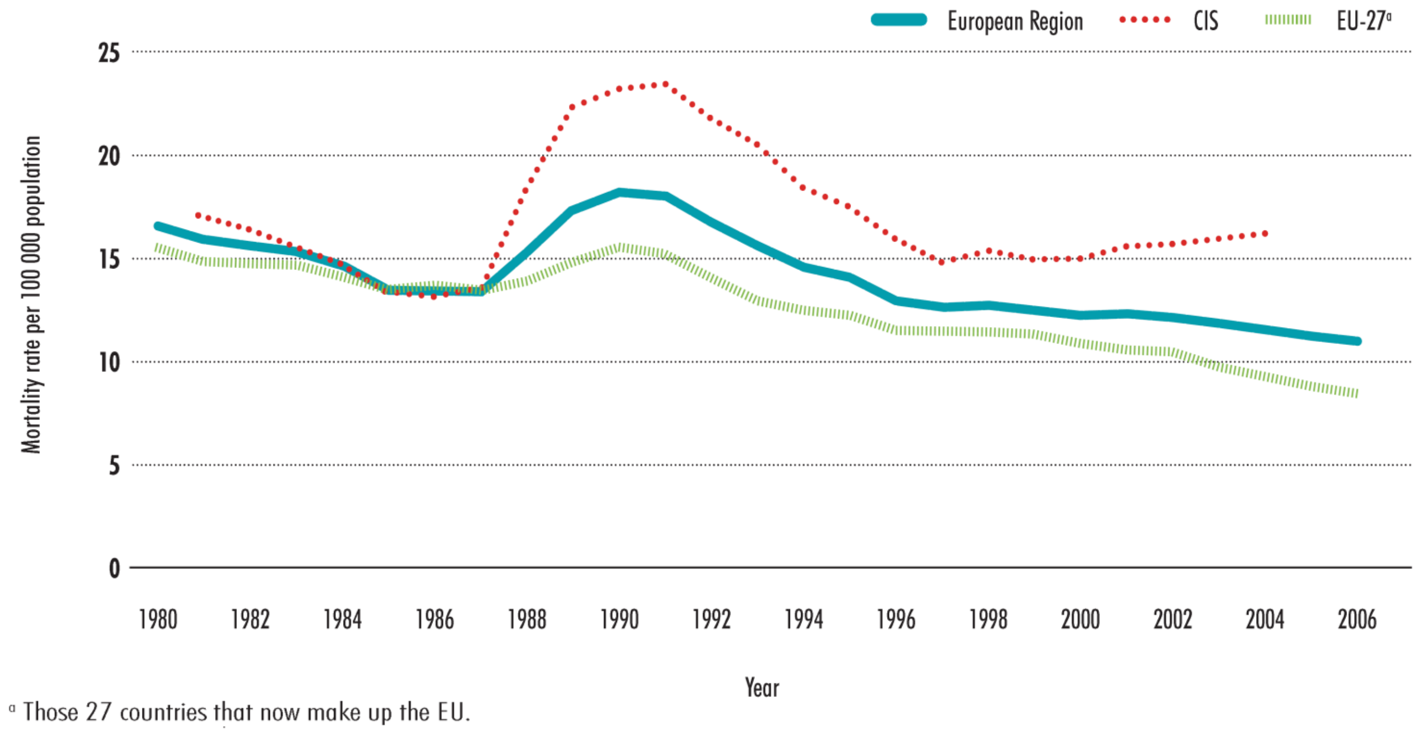
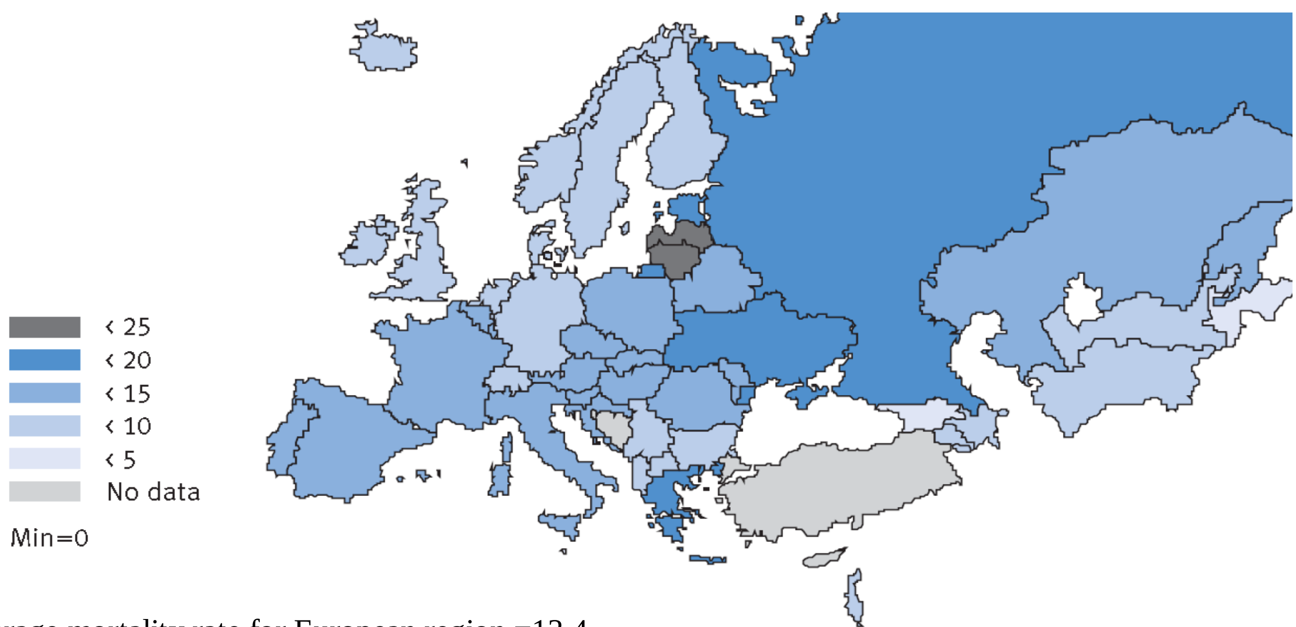


Figure 4.10: Mortality rates from road traffic injuries per 100 000 populations, WHO European Region, CIS and EU, 1980–2006



Average mortality rate for European region =13.4

Figure 4.11: Standardized mortality rates from road traffic injuries per 100 000 populations in the WHO European region, 2002 or last year available

The EU publishes various statistics and other data on road safety. We will provide here the CARE database. This 'Community database on accidents on the roads in Europe'(CARE) contains detailed data on accidents resulting in death or injury on a country-by-country basis. The fatalities are classified by user, gender, and mode of transport, age, month and year. CARE is a Community database on road accidents resulting in death or injury. There are no statistics on damage, only accidents are kept. The major difference between CARE and most other existing international databases is the high level of disaggregation, i.e. CARE is based on detailed data of individual accidents as collected by the Member States.

To minimize both the time taken to implement the database and the inconvenience to the national administrations, the national data sets are integrated into CARE in their original national structure and definitions but without any confidential data. A framework was designed to enable access to the data at EU level. The CARE fatality database contains almost all road fatalities in the EU and its functional use is comparable to the Fatality Analysis Reporting System (FARS) in the USA.

The road fatalities database from the year 1991 to 2010 reveals the satisfactory trend of reduction of the number (table 4.7). The White Paper of the European Commission “European transport policy for 2010: time to decide” proposed in the year 2001 to reduce the number of road fatalities in halve by the year 2010. The database showed a higher level of fatalities within the targeted years (figure 4.12). The estimated road traffic death per 100000 populations of EU regions is shown in the table 4.8.

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010 - 2001
Belgique/België	1.873	1.671	1.660	1.692	1.449	1.356	1.364	1.500	1.397	1.470	1.486	1.306	1.214	1.162	1089	1069	1071	944	944	-44%
България (Bulgaria)	1.114	1.299	1.307	1.390	1.264	1.014	915	1.003	1.047	1.012	1.011	959	960	943	957	1043	1006	1061	901	-23%
Česká republika	1.331	1.571	1.524	1.637	1.588	1.570	1.597	1.360	1.455	1.486	1.334	1.431	1.447	1.382	1286	1063	1221	1076	901	-40%
Danmark	606	577	559	546	582	514	489	499	514	498	431	463	432	369	331	306	406	406	303	-39%
Deutschland	11.300	10.631	9.949	9.814	9.454	8.758	8.549	7.792	7.772	7.503	6.977	6.842	6.613	5.842	5361	5091	4949	4477	4152	-48%
Eesti	490	287	321	364	332	213	280	284	232	204	199	223	164	170	169	204	196	132	98	-61%
Ireland	445	415	431	404	437	453	473	458	414	418	412	376	337	374	396	365	338	280	239	-48%
Ελλάδα (Elláda)	2.112	2.158	2.160	2.253	2.412	2.157	2.105	2.182	2.116	2.037	1.880	1.634	1.605	1.670	1658	1657	1612	1555	1456	-33%
España	8.837	7.818	6.375	5.612	5.749	5.482	5.604	5.956	5.738	5.777	5.517	5.347	5.400	4.749	4442	4104	3823	3100	2714	-57%
France	10.483	9.902	9.865	9.019	8.892	8.540	8.445	8.920	8.486	8.079	8.162	7.655	6.058	5.530	5318	4709	4620	4275	4273	-51%
Italia	8.109	8.053	7.187	7.091	7.020	6.676	6.714	6.313	6.688	7.061	7.096	6.980	6.563	6.122	5818	5669	5131	4725	4237	-45%
Κύπρος (Kypros)/Kibris	103	132	115	133	118	128	115	111	113	111	98	94	97	117	102	86	89	82	71	-39%
Latvija	997	787	724	774	660	594	567	677	652	635	558	559	532	516	442	407	419	316	254	-61%
Lietuva	1.173	836	958	765	672	667	752	829	748	641	706	697	709	752	773	759	739	499	370	-58%
Luxembourg	83	69	78	65	70	71	60	57	58	76	70	62	53	49	46	36	46	35	47	-56%
Magyarország	2.120	2.101	1.678	1.562	1.589	1.370	1.391	1.371	1.306	1.200	1.239	1.429	1.326	1.296	1278	1303	1232	996	822	-40%
Malta	16	11	14	6	14	19	18	17	4	15	16	16	16	13	17	11	14	15	21	-6%
Nederland	1.281	1.253	1.235	1.298	1.334	1.180	1.163	1.066	1.090	1.082	993	987	1.028	804	750	730	709	677	644	-46%
Österreich	1.551	1.403	1.283	1.338	1.210	1.027	1.105	963	1.079	976	958	956	931	878	768	730	691	679	633	-42%
Polska	7.901	6.946	6.341	6.744	6.900	6.359	7.310	7.080	6.730	6.294	5.534	5.827	5.640	5.712	5444	5243	5583	5437	4572	-29%
Portugal	3.217	3.086	2.701	2.505	2.711	2.730	2.521	2.126	2.028	1.877	1.670	1.655	1.542	1.294	1247	969	974	885	840	-49%
România	3.078	2.816	2.826	2.877	2.845	2.845	2.863	2.778	2.468	2.466	2.461	2.398	2.235	2.418	2461	2478	2800	3061	2796	-3%
Slovenija	462	493	493	505	415	389	357	309	334	314	278	269	242	274	258	262	293	214	171	-50%
Slovensko	614	677	584	633	660	616	788	819	647	628	614	610	645	603	560	579	627	622	384	-54%
Suomi/Finland	632	601	484	480	441	404	438	400	431	396	433	415	379	375	379	336	380	344	279	-37%
Sverige	745	759	632	589	572	537	541	531	580	591	583	560	529	480	440	445	471	397	358	-54%
United Kingdom	4.753	4.379	3.957	3.807	3.765	3.740	3.743	3.581	3.564	3.580	3.598	3.581	3.658	3.368	3336	3298	3059	2645	2337	-46%
	75.426	70.731	65.441	63.903	63.155	59.409	60.267	58.982	57.691	56.427	54.302	53.342	50.351	47.290	45.346	43.104	42.500	38.935	34.817	-44%

Table 4.9: No of Fatalities in the European Union countries (CARE database)

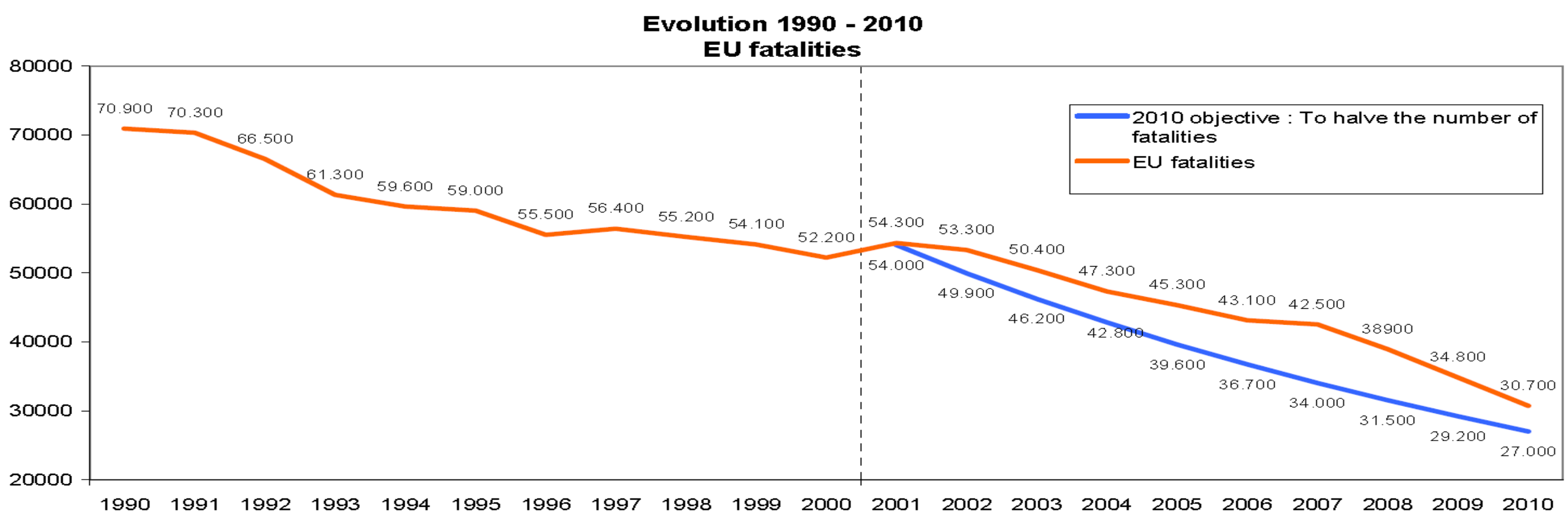


Figure 4.12: Fatalities trend in the European Union countries (CARE database)

Country	General information			Vehicles		Road traffic deaths				
	Population[a] for 2007	Gross national income per capita[b] for 2007 in US dollars	Income level[c]	Number of vehicles	Private car ownership per 1000 persons	Reported number of road traffic deaths[d]	Death defined in the country[e]	Estimated number of road traffic deaths[e]		Estimated road traffic death rate per 100 000 population[f]
								Point estimate	90% confidence interval	
Albania	3 190 012	3 290	Middle	349 646	74.5	499	On the scene	445	366–522	13.9
Armenia	3 002 271	2 640	Middle	366 836	95.9	371	No time frame	417	352–489	13.9
Austria	8 360 746	42 700	High	5 796 973	507.5	691	Within 30 days	691	—	8.3
Azerbaijan	8 467 167	2 550	Middle	784 018	71.7	1 195	Within 7 days	1 099	900–1 319	13.0
Belarus	9 688 795	4 220	Middle	3 147 625	241.7	1 517	Within 30 days	1 517	—	15.7
Belgium	10 457 343	40 710	High	6 362 161	482.8	1 067	Within 30 days	1 067	—	10.2
Bosnia and Herzegovina	3 934 816	3 790	Middle	675 063	145.8	428[h]	Within 30 days	428	—	10.9
Bulgaria	7 638 831	4 590	Middle	2 628 680	258.2	1 006	Within 30 days	1 006	—	13.2
Croatia	4 555 398	10 460	Middle	1 949 936	327.5	619	Within 30 days	619	—	13.6
Cyprus	854 671	24 940	High	592 480	480.4	89	Within 30 days	89	—	10.4
Czech Republic	10 186 330	14 450	High	5 455 110	403.2	1 222	Within 30 days	1 222	—	12.0
Estonia	1 335 333	13 200	High	708 794	394.2	196	Within 30 days	196	—	14.7
Finland	5 276 892	44 400	High	4 656 370	540.0	380	Within 30 days	380	—	7.2
France	61 647 375	38 500	High	39 926 000	498.0	4 620	Within 30 days	4 620	—	7.5
Georgia	4 395 420	2 120	Middle	567 900	107.6	737	Within 20 days	737	—	16.8
Germany	82 599 471	38 860	High	55 511 374	564.5	4 949	Within 30 days	4 949	—	6.0
Greece	11 146 918	29 630	High	7 212 236	455.0	1 657	Within 30 days	1 657	—	14.9
Hungary	10 029 683	11 570	High	3 625 386	300.4	1 232	Within 30 days	1 232	—	12.3
Iceland	301 006	54 100	High	293 299	688.9	30	Within 30 days	30	—	10.0
Ireland	4 300 902	48 140	High	2 444 159	440.6	365	Within 30 days	365	—	8.5
Israel	6 927 677	21 900	High	2 283 634	257.1	398	Within 30 days	398	—	5.7
Italy	58 876 834	33 540	High	43 262 992	610.1	5 669	Within 30 days	5 669	—	9.6
Kazakhstan	15 421 861	5 060	Middle	3 105 954	157.2	4 714	Within 7 days	4 714	—	30.6
Kyrgyzstan	5 316 543	590	Low	318 581	—	1 214	Within 1 year	1 214	—	22.8
Latvia	2 277 040	9 930	Middle	1 062 935	358.9	407	Within 30 days	407	—	17.9
Lithuania	3 389 937	9 920	Middle	1 781 686	467.4	759	Within 30 days	759	—	22.4
Malta	406 582	14 575[g]	High	346 118	647.0	14	Within 30 days	14	—	3.4
Montenegro	597 983	5 180	Middle	199 014	298.5	122	Within 30 days	122	—	20.4
Netherlands	16 418 824	45 820	High	8 862 935	440.5	791	Within 30 days	791	—	4.8
Norway	4 698 097	76 450	High	2 599 712	442.7	233	Within 30 days	233	—	5.0
Poland	38 081 971	9 840	Middle	18 035 047	354.6	5 583	Within 30 days	5 583	—	14.7
Portugal	10 623 031	18 950	High	5 948 269	496.5	1 110	On the scene	1 110	—	10.4
Republic of Moldova	3 793 604	1 260	Middle	448 202	87.3	571	Within 1 year	571	—	15.1
Romania	21 437 887	6 150	Middle	4 611 362	170.1	2 712	Within 30 days	2 712	—	12.7
Russian Federation	142 498 532	7 560	Middle	38 695 996	195.5	35 972	Within 7 days	35 972	—	25.2
San Marino	30 926	41 044[g]	High	51 590	—	1	Within 30 days	1	—	3.2
Serbia	9 858 424	4 730	Middle	2 235 389	154.0	962	Within 30 days	962	—	9.8
Slovakia	5 390 035	11 730	High	2 039 745	272.1	815	Within 24 hrs	815	—	15.1
Slovenia	2 001 506	20 960	High	1 286 903	509.9	293	Within 30 days	293	—	14.6
Spain	44 279 180	29 450	High	31 441 152	480.0	4 104	Within 30 days	4 104	—	9.3
Sweden	9 118 955	46 060	High	5 500 000	464.4	471	Within 30 days	471	—	5.2
Switzerland	7 483 973	59 880	High	5 356 000	515.3	370	Within 30 days	370	—	4.9
Tajikistan	6 735 996	460	Low	268 018	28.8	464	Within 30 days	951	767–1 196	14.1
The former Yugoslav Republic of Macedonia	2 038 464	3 460	Middle	259 421	109.9	140	Within 30 days	140	—	6.9
Turkey	74 876 695	8 020	Middle	13 311 000	87.1	6 022	On the scene	10 066	8 394–11 839	13.4
Turkmenistan	4 965 278	1 234[g]	Middle	651 564	80.9	702	Within 7 days	926	694–1 343	18.6
Ukraine	46 205 382	2 550	Middle	—	—	9 921	Within 30 days	9 921	—	21.5
United Kingdom	60 768 946	42 740	High	34 327 520	476.5	3 298	Within 30 days	3 298	—	5.4
Uzbekistan	27 372 260	730	Low	—	—	2 644	On the scene	2 644	—	9.7

Table 4.10: General information, vehicles and road traffic deaths for countries in the WHO European Region. (European status report on road safety, WHO 2009)

Pedestrians, cyclists, users of motorized two-wheelers and other vulnerable road users are at greater risk of serious injury in road crashes because they do not have a protective shell. Fig. 4.13 shows the distribution of deaths by road user categories for the European Region, the CIS and the EU. For the Region as a whole, vulnerable road users account for 39% of road traffic deaths. This is slightly less than the global figure of 46% [112]. The distribution of vulnerable road users within the Region differs notably. In the EU, the largest proportions of victims are motorized two-wheeler riders and cyclists. Greece, Malta, Cyprus, Italy and France have the highest proportions of deaths of motorized two-wheeler users among victims of road crashes, exceeding 1 in 4 deaths (table 4.9). Greater use of motorized two wheelers in these countries, specially in urban areas, and because the licensing age for drivers is less than 18 years is the partly reason of high rate of death. [113, 114].

The highest proportion of pedestrian fatalities of 37% of all road deaths for the CIS countries: Ukraine, Tajikistan and Kyrgyzstan have the highest shares of pedestrian victims in the Region (56%, 44% and 43%, respectively). One reason is the fact that urban design in many CIS cities dates back to when motorized traffic was very limited and professional drivers did most driving. Improvements in road infrastructure, driver training and enforcement have failed to adapt to the increase in motorization. The needs of vulnerable road users have not yet been properly taken into account. For example, most CIS countries still have urban speed limits of 60 km/h. The speed limit should be reduced to avoid the collision consequences. [115]

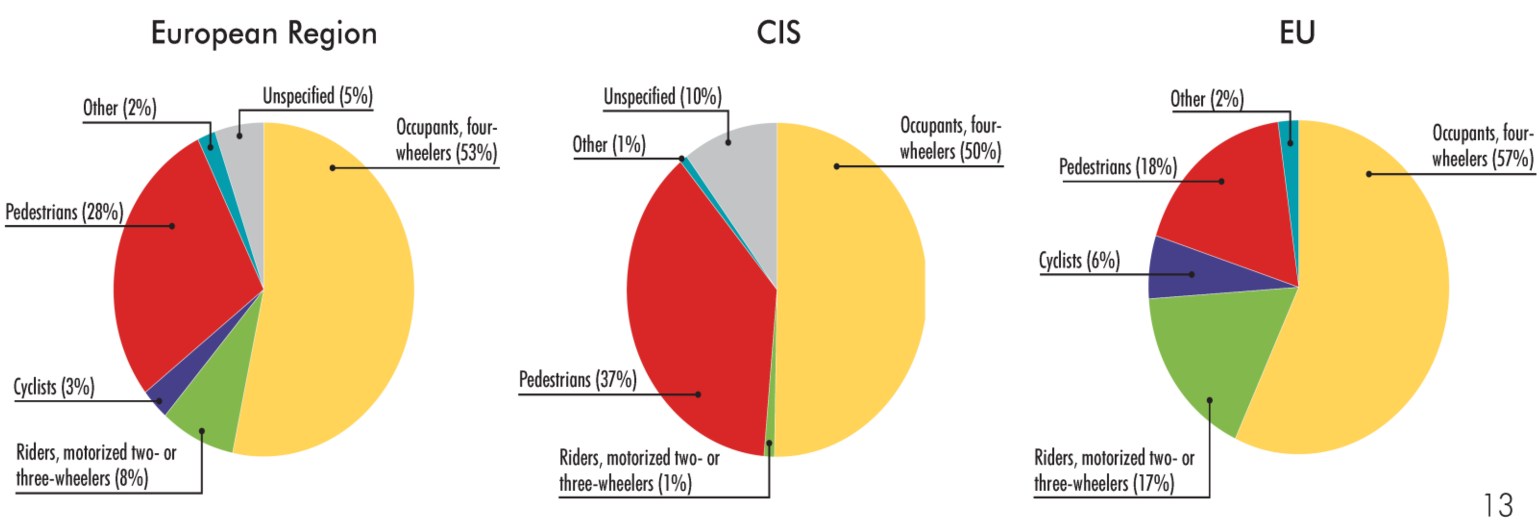


Figure 4.13: Distribution of road traffic injury deaths by road user category, WHO European Region, CIS and EU. (European status report on road safety, WHO 2009)

Country	Road user deaths (%)					Road traffic injuries		
	Drivers and passengers of four-wheeled vehicles	Drivers and passengers of motorized two-wheelers	Cyclists	Pedestrians	Other or unspecified users	Number of people injured	Injuries per 100 000 population	Ratio of injuries to deaths
Albania	45.3	9.0	5.7	40.0	—	1 344	42.1	3.0
Armenia	60.3	—	0.3	39.4	—	2 720	90.6	6.5
Austria	59.0	17.4	5.4	15.6	2.6	53 211	636.4	77.0
Azerbaijan	59.7	1.2	0.9	38.1	0.1	3 432	40.5	3.1
Belarus	47.3	3.8	9.1	39.8	—	7 991	82.5	5.3
Belgium	56.0	15.2	8.2	9.7	11.0	65 850	629.7	61.7
Bosnia and Herzegovina	61.0	4.7	5.8	23.7	4.8	11 647	296.0	27.2
Bulgaria	65.0	0.0	4.5	26.3	4.2	9 827	128.6	9.8
Croatia	49.9	18.8	4.5	20.0	6.8	25 092	550.8	40.5
Cyprus	50.6	28.1	3.4	18.0	—	2 119	247.9	23.8
Czech Republic	59.4	11.4	9.5	19.2	0.5	23 060	226.4	18.9
Estonia	66.0	6.0	9.0	19.0	—	3 270	244.9	16.7
Finland	70.3	10.8	5.8	12.6	0.5	8 446	160.1	22.2
France	59.2	25.0	3.1	12.1	0.6	77 007	124.9	16.7
Georgia	—	—	0.3	27.7	72.0	7 349	167.2	10.0
Germany	58.0	18.0	10.0	14.0	1.0	431 419	522.3	87.2
Greece	50.3	30.2	1.3	16.1	2.1	20 675	185.5	12.5
Hungary	54.4	10.1	11.7	22.7	1.1	27 452	273.7	22.3
Iceland	85.0	5.0	—	10.0	—	2 092	695.0	69.7
Ireland	61.9	7.9	2.5	20.0	7.7	8 575	199.4	23.5
Israel	57.6	9.3	1.5	31.6	—	2 079	30.0	5.2
Italy	49.0	26.0	5.5	13.4	6.1	332 995	565.6	58.7
Kazakhstan	—	—	—	16.2	83.8	32 988	213.9	7.0
Kyrgyzstan	55.0[i]	—	1.0	43.0	1.0	6 223	117.0	5.1
Latvia	50.4	4.2	8.1	37.3	—	5 404	237.3	13.3
Lithuania	53.7	4.5	6.9	31.9	3.0	8 254	243.5	10.9
Malta	35.7	28.6	—	35.7	—	1 195	293.9	85.4
Montenegro	75.4	4.1	—	20.5	0.1	2 796	467.6	22.9
Netherlands	46.0	18.0	24.0	12.0	—	16 750	102.0	21.2
Norway	67.0	17.0	3.0	10.0	3.0	11 755	250.2	50.5
Poland	51.0	5.0	9.0	35.0	—	63 224	166.0	11.3
Portugal	54.6	22.1	3.5	16.1	3.7	46 318	436.0	41.7
Republic of Moldova	57.3	4.1	2.4	34.3	1.9	2 985	78.7	5.2
Romania	74.5	8.0	6.8	10.8	—	29 832	139.2	11.0
Russian Federation	62.0	2.1	—	35.9	—	292 206	205.1	8.1
San Marino	60.0[i]	20.0[i]	—	20.0[i]	—	431	1463.1	431.0
Serbia	58.6	5.6	9.2	25.1	1.5	22 201	225.2	23.1
Slovakia	49.6	8.0	8.5	33.9	—	11 310	209.8	13.9
Slovenia	64.5[i]	18.1	5.8	11.3	0.3	16 449	821.8	56.1
Spain	62.0	19.0	2.0	15.0	1.0	143 450	324.0	35.0
Sweden	65.0	16.0	6.0	12.0	1.0	26 636	292.1	56.6
Switzerland	48.0	22.0	9.0	21.0	—	26 718	357.0	72.2
Tajikistan	48.7	1.1	6.0	43.6	0.7	2 048	30.4	2.2
The former Yugoslav Republic of Macedonia	41.4	10.7	3.6	34.3	10.0	6 133	300.9	43.8
Turkey	55.0	8.0	1.8	18.9	16.3	169 080	225.8	16.8
Turkmenistan	—	—	4.6	28.9	66.5	1 606	32.3	1.7
Ukraine	44.3[i]	—	—	55.7	—	40 887	88.5	4.1
United Kingdom	55.0	19.0	4.0	21.0	1.0	264 288	434.9	80.1
Uzbekistan	—	—	—	—	—	—	—	—

Table 4.11: Road user deaths by type and road traffic injuries for countries in the WHO European Region. (European status report on road safety, WHO 2009)

Using the constraint devices the severity of the accidents for the VRUs should be better addressed within the regions and better enforcement for the implementation of seat belt, helmet wearing is needed. Wearing helmets protects the brain and face from serious injury if motorized two-wheelers crash and can save life. A comprehensive law on helmet use applies to all riders of all motorized two-wheelers on all roads and irrespective of age, religion or engine size. Universal helmet use has been reported as achieved only in Norway and Switzerland. Within the WHO European region halve of the countries have such law of helmet wearing but still long way to better implement it. The seat-belt usage is available for most countries (65%). These range from 98% in France to 30% in Albania for front seat occupants.

Road traffic deaths and injuries have vast costs. Data are collected using several methods, but 14 of the countries use a similar method. This shows that the economic burden per person of road traffic injuries varies greatly across the Region and is usually higher in countries with higher income (Fig. 4.14). The estimated economic burden of road traffic injury ranges from 0.4% to 3.1% of GDP. Some countries also reported estimated costs per death in an attempt to express the cost of a human life in monetary terms.

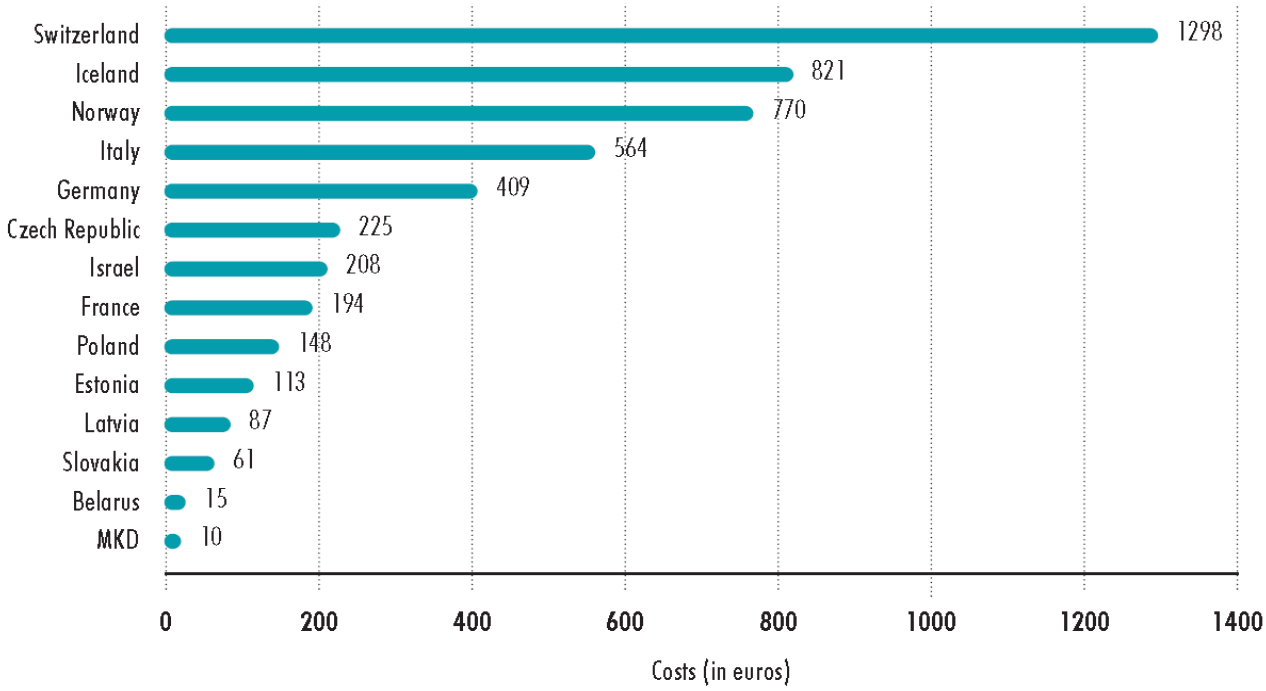


Figure 4.14: Costs (in Euros) of road traffic deaths and injuries per person, gross output method, selected countries in the WHO European Region (European status report on road safety, WHO 2009)

4.4 ROAD SAFETY IN THE UNITED STATES:

The United States was at the forefront of traffic safety for most of the 20th century. Unfortunately, that is no longer the case. Evans (2004) pointed out that, “By 2002 the United States had dropped from first to 16th place in deaths per registered vehicle, and from first to 10th place in deaths for the same distance of travel”. [116]

The most basic measures change the number of fatalities over the most recent decade for the United States and for 17 other developed countries are shown in Table 4.10. In the United States, there was an increase of 5% in road fatalities from 1994 to 2004. In contrast, during the same period most other developed countries, including all of the 17 comparison countries, experienced substantial reductions in fatalities. It happens because the increase in the U.S. population was greater than the corresponding increase in road fatalities, there was a slight reduction in terms of the societal burden of road crashes, with the rate per population dropping by7% which compares this change to the changes in the Netherlands (a country with one of the largest drops in total fatalities) and Sweden (a country with a more moderate drop in total fatalities). It turns out that the reductions in the fatality rate per population in these two countries were substantially greater than in the United States (41% in the Netherlands and 21% in Sweden), and the absolute rate for 2004 in these countries was substantially lower than that in the United States. [117]

The National Highway Traffic Safety Administration (NHTSA) presents descriptive statistics about traffic crashes of all severities, from those that result in property damage to those that result in the loss of human life.
The Fatality Analysis Reporting System (FARS) is probably the better known of the two sources. Established in 1975, FARS contains data on the most severe traffic crashes, those in which someone was killed. The second source is the National Automotive Sampling System General Estimates System (GES), which began operation in 1988. GES contains data from a nationally representative sample of police-reported crashes of all severities, including those that result in death, injury, or property damage. [118]

Country	**Change in road fatalities from 1994 to 2004 (%)**
U.S.A	**+5**
Norway	**-8**
U.K	**-12**
Spain	**-16**
Australia	**-18**
Sweden	**-19**
Italy	**-21**
Finland	**-22**
New Zealand	**-25**
Switzerland	**-25**
Denmark	**-32**
Japan	**-33**
Austria	**-34**
Netherlands	**-38**
France	**-39**
Germany	**-40**
Portugal	**-41**
South Korea	**-43**

Table 4.12: Percentage changes in road fatalities between 1994 and 2004 in the U.S. (FARS, 2006) and 17 other developed countries (IRTAD, 2006).

FARS data are obtained solely from the State's existing documents:

- Police Accident Reports,
- Death Certificates State,
- Vehicle Registration Files,
- Coroner/Medical Examiner Reports,

- State Driver Licensing Files,
- Hospital Medical Reports,
- State Highway Department Data,
- Emergency Medical Service Reports,
- Vital Statistics Other State Records.

The General Estimates System (GES) and The National Automotive Sampling System (NASS) data are obtained from a nationally representative probability sample selected from all police-reported crashes. In 1988 the system began operation. To be eligible for the GES sample, a police accident report (PAR) must be completed for the crash, and the crash must involve at least one motor vehicle traveling on a traffic way and must result in property damage, injury, or death. Although various sources suggest that about half the motor vehicle crashes in the country are not reported to police, the majority of these unreported crashes involve only minor property damage and no significant personal injury. By restricting attention to police-reported crashes, the GES concentrates on those crashes of greatest concern to the highway safety community and the general public.
Some statistics and figure showed as below: [118]

- Fatal crashes decreased by 9.9 percent from 2008 to 2009, and the fatality rate dropped to 1.13 fatalities per 100 million vehicle miles of travel in 2009.
- The injury rate per 100 million vehicle miles of travel decreased by 6.3 percent from 2008 to 2009.
- The occupant fatality rate (including motorcyclists) per 100,000 population, which declined by 22.7 percent from 1975 to 1992, decreased by 26.8 percent from 1992 to 2009.
- The occupant injury rate (including motorcyclists) per 100,000 population, which declined by 13.6 percent from 1988 to 1992, decreased by 40.0 percent from 1992 to 2009.
- The non-occupant fatality rate per 100,000 populations has declined by 60.2 percent from 1975 to 2009.
- The non-occupant injury rate per 100,000 populations has declined by 51.9 percent from 1988 to 2009.
- The percent of alcohol-impaired driving fatalities has declined from 48 percent in 1982 to 32 percent in 2009.

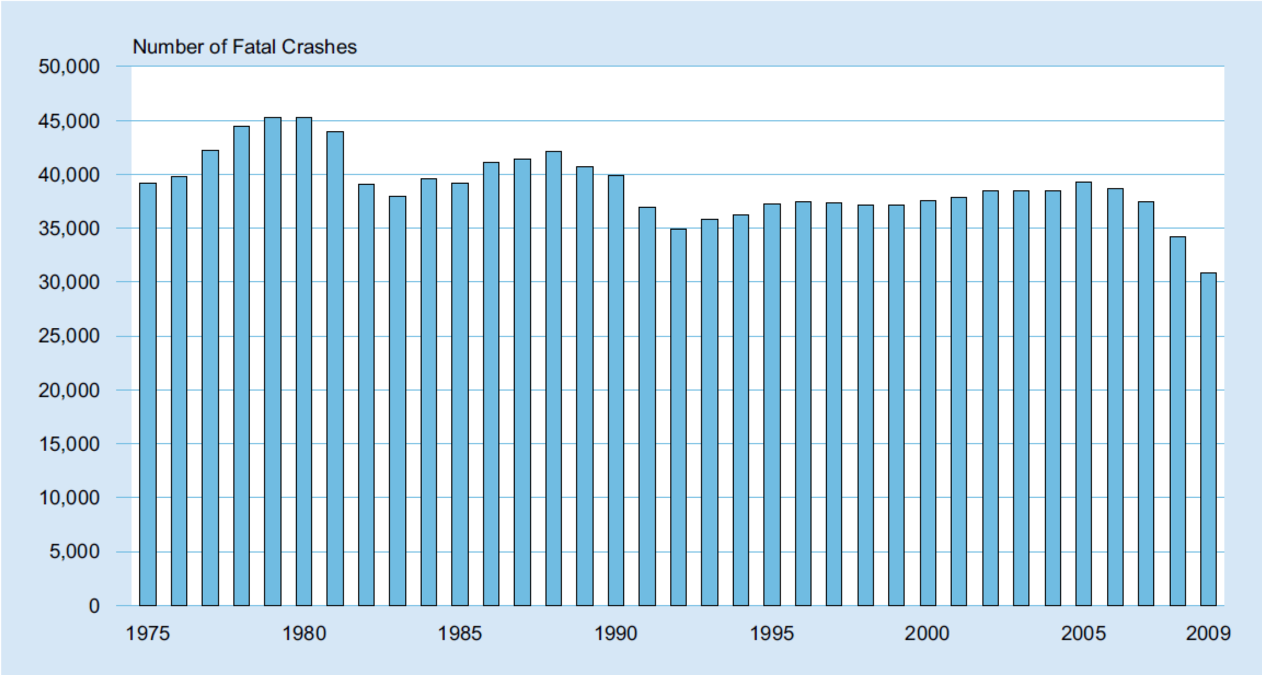


Figure 4.15: Fatal Crashes in USA within the year 1975-2009

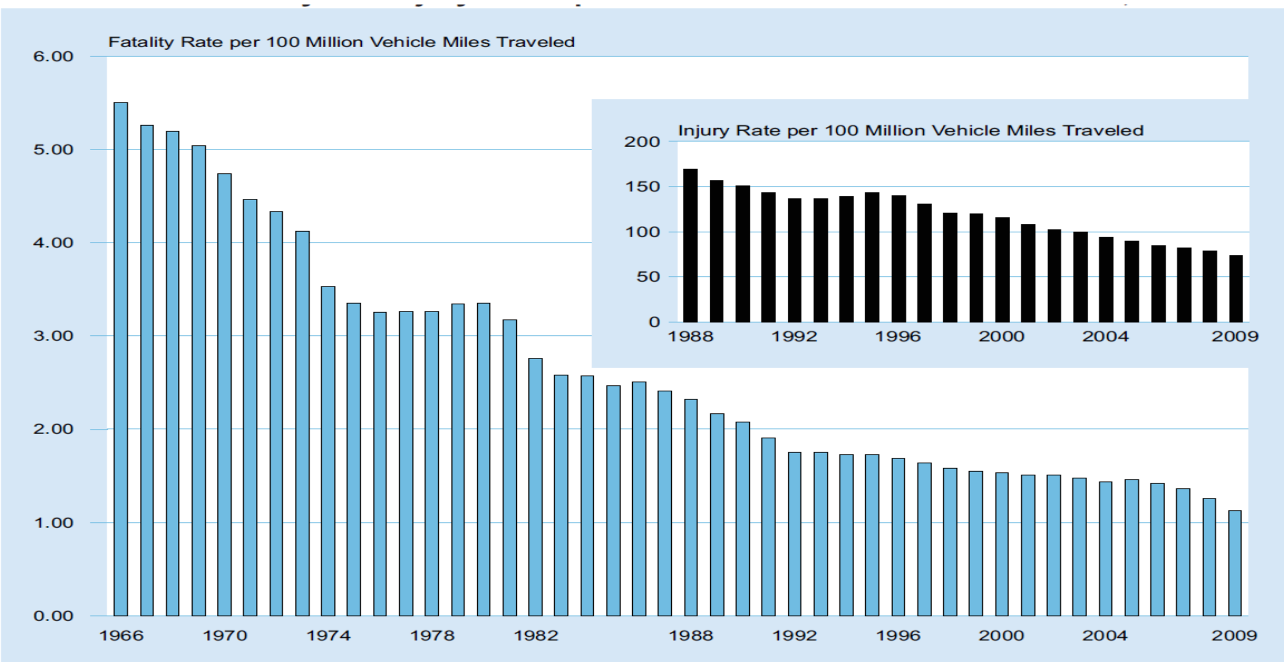


Figure.4.16: Motor Vehicle Fatality and Injury Rates per 100 Million Vehicle Miles Traveled, 1966-2009.

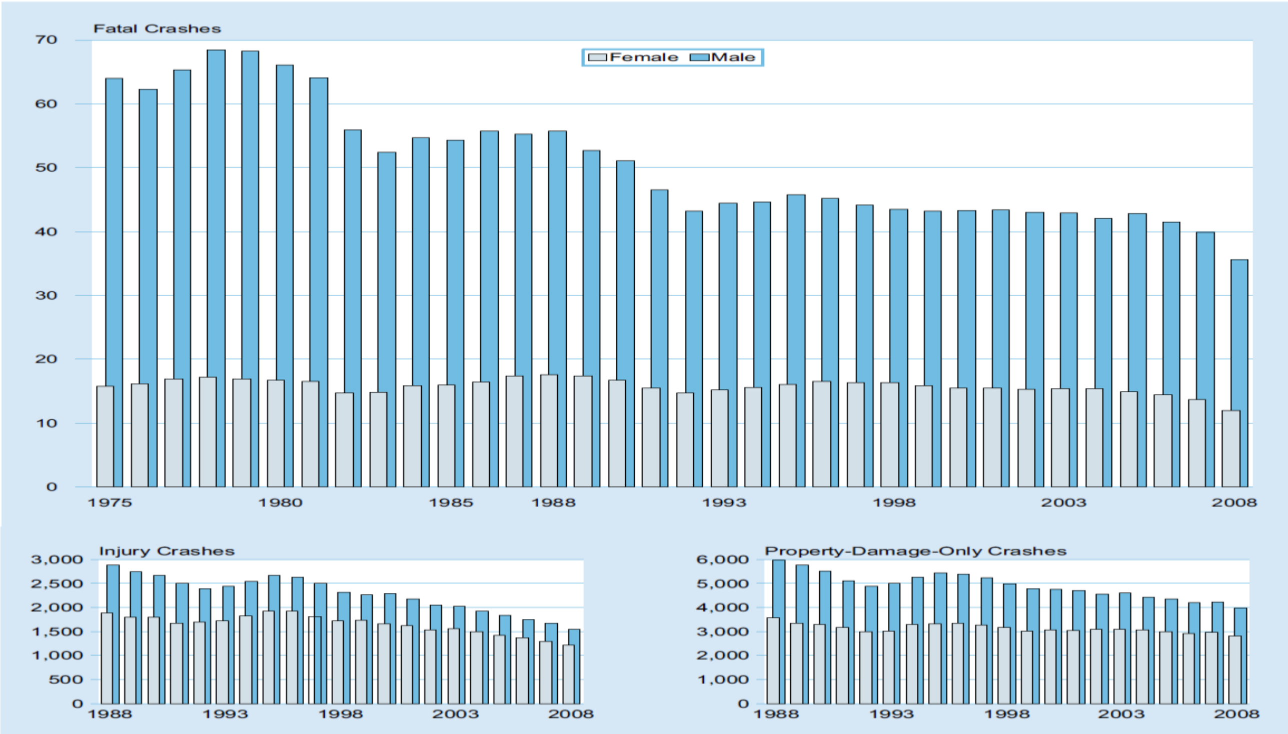


Figure 4.17: Driver Involvement Rate per 100,000 Licensed Drivers 16 Years and Older by Sex and Crash Severity, 1975-2008.

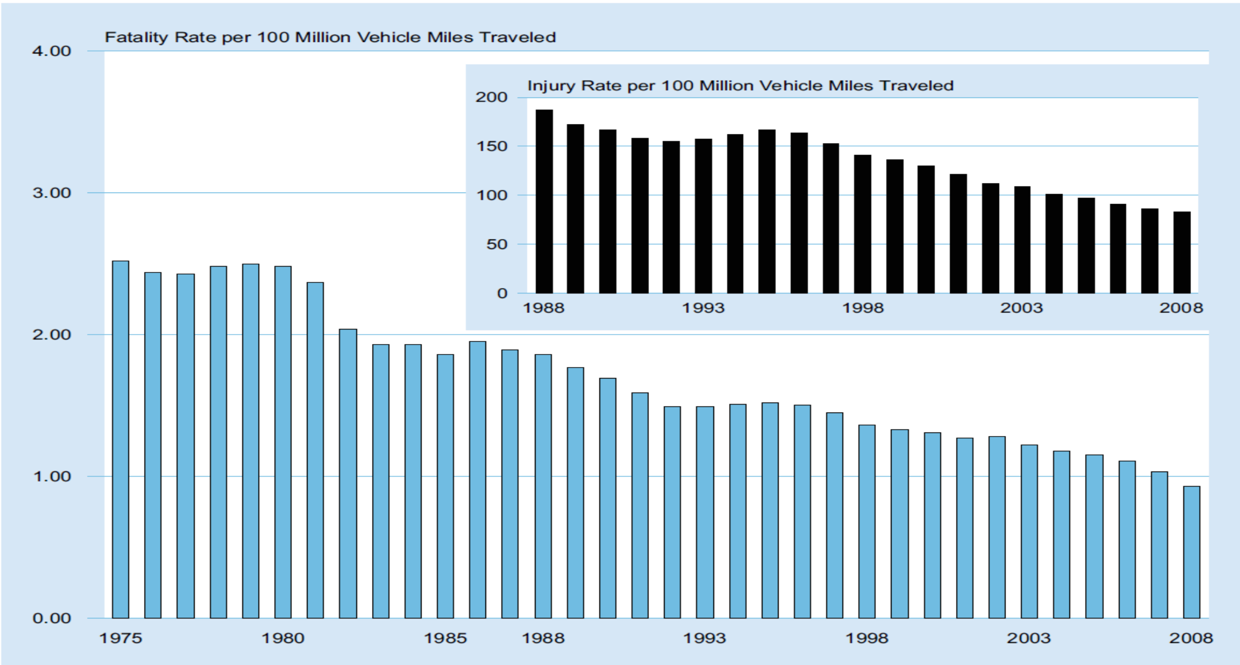


Figure 4.18: Passenger Car Occupant Fatality and Injury Rates per 100 Million Vehicle Miles Traveled, (1975-2008)

The present study was designed to examine five factors that are very important to improve road safety in the United States that's as below: [117]

- Exceeding posted speed limits,
- Not wearing safety belts,
- Alcohol-impaired driving,
- Visibility problems in nighttime driving,

- Young driver problems.

These five factors could be viewed as opportunities not yet taken because of two reasons. First, they have garnered almost universal support as being among the major factors in road safety. For example, WHO (2004) lists all but young drivers among the five key areas for effective intervention. (The fifth area on the WHO list is wearing helmets.) Second, several effective policy and technological countermeasures for these factors have been known for years. [119]

- **Exceeding Posted Speed Limits:**

The speed and crush relation is not only statistical but also casual. In 2003, 13,380 people (31.4% of all road traffic fatalities) were killed in speeding-related crashes in the United States. According to the power model, the risk of injury in an accident increases by the second power of the mean speed, and the risk of a fatal accident increases by the fourth power of the mean speed. [120], [121], [122]

Every licensed driver knows that the posted speed limits should be obeyed but it designed to ensure upon the driver's education. In addition to driver education, information and publicity campaigns regarding the impacts of speed have been used. However, these measures have had no major success.

It happens; this is the situation because the lack of information and attitude towards speed and speed limits are not the main problems. Indeed, the results of a national survey (Royal, 2003) showed that most drivers indicate that it is important to reduce speeding on all types of roads: the highest support was for streets (90%), followed by two-lane roads (86%), non-interstate multilane roads (81%), and multi-lane interstate highways (77%). Almost all drivers (98%) indicated that speeding by others is a threat to themselves and to their family. In addition, only a small minority (8–35%, depending on the road type) stated that the speed limits were too low. [123]

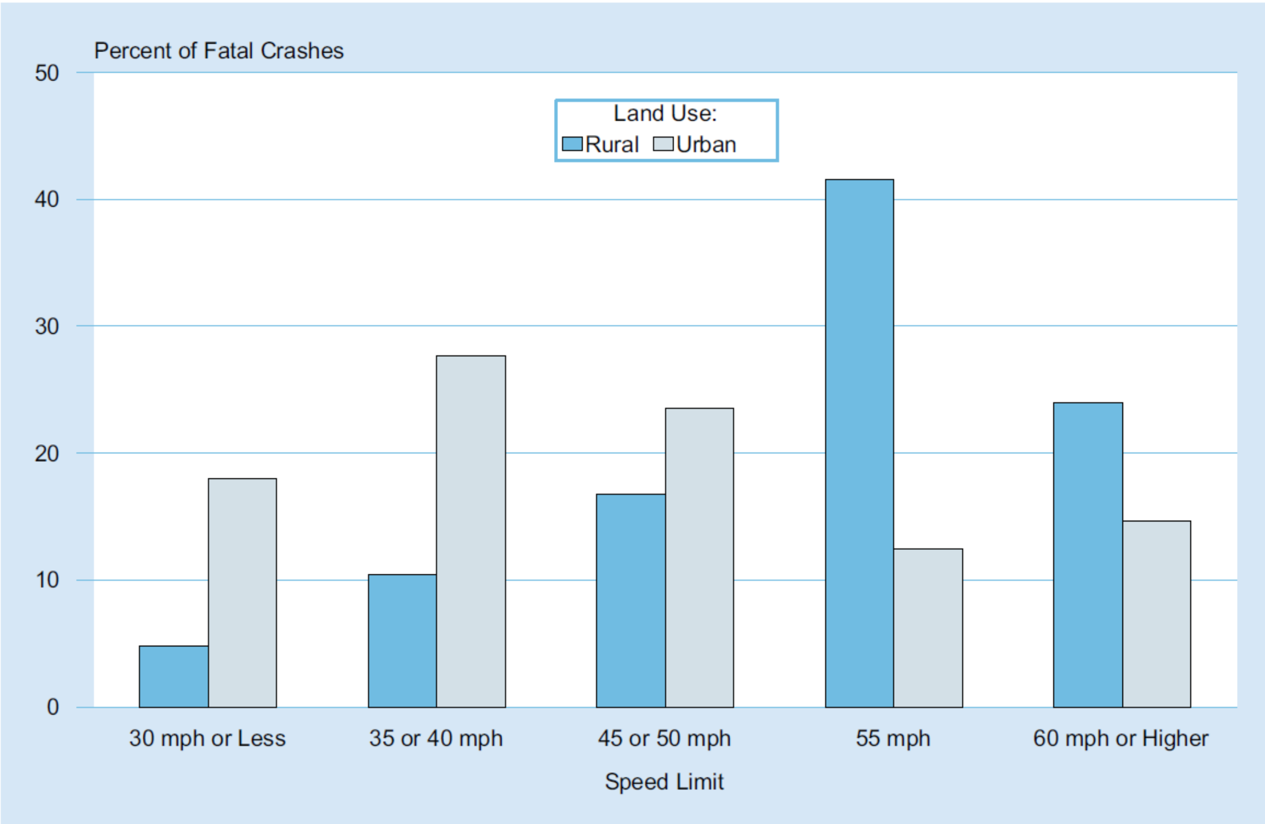


Figure 4.19: percentage of fatal crushes by speed limit and land use. (U.S. DOT 2009)

Traditional speed enforcement involves police officers, usually in police vehicles. However, only a small proportion of all speeding violations are detected: more than 70% of drivers admit exceeding the speed limit within a past month, but only 10% report having been stopped within the past 12 months (Royal, 2003). [123]

- **Use of Safety Belts:**

The most effective technology for reducing injury severity in a motor-vehicle crash is the safety belt. Depending upon the vehicle type, Kahane (2000) has estimated that use of three-point safety belts reduces the risk of fatality by 45–60%. Safety belts are only effective, however, if they are used. Of all the U.S. passenger vehicle occupants killed in 2004, 55% were not restrained by an occupant protection system. The problem is more significant when certain subgroups are considered. In 2004, 68% of passenger vehicle occupant fatalities aged 13–15 years were not restrained, and in 69% of pickup truck fatalities, the occupant was not restrained. If all passenger vehicle occupants used safety belts, NHTSA (2005) estimates that 5,839 lives would have been saved in 2004. This equates to about a 14% reduction in motor vehicle- related fatalities. [124], [125]

- **Alcohol-Impaired Driving:**

In the year of 2004, in the United States, alcohol-impaired drivers were involved in 14,968 fatal crashes, 168,000 injury crashes, and 247,000 property-damage-only crashes, resulting in 16,694 fatalities and 248,000 injuries (NHTSA, 2005). All told, the economic cost to society for medical care, insurance premiums, lost productivity, and other indirect costs due to alcohol-impaired driving exceeded $51 billion in 2002 (NHTSA, 2002). [125], [126]

To reduce heavy alcohol consumption there are many policy and program measures and behaviors that are unacceptably risky when combined with alcohol, such as driving. A few examples of effective programs targeting the person directly are self-help and 12-step programs, such as Alcoholics Anonymous (Davis, Campbell, Tax, & Lieber, 2002), one-on one or group Cognitive Behavioral Therapy, Motivational Interviewing, and brief interventions. These treatments can target at-risk alcohol consumption in general or alcohol impaired driving in particular. [127]

Current technology for reducing alcohol-impaired driving includes active and passive breath sensors. Current breath alcohol sensors are reliable and accurate, and provide immediate results (Jacobs, 2003); however, their use in enforcement is limited to BAC testing after police officers have stopped potentially alcohol-impaired drivers. Alcohol detection technology in non-enforcement programs can also deter alcohol-impaired driving. [128]

- **Night Time Driving:**

Day time driving is safer than night time driving. For example, the current fatality rate per 100,000,000 vehicle miles is 2.27 times higher at night than during the day (NSC, 2004). Given that about 25% of the distance traveled is at night, if the night rate per vehicle mile had been as low as the day rate, 10,282 fewer deaths (24% of the total of 42,636) would have occurred in 2004. [129]

Many of the major problems that can be regarded, at a certain level of analysis, as unified and homogeneous, the problem of increased risk at night can also be viewed as a collection of related but separable mechanisms. i.e. night time risk is influenced by a number of factors that are not unique to night time including alcohol, fatigue, and the proportion of young drivers. Each of these factors has a stronger influence at night, but also accounts for some amount of risk throughout the day. The lack of natural lights is the only major factor for night time driving.

In the night time risk related with the darkness, a major reason for not implementing more of the many options that are available may be that the problem was not well understood prior to the recent work that isolated and quantified that component of risk, independent of factors that are only partially related to night, such as alcohol and fatigue. One reason that it required a careful analysis of crash data to recognize this problem may be that the extent and nature of the visibility problem at night, especially the key role of pedestrian detection, is not fully recognized by drivers themselves because of selective degradation of their visual abilities in night driving (Leibowitz & Owens, 1977). Their ability to see in ways that allow them to stay on the road is little changed at the low light levels typical of roads at night, while their ability to detect and recognize objects such as pedestrians is strongly diminished. Thus, they may be overconfident about their general ability to see what they need to see while driving at night. [130]

- **Young Drivers:**

The higher rates of fatal crash involve with young drivers than any other age group. While in most U.S. states, a license to drive unsupervised requires a driver to be at least age 16, there is some variation, from 14 years and 3 months (with driver education) in South Dakota to 17 years in New Jersey (IIHS, 2006). Age limits on driver licensure in the United States are based historically on the need for young drivers to manage trucks in agricultural areas, and to provide teens with the means of getting to their places of employment. These continue to be common arguments for maintaining the current age limits in the United States. Due to poor driving record of young drivers (under age 25) the insurance companies have for a long time charged. Recently, however, this has changed somewhat, as some insurance agencies have begun to provide discounts for youth who agree to some degree of on-road monitoring (Progressive, 2004). [131], [132]

The National Highway Traffic Safety Administration (NHTSA, 2005), report shows 7,709 drivers of motor vehicles (including motorcycles) who were ages 16 to 20 were involved in fatal crashes in 2004 (a rate of 61.8 per 100,000 licensed drivers), among whom male drivers were more than twice as likely to be involved in fatal crashes as female drivers. The whose age limit between 21 to 24 had the next highest rate of any age group, at 46.5 per 100,000 licensed drivers, with 6,382 drivers involved in fatal crashes. In this age group, male drivers were more than three times as likely to be involved in fatal crashes as female drivers. In comparison, fatal involvement rates for other age groups ranged from 18.7 for 65- to 74-year-old drivers to 31.0 for 25- to 34-yearold drivers, clearly demonstrating the excess risk presented by drivers 16 to 24 years old. [125]

Lot of countermeasure has been adopted to address the particular crash characteristics seen among young drivers. Most of these are policy-based. High rates of alcohol-related fatal crashes led to changes in states' minimum legal drinking age laws, and by 1988 all states had raised their drinking age to 21. During the changeover, states with a minimum legal drinking age of 21 were found to have substantially fewer single-vehicle, night time (proxy for alcohol-related) fatal crashes among drivers under age 21 (O'Malley & Wagenaar, 1991). In 1998, all states had also adopted lower legal blood alcohol concentration limits for drivers under age 21 (“zero tolerance” laws). During that changeover, states with a zero tolerance law were found to have further decreased their rates of single vehicle, night time fatal crashes (Hingson, Heeren, & Winter, 1994). [133], [134].

4.5 COUNTRY PROFILE:

4.5.1 ITALY

According to annual IRTAD report (2010) in the year 2009, 215405 injury crashes occurred and 4237 persons were killed on the Italian roads. Compared to 2008, this represents a 2% decrease in crashes and a 10% reduction in fatalities.

For the long term trend, during the years 1970 to 2009, the number of fatalities decreased by 62% (table 4.13) but the number of injury crashes increased by 16%. The number of vehicles increased fourfold. In recent years (2000-2009), the number of fatalities decreased by 40% and the number of injury crashes started decreasing in 2001 (-16% since 2000).

	1970	1980	1990	2000	2005	2008	2009	2009 % changeover 2008	2000	1970
Fatalities	11 025	9 220	7 151	7 061	5 818	4 725	4 237	-10%	-40%	-62%
Injury crashes	173 132	163 770	161 782	256 546	240 011	218 963	215 405	-2%	-16%	+24%

Death within 30 days

Table 4.13: Reported road fatalities and injury crashes 1970-2009 (IRTD 2010)

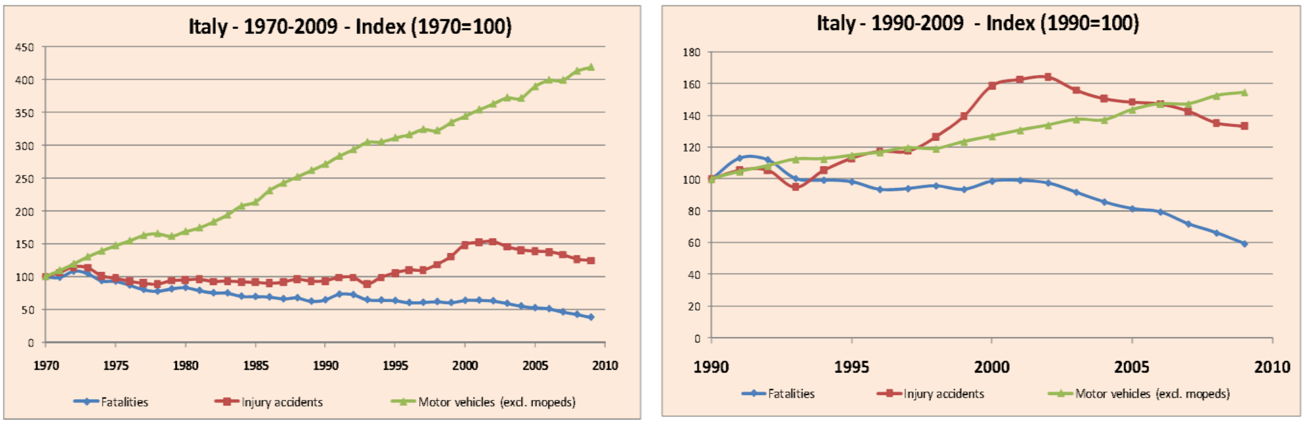


Figure 4.20: Reported road fatalities, injury crashes and vehicles 1970-2009 (IRTD 2010)

During the past nine years the death rate (in terms of deaths per 100 000 population) has decreased by 42% and the death rate (expressed in deaths per 10 000 vehicles) decreased by 50% while motorization has increased by 19 % (table 4.14).

	1970	1990	2000	2009	2009 % changeover 2000	1970
Deaths/100 000 population	20.5	12.6	12.2	7.1	-42%	-66%
Deaths/10 000 registered vehicles	7.9	2.1	1.7	0.9	-50%	-89%

Table 4.14: Risk rates 1970-2009 (IRTD 2010)

In the past decade, the number of fatalities decreased for all user groups except for motorcyclists, for this road user group the number of fatalities increased by 35% compared to 2000 (table 4.15). In 2009, moped riders (-28%) represent the road user group that has seen the largest decrease compared to 2008. The number of fatalities for vulnerable users, such as pedestrians and cyclists, have increased by +3% and +2%, respectively.

	1970		2000		2008		2009		2009 % changeover		
									2008	2000	1970
Bicyclists	1 204	11%	401	6%	288	6%	295	7%	+2%	-26%	-75%
Mopeds	1 194	11%	637	9%	294	6%	212	5%	-28%	-67%	-82%
Motorcycles and scooters	948	9%	770	11%	1 086	23%	1 037	24%	-5%	+35%	+9%
Car occupants	4 173	38%			2 098	44%	1 785	42%	-15%		-57%
Pedestrians	2 863	26%	982	14%	648	14%	667	16%	+3%	-32%	-77%
Others	643	6%			311	7%	241	6%	-23%		-95%
Total	11 025	100%	7 061	100%	4 725	100%	4 237	100%	-10%	-40%	-62%

Table 4.15: Reported fatalities by road user type 1970, 2000, 2008, 2009 (IRTD 2010)

From 1980, the reduction in fatalities has benefited all age groups, but the most impressive reduction concerned the youngest groups (6-9, 0-5 and 10-14), for which fatalities respectively decreased by 92%, 87% and 85%. Young people (18-24) have a higher risk compared to the other age groups (table 4.16).

	1980	1990	2000	2008	2009	2009 % changeover		
						2008	2000	1980
0-5	150	69	39	29	19	-34%	-51%	-87%
6-9	165	60	34	14	13	-7%	-62%	-92%
10-14	261	118	63	43	39	-9%	-38%	-85%
15-17	572	429	211	163	121	-26%	-43%	-79%
18-20	683	640	485	286	234	-18%	-52%	-66%
21-24	753	786	740	351	345	-2%	-53%	-54%
25-64	4 211	3 245	3 637	2 598	2 265	-13%	-38%	-46%
>65	1 941	1 436	1 437	1 100	1 111	1%	-23%	-43%

Table 4.16: Reported fatalities by age group 1980, 1990, 2000, 2008, 2009 (IRTD 2010)

The current BAC limit in Italy, which came into force in 2001, is 0.5 g/l. Since July 2010, there is zero tolerance for young drivers, novice drivers and professional drivers, for whom the BAC limit is equal to 0 g/l. The general speed limits are: Urban areas 50 km/h, rural roads 90-110 km/h and motorways 130 km/h. In 2009, inappropriate speed was reported in about 8% of injury crashes.
In Italy, Seat-belt usage is compulsory in front seats since 1988 and rear seats since 1994. Table 4.17 shows seat-belt use in 2005, 2006 and 2007.

	2005	2006	2007
General (rear and front seats)	72%	72%	65%

Table 4.17: Seat belt wearing rates in Italy (IRTD 2010)

Since 1986, all motorcyclists are required to wear a helmet. The same obligation for moped riders (older than seventeen) was introduced in 2000. Since 2010, helmet wearing has been compulsory for cyclists under 14.
The helmet wearing rate varies considerably across the country.
In Italy, the Road Safety National Plan covers the period 2001-2010. The Plan set a target to reduce the number of road fatalities by 50% between 2001 and 2010 (in line with the EU target). The Plan is structured according to a two-level action strategy:

•The first-level actions support, also economically, the implementation of immediately feasible measures in high-risk situations.
•The second-level actions aim at the implementation of a new and efficient system made up of techniques and tools for the analysis of risk factors, road safety monitoring and of methods and criteria for road safety management. The revision of the Road Safety National Plan is expected in 2011.

The 2010 targets identified in the Road Safety National Plan are:
• to reduce the number of fatalities by 50% compared to 2001;
• to reduce the number of injuries by 20% compared to 2001.

The figure below shows the progress made towards the ECMT target, approved by Transport Ministers in 2002, of a 50% reduction in the number of fatalities by 2012 compared to the level in 2000.

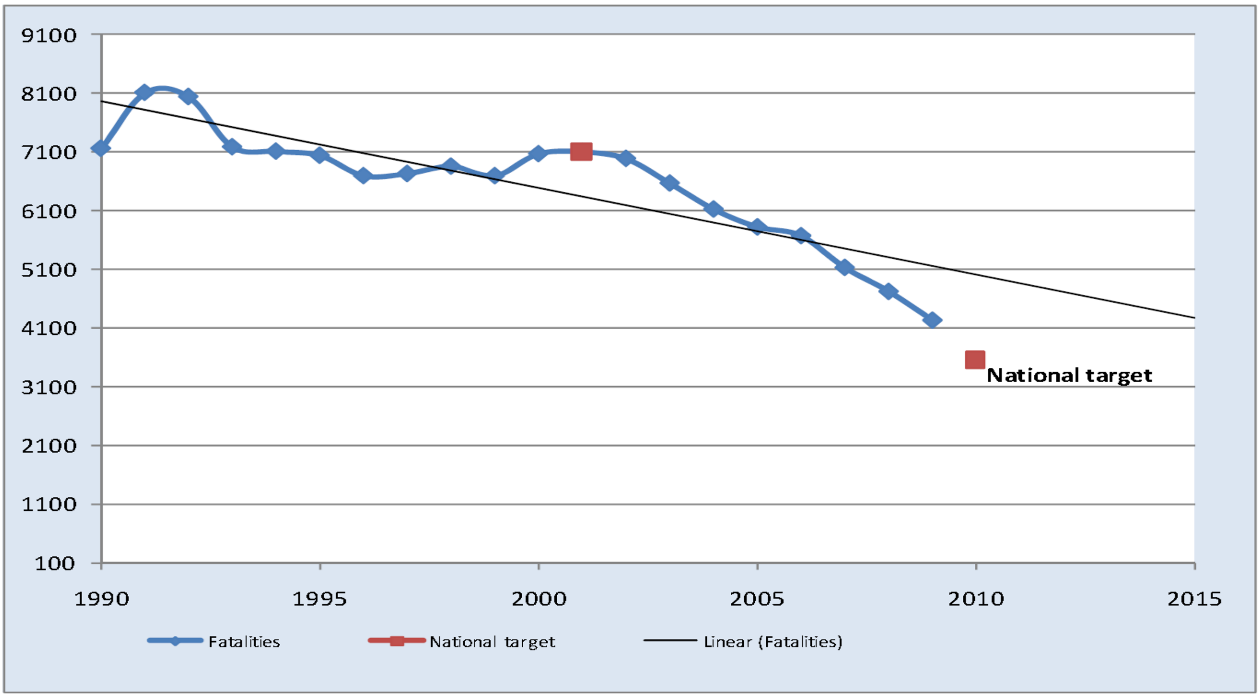


Figure 4.21: Progress towards road safety target in Italy. (IRTD 2010)

4.5.2 FRANCE

In the short term trends, the results for 2009 are mitigated, with a quasi stability in the number of fatalities and a slight decrease in the number of injury accidents (-2.9%) and in the number of injured (-3.1%). [98]

- 4 273 fatalities in 2009 (compared to 4 275 in 2008)
- 72 315 injury accidents (73 390)

- 90 934 injured.

To understand the situation, it is important to look more precisely at the evolution of safety for the different road users. Despite an increase in mobility (+1.2%) (Which followed an historical decline in 2008 as a consequence of the economic crisis), there has been an overall continuous decrease I the number of road users killed, with the exception of motorcyclists for which the situation deteriorated seriously in 2009, with an 11.7% increase in the number of fatalities.

In the long term trend, between 1970 and 2009, the number of fatalities decreased by 74% and the number of injury crashes by 69%. In the same period, the number of vehicles tripled. In recent years (2000-2009), the decrease in the number of fatalities has been sustained (-48%). A significant change was introduced in July 2002, when President Chirac announced that road safety was among the priorities of his mandate. Since then, a determined road safety policy has been developed, with effective measures regarding speed management, drink-driving and seat-belt use, the strengthening of the demerit point system, etc. While the rate of decrease has been sustained until 2009, there has been a slowing down in the progress made in 2009, mainly in the period March to May. Nevertheless the downward trend recommenced in autumn 2009 and preliminary results for 2010 are encouraging.

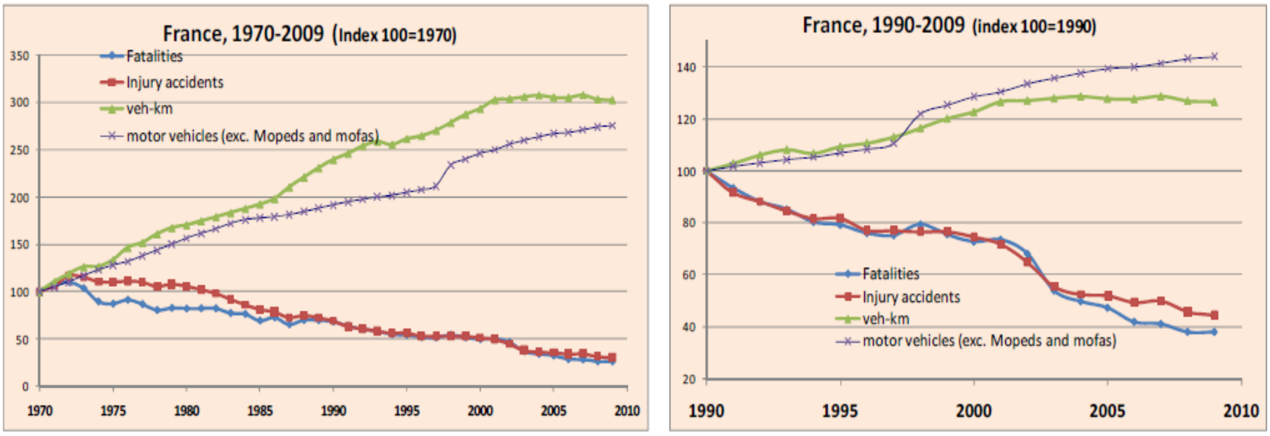


Figure 4.22: Change in numbers of road fatalities, injury crashes and vehicles (1970-2009).

Between 1970 and 2009 the mortality rate, expressed in terms of deaths per 100 000 population, was divided by nearly a factor of 5, and the fatality risk (expressed in deaths per distance travelled) decreased by 91%, shown in below figure.

				Change	
	1970	2000	2009	2000-2009	1970-2009
Deaths/100 000 population	32.55	12.9	6.80	-47%	-79%
Deaths/billion veh-km	90.36	15.1	7.75	-49%	-91%
Deaths/ 10 000 registered vehicles		2.4			

Table 4.18: Risk indicators 1970, 2000 and 2009. (IRTD 2010)

Considering road users, since 1970, all road users benefited significantly from progress in road safety, with the exception of motorized two wheelers. The number of motorcyclists killed increased dramatically (+166%) since 1970 (see below table). In the year 2009, all road user groups with the exception of motorized two wheelers and cyclists benefitted from a slight decrease in mortality (-3.2% on average). Motorized two wheelers continued to be the user group most at risk. In 2009, they represented 1.6% of the motorized traffic but 28% of fatalities and 33% of motorized road users. In 2009, the number of motorcyclists killed increased by 11.7%. This increase mainly concerned motorcyclists (and to a lesser extent riders of mopeds and mofas). Improving the safety of motorized two wheelers is a priority of the current road safety strategy. Below figure shows the respective change in the number of mopeds and motorcycles in traffic and the number of moped and motorcycle riders killed.

	1970		2000*		2008		2009		2009 % changeover 2008	2000	1970-
Bicyclists	867	5%	273	3%	148	3%	162	4%	+9,5%	-40,7%	-81,3%
Mopeds	2 874	17%	461	6%	273	6%	299	7%	+2,7%	-35,1%	-89,6%
Motorcycles and scooters	334	2%	947	12%	795	19%	888	21%	+11,7%	-6,2%	+165,9%
Car occupants	8 199	50%	5 351	65%	2205	52%	2160	51%	-2,0%	-59,6%	-73,7%
Pedestrians	3 490	21%	848	10%	548	13%	496	12%	-9,5%	-41,5%	-85,8%
Others	681	4%	365	4%	288	7%	268	6%	-6,9%	-26,6%	-60,6%
Total	16 445	100%	8 170	100%	4275	100%	4273	100%	-0,0%	-47,7%	-74,0%

Table 4.19: Fatalities by road user group 1970, 2000, 2008 and 2009. (IRTD 2010)

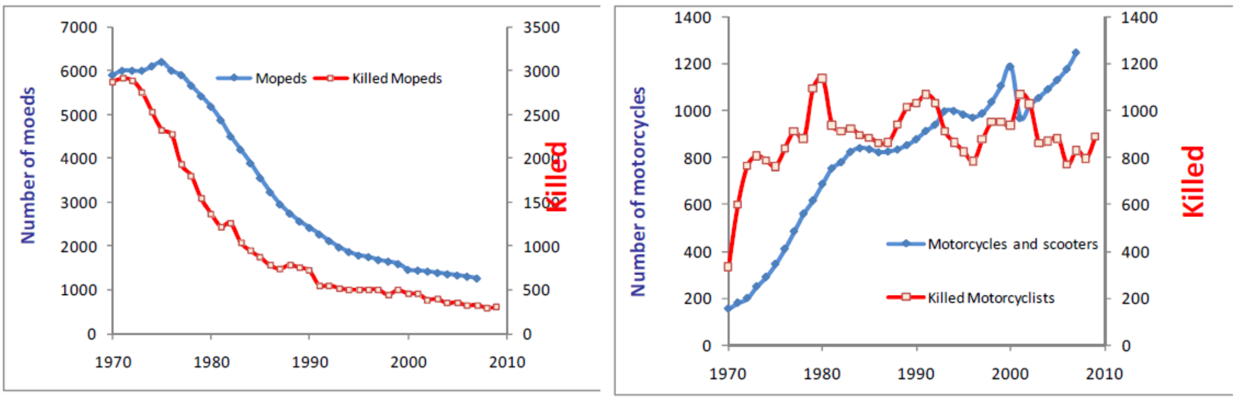


Figure 4.23: Relative evolution of the number of motorized two-wheelers in traffic and the number of moped riders and motorcyclists killed in traffic. (IRTD 2010)

Age group is very important in road fatalities. Since 1980, the reduction in fatalities has benefitted all age groups, but the most impressive reduction concerned the youngest groups 6-9 years, 10-14 and 0-5 for which fatalities respectively decreased by 92%, 86% and 83%.

Young people are over represented in road fatalities (see below Figure). The 18-24 age group represents around 9% of the population but 21% of road fatalities. The 18-20 group continues to be the one most at risk, with a rate of 18 fatalities per 100 000 population of the same age, while the rate for the general population is around 7.

In 2009, there was a slight relative increase in the share of fatalities among those aged 25 to 65.

	1980	1990	2000*	2008	2009	2009 % changeover 2008	2009 % changeover 2000	2009 % changeover 1970
0-5	296	220	125	42	49	17%	-60%	-83%
6-9	261	132	68	25	21	-16%	-69%	-92%
10-14	362	222	173	58	52	-10%	-70%	-86%
15-17	840	534	354	172	189	10%	-46%	-78%
18-20	1 693	1 224	867	424	403	-5%	-53%	-76%
21-24	1 703	1 566	879	534	498	-7%	-43%	-71%
25-64	6 118	5 684	4 204	2 209	2 265	3%	-46%	-64%
>65	2 092	1 603	1 358	811	796	-2%	-41%	-62%

Table 4.20: Reported fatalities by age group 1980, 1990, 2000, 2008 and 2009. (IRTD 2010)

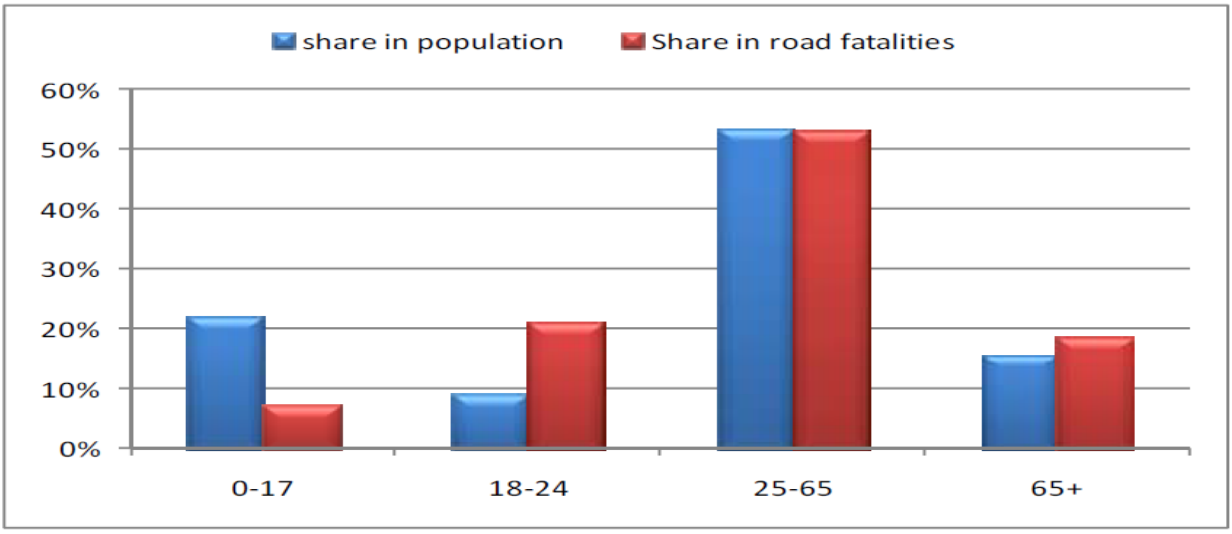


Figure 4.24: Relative representation in fatalities by age group 2009. (IRTD 2010)

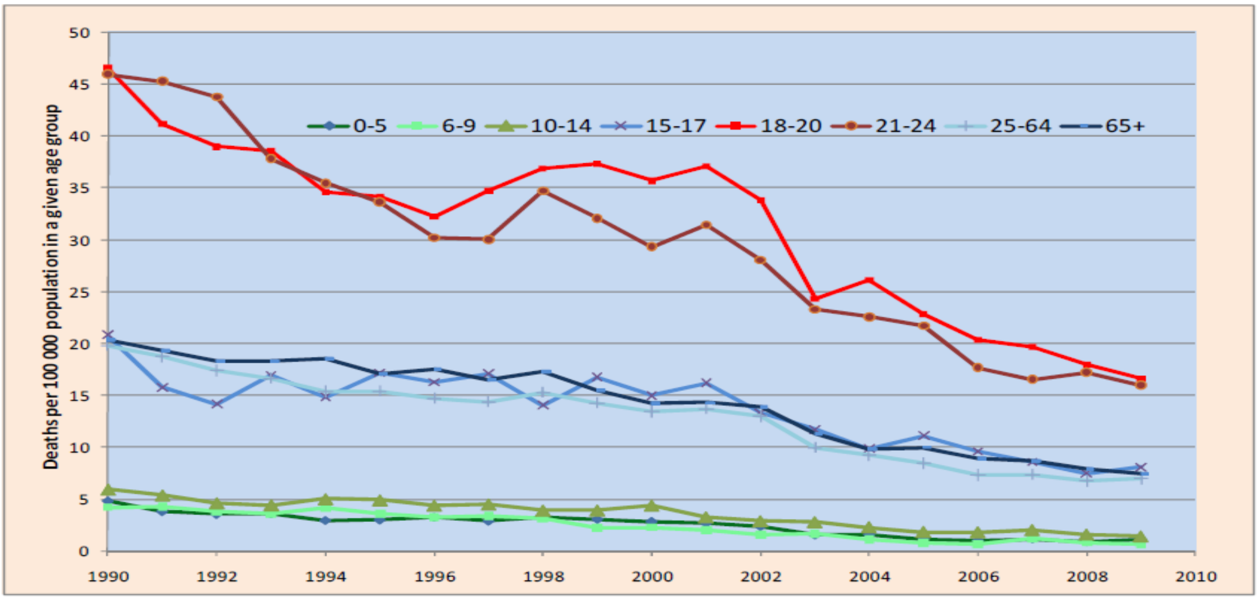


Figure 4.25: Change in fatality risks by age group (deaths per 100 000 populations in a given group), 1990-2009. (IRTD 2010)

The maximum permissible blood alcohol content is 0.5 g/l and 0.2 g/l for bus drivers. In 2009, alcohol was a contributing factor in 24% of fatalities. Among those drivers killed, 30.1% had a BAC above the limit (this figure was 28.3% in 2008). Drink-driving is now the first cause of fatalities in France (mainly due to the fact that speed-related crashes have diminished).

In 2002, speed enforcement was significantly strengthened with the introduction of automatic speed cameras. Between 2002 and 2009, the average speed decreased by 10% and the rate of speed violation decreased from 52% in 2002 to 26% in 2009. It is estimated that this contributed toward saving 11 000 lives between 2003 and 2009. In 2009, the decrease in average speed by passenger cars continued. It is estimated that the average speed decreased by 0.6 km/h, contributing to the saving of 130 lives. Nevertheless, 760 lives could have been saved in 2009 if speed limits had been strictly respected. Between 10-15% of car and truck drivers drive 10 km/h above the limit. This proportion is significantly higher for motorcyclists (between 25-30%).

The seat-belt usage rate is very high in France, and among the best in OECD/ITF countries (see below Table). However, in 2009 the wearing rate for drivers slightly decreased in urban areas (from 96.3% in 2008 to 94.6% in 2009). Regarding rear-seat passengers, the usage rate progressed for adults (78%) but slightly decreased for children (96.6%).

	1980	1990	2000	2009
Motorway – driver	94%	91%	96%	99%
Rural roads – driver	79%	87%	94%	99%
Urban areas – driver	55%	55%	78%	95%

Table 4.21: Change in seat-belt usage rate. (IRTD 2010)

4.5.3 NETHERLAND

The numbers of road fatalities and hospitalizations, which have shown a decreasing trend, fell further in 2009 to 720 fatalities and 7 0282 reported hospitalizations, respectively, a 4% and a 24% decrease compared to 2008. The impact of the economic recession on the reduction in fatalities is unclear; however, it can be noted that a sharp decrease in the sale of new vehicles was observed in 2009.

Statistics in the Netherlands distinguish between reported and real numbers of crashes. The former category covers crashes reported by the police, while real numbers are higher, as they take into account data from sources such as hospitals and death certificates. Between 1970 and 2009, the number of fatalities decreased by nearly 80% and the number of injury crashes by 67%, while the number of vehicles tripled. In recent years (2000-2009), the number of fatalities continued to fall, by 41%.In very recently, research on serious traffic injuries shows that the number of police reported hospitalized casualties is not a good indicator of serious injury. The research derived a new series of MAIS 2+ (Maximum Abbreviated Injury Scale of at least 2) casualties for 1993-2008. It represents a decrease over 1993-2006 and an increase in the last two years.

Reported numbers	1970	1980	1990	2000	2008	2009	2009 % changeover 2008	2000	1970
Fatalities	3 181	1 996	1 376	1 082	677	644	-4.9%	-40.5%	-79.8%
Seriously injured (hospitalised)		18 616	13 658	11 505	9 310	7 028	-24.5%	-38.9%	
Injury crashes	58 883	49 383	44 915	37 947	23 708	19 378	-18.3%	-48.9%	-67.1%
Real numbers									
Fatalities				1 66	750	720	-4.0%	-38.3%	
Seriously injured (MAIS 2+)				16 700	17 600				

Table 4.22: Number of road fatalities, seriously injured and injury crashes 1970-2009. (IRTD 2010)

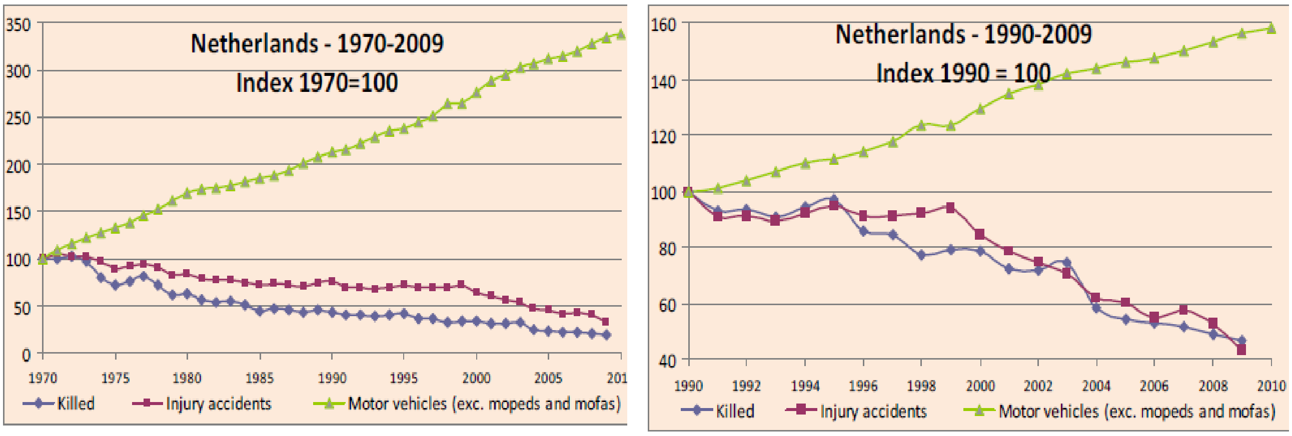


Figure4.26: Evolution in numbers of road fatalities, injury crashes and vehicles 1970-2009.

The number of fatalities varies with age. In experienced riders and drivers are killed more often in traffic, as are vulnerable road users. Most cyclists who are killed are between the ages of 12 and 25, and the largest age group for car driver fatalities is 18 to 25. Since 1970, the reduction in fatalities has benefited all age groups, but the most impressive reduction concerned the youngest group (0-14), for which fatalities decreased by 95%, from 459 in 1970 to 23 in 2009.
In the year of 2009, the number of young people killed (18-24) was higher than in 2008, see below table.

	1970	1980	1990	2000	2008	2009	2009 % changeover 2008	2000	1970
0-5	175	36	22	15	6	3	-50.0%	-80%	-98%
6-9	144	78	28	14	2	4	100.0%	-71%	-97%
10-14	140	89	50	27	15	16	6.7%	-41%	-89%
15-17	222	147	81	54	32	26	-18.8%	-52%	-88%
18-20	280	253	129	118	47	53	12.8%	-55%	-81%
21-24	309	206	152	109	60	73	21.7%	-33%	-76%
25-64	1 263	726	607	510	341	282	-17.3%	-45%	-78%
>65	648	461	307	235	174	187	7.5%	-20%	-98%

Table 4.23: Reported fatalities by age group. (IRTD 2010)

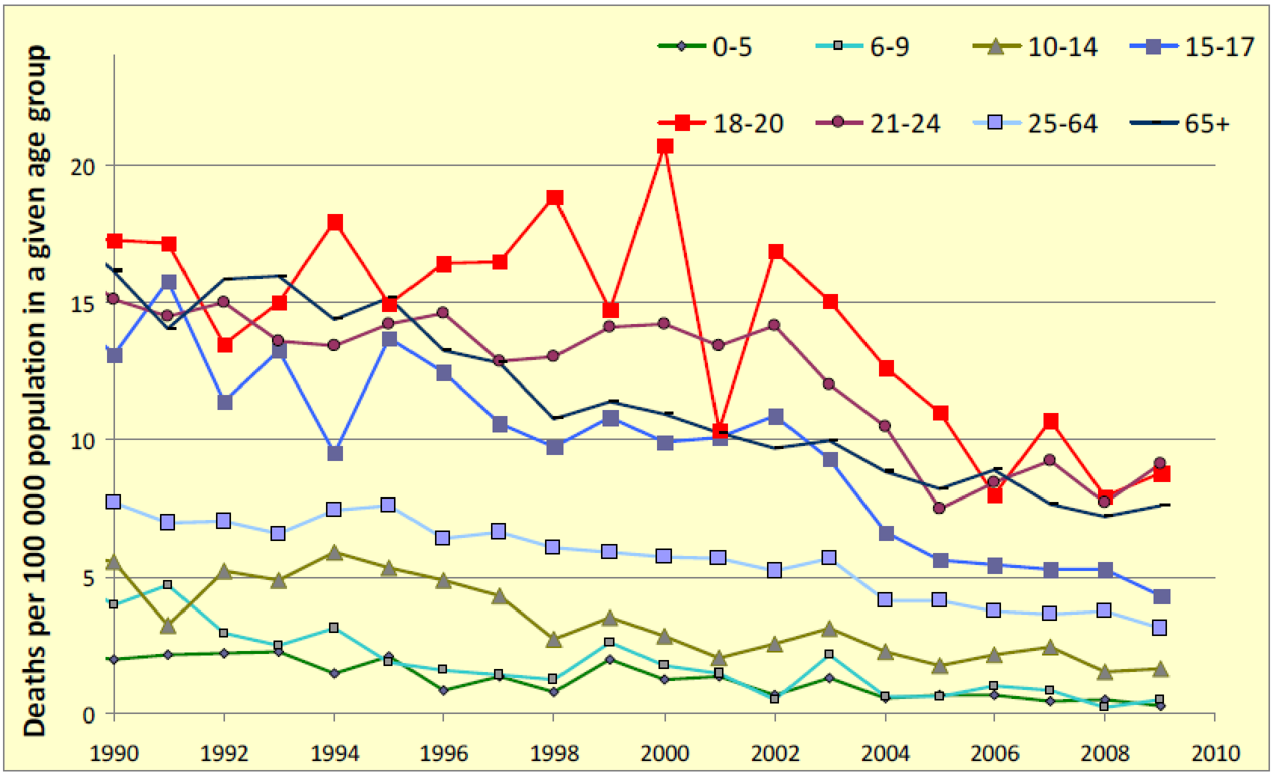


Figure 4.27: Evolution of fatality risks by age group (deaths per 100 000 populations in a given group) 1990-2009. (IRTD 2010)

Till 2006, the BAC limit in the Netherlands was 0.5 g/l for all drivers. Since 2006, a lower limit of 0.2 g/l has applied for novice drivers (first five years). Driving under the influence of alcohol and/or drugs was a contributing factor in an estimated 30% of fatal crashes in 2008. The prevalence of driving under the influence of alcohol on weekend nights is stable at 3%. Among novice drivers, the prevalence is higher at 5%, and in about half of these cases the BAC is between 0.2% and 0.5%. It is prohibited to drive a vehicle whilst under the influence of a substance (for example, alcohol, medication or drugs) that affects the driving ability in such a way that one is unfit to drive. This is stated in Section 8 of the 1994 Road Traffic Act. A stricter version of the law is being prepared regarding drugs and driving. Legal blood concentration limits have been established for a number of illegal drugs. This list was made up by an international commission of experts from the Netherlands, Belgium and Germany, chaired by the Netherlands' Forensic Institute (NFI). The list includes amphetamines, Meta amphetamines, XTC, THC, cocaine, morphine and GHB. By 2012, a saliva test will indicate any of these substances, except GHB. After a positive saliva test, a blood test will be used as supporting evidence. For some illegal drugs a tester is not yet available. In these cases, the police still have to determine fitness to drive by examining speech, eyes and balance.

Seat belt use has a crucial role to reduce consequences of road accident. Seat-belt use has been compulsory in front seats since 1975 and in rear seats since 1992. The rate of seat-belt use is around 95% in front seats and 80% in rear seats in passenger cars. For vans, the rate of use is lower.

	1980	1990	2000	2005	2008
General	-	-	-	-	-
Front seat – driver	-	-	79%	92%	95%
Front seat – passenger	-	-	80%	90%	94%
Rear seat	-	19%	32%	64%	81%
Motorway – driver	-	-	-	-	-
Rural roads – driver	73%	78%	86%	93%	96%
Urban areas – driver	57%	59%	74%	91%	95%

Table 4.24: Evolution in seat-belt use for car occupants. (IRTD 2010)

4.5.4 JAPAN

In the year of 2009, the number of road fatalities decreased by 4%, reaching its lowest level since recordkeeping began. The number of injury crashes also fell by 4%.
On the other hand, In between 1970 and 2009, the number of fatalities decreased by 74% but the number of injury crashes rose by 3%. In the same period, the number of vehicles and the distance travelled (vehicle kilometers) were multiplied by more than three. In recent years (2000-2009), the decline in the number of fatalities was sustained (-45%).

								2009 % changeover		
	1970	1980	1990	2000	2005	2008	2009	2008	2000	1970
Fatalities	21 795	11 388	14 595	10 403	7 931	6 023	5 772	-4%	-45%	-74%
Injury crashes	718 080	476 677	643 097	931 934	933 828	766 147	736 688	-4%	-21%	3%

Table 4.25: Reported road fatalities and injury crashes 1970-2009. (IRTD 2010)

Japan reached its maximum number of traffic deaths in the late 1960s. Since then, fatalities have seen a steady decrease, with some fluctuations over the years.

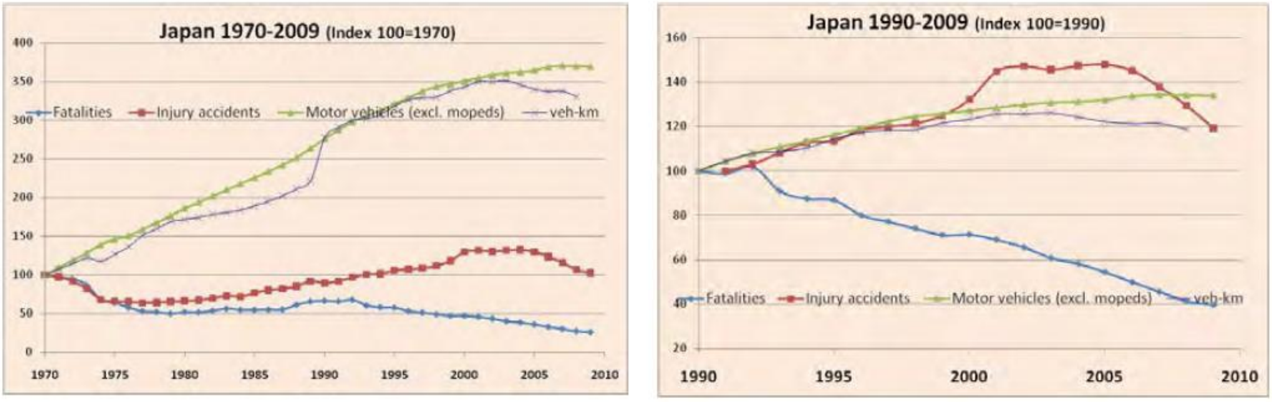


Figure 4.28: Reported road fatalities, injury crashes and vehicles 1970-2009. (IRTD 2010)

Since 1980, the reduction in fatalities has benefitted all age groups except the elderly (+65). It happens due to ageing of Japanese society. In 2009, victims over age 65 accounted for more than half of all fatalities. Unlike in other countries, the oldest age group is also the one the most at risk in traffic. Young people (18-20) have a slightly higher risk than the general population but the difference is much less marked than in other countries. The most impressive reduction concerned the youngest group (0-9), for which the fatality figure was reduced by more than 90% in 29 years.

The national goal of making Japan's roads the "safest in the world", by reducing annual traffic fatalities to below 5 000 by 2012, can be realized only if greater effort is made to improve senior traffic safety. The government is now implementing a diverse array of strategies to improve the safety of those at the upper end of an ageing society.

							2009 % changeover		
	1970	**1980**	**1990**	**2000**	**2008**	**2009**	**2008**	**2000**	**1980**
0-5	1 537	647	312	88	55	47	-15%	-47%	-93%
6-9	666	381	198	76	45	42	-7%	-45%	-89%
10-14	381	151	143	75	45	27	-40%	-64%	-82%
15-17	1 218	909	1 006	327	134	133	-1%	-59%	-85%
18-20		1 034	1 820	690	274	242	-12%	-65%	-77%
21-24		814	1 381	772	247	242	-2%	-69%	-70%
25-64	10 568	5 233	6 261	4 635	2 273	2082	-8%	-55%	-60%
>65	3 554	2 220	3 475	3 740	2 950	2957	0%	-21%	33%
Total	***21 795***	***11 388***	***14 595***	***10 403***	***6 023***	***5772***	***-4%***	***-45%***	***-49%***

Table 4.26: Reported fatalities by age group 1970, 1980, 1990, 2000, 2008 and 2009.

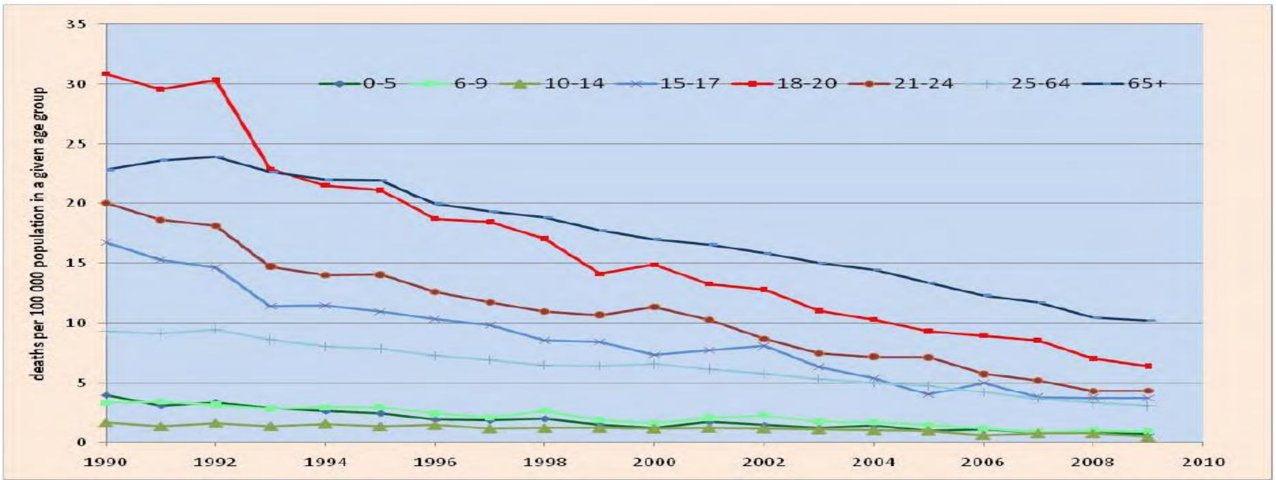


Figure 4.29: Reported death rate by age band (Fatalities per 100 000 populations in a given group, (1990-2009). (IRTD 2010)

In 2002, the maximum BAC was lowered from 0.5g/l to 0.3g/l. Since then, the number of fatal crashes caused by alcohol has been divided by 4. In 2009, it was estimated that 6.7% of fatal crashes were alcohol (i.e. a driver or a cyclist with a positive BAC, even below the limit).
Seatbelt wearing has been compulsory in front seats since 1985 and in rear seats since 2008 only. The use of seat-belts in rear seats is still very low. Helmet wearing is compulsory for all motorcycle and moped riders. The usage rate is around 99%.

	1990	2002	2008	2009
Drivers	77%	88%	96%	97%
Passenger - Front seat	72%	75%	90%	91%
Passengers - Rear seats	-	7%	31%	34%
Motorways – driver	90%	97%	98%	99%
Passenger - Front seat	84%	91%	96%	97%
Passengers - Rear seats	-	9%	63%	63%

Table 4.27: Seat-belt wearing rates for car occupants. (IRTD 2010)

4.5.5 CHINA

According to the statistics of the year 2007, the population of the people's republic of China was estimated 1336317116 and the per capita income $ 2360 (middle income country). The Lead agency funded by ministerial decision in national budget is the institutional framework on road traffic safety. Also China has National road safety strategy which is funded to implement countrywide.
The reported road traffic fatalities (2006) are 89 455, out of which 76% males and 24% females. The death rates by road user categories reflect high percentage for motorbike riders which is 28%, the second place is pedestrians (26%) and the other i.e. cyclists, passengers of cars are shown in figure (4.30).

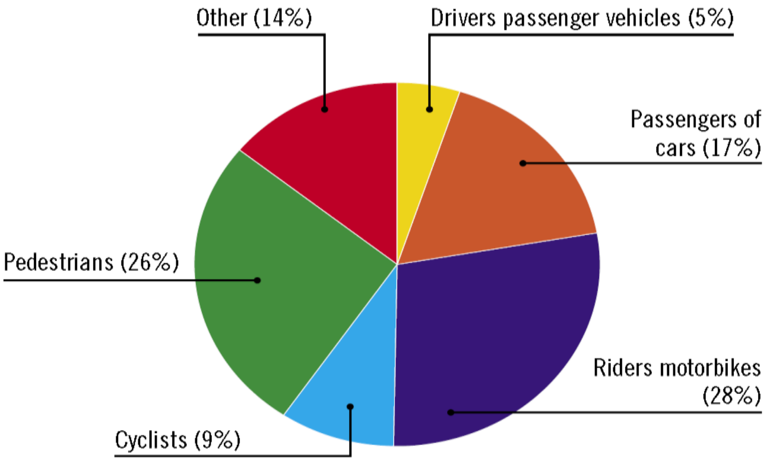


Figure 4.30: Deaths by Road User Category in China. (WHO 2009)

The speed limit can be set by the Local authorities. The nationwide the speed limit for urban roads is 30-50 km/hr. The drink driving law prevails within the country. The BAC limit for the general population and the young-novice driver is 0.02 g/dl. The road traffic deaths involving alcohol related driving contribute 4% of the whole fatalities. The seat belt wearing rate is 50% and helmet wearing rate is 16%. There is no child restraint law for the enactment.
The following figure (4.30) shows the road traffic death trend in China.

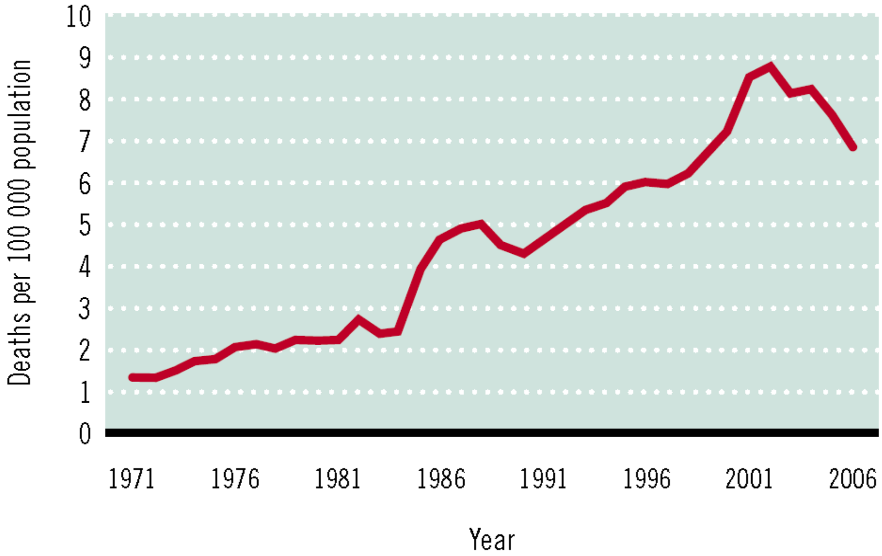


Figure 4.31: Trends in road traffic deaths in China. (WHO 2009)

4.5.6 BANGLADESH

According to the statistics of the year 2007, the population of the people's republic of Bangladesh was estimated 158664959 and the per capita income $ 470 (low income country).
The reported road traffic fatalities (2006) are 3160, out of which 89% males and 11% females. The death rates by road user categories reflect high percentage for pedestrians which is 54%, the second place is passengers 4-wheelers (22%) and the other i.e. cyclists, motorbike riders are shown in figure (4.32).

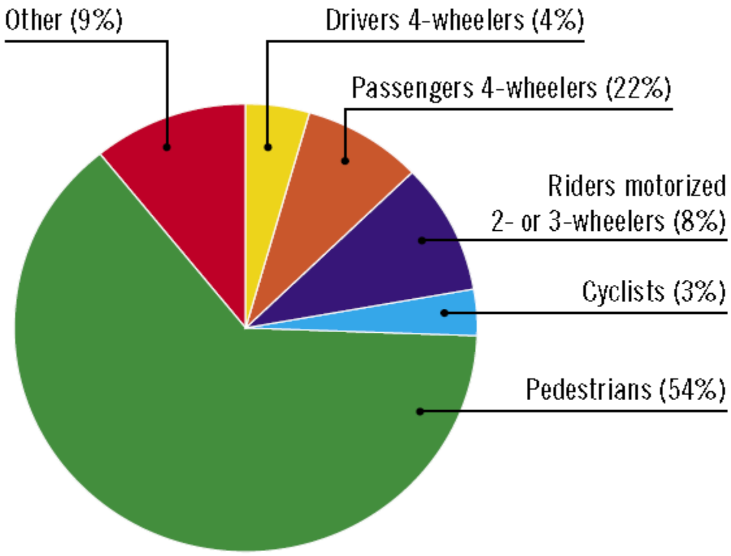


Figure 4.32: Deaths by Road User Category in Bangladesh. (WHO 2009)
The speed limit cannot set by the Local authorities. The nationwide the speed limit for urban roads is 25 km/hr. The drink driving law prevails within the country. But there is no BAC limit for the general population and the young-novice driver. There is no seat belt wearing law and child restraint law. The helmet wearing law prevails but the enforcement level less effective.
The trend shows the increasing number of road traffic death in Bangladesh (figure 4.32)

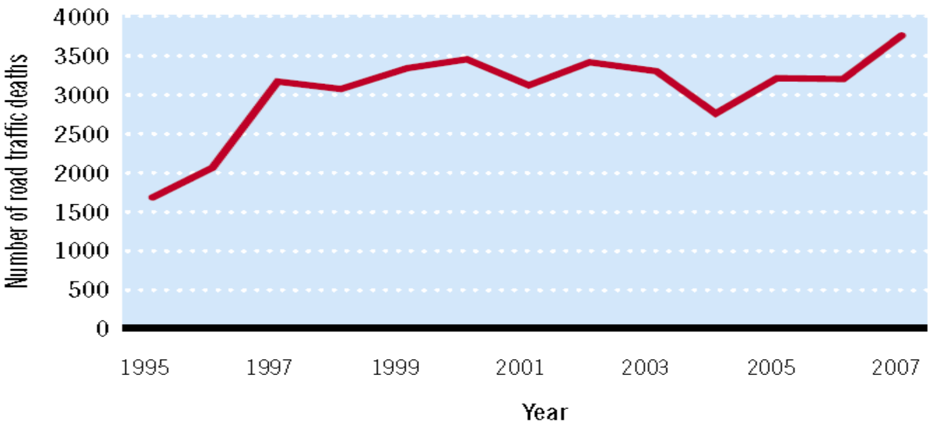


Figure 4.33: Trends in road traffic deaths in Bangladesh. (WHO 2009)

4.6 CONCLUSION:

Road traffic fatalities remain a major public health problem with the highest fatality rates per 100000 populations in middle-income and low-income countries. Pedestrians, cyclists and users of motorized two or three-wheelers together account for approximately half of all road traffic death around the world. Vulnerable road users are particularly at risk in low-income and middle-income countries in Asia. Within the WHO European region road traffic injuries represent the leading cause of death among adolescents and young adults. Mortality rates in the Commonwealth of Independent States (CIS) are up to four times higher than those of the Nordic countries. In EU regions, pedestrians, cyclists and motorized two-wheelers constitute 39% of all deaths in road crashes. The economic burden of road crashes is as much as 3% of GDP.

According IRTD annual report 2010, road deaths decreased in most IRTAD countries, carrying forward the significant reductions in the number of road deaths accomplished in 2008 (See Table 4.4). Several countries, such as the United States, even reached their lowest fatality records for the past 50 years in 2009.Reporting of FARS database, more than 5.5 million police-reported motor vehicle crashes occurred in the United States in 2009. Twenty-eight percent of those crashes (1.52 million) resulted in an injury, and less than 1 percent (30,797) resulted in a death and nearly one-half of all fatal crashes in 2009 occurred on roads with posted speed limits of 55 mph or more, as compared with 23 percent of injury crashes and 23 percent of property-damage-only crashes. In U.S. thirty-two percent of all fatal crashes involved alcohol-impaired driving, where the highest blood alcohol concentration (BAC) among drivers involved in the crash was .08 grams per deciliter (g/dL) or higher. For fatal crashes occurring from midnight to 3 a.m., 66 percent involved alcohol-impaired driving.

Many countries have inadequate legislation to control speed in urban areas, drink–driving and the use of helmets (for riders of motorized two wheelers), seat-belts and child car restraints. Even well-designed legislation has no effect if it is not properly enforced. In most countries in the Region, the current enforcement of speed control, drink–driving and use of helmets, seatbelts and child car restraints is reported as not being effective enough. Governments need to ensure that comprehensive laws cover the main risk factors of speed, drink–driving and use of helmets (for riders of motorized two-wheelers), seat-belts and child car restraints. Enforcement of such legislation needs to be improved. This requires well-publicized enforcement campaigns, perceived certainty of being apprehended and severity and promptness of punishment for violations.

CHAPTER 5
POLICIES IN ROAD SAFETY

5.1 Abstract:

Every year lot of people killed and seriously injured due to road accident all over the world and now acknowledged to be a global phenomenon with authorities in virtually all countries of the world concerned about the road safety policy. Policies have a crucial role to minimize the road fatalities and injuries. There is no effect on road safety unless policies are implemented. The aims of this chapter are to explore the policies to the effectiveness of road safety improvements. Such as: how to formulate policy and how to implement it. The road safety policy in Europe and United States are described in this chapter. Few country profiles for road safety policies are delineated for better understanding of national road safety policies.

5.2 Introduction:

The highly expansion of the road network and its development and the increase in number of motor vehicles have led to a substantial rise in levels of both passenger and freight movement. Concomitantly safety related issues have emerged. The number of road accidents and fatalities has been growing in recent years, which call for concerted and multi-disciplinary preventive and remedial efforts. As road accidents involve roads, motor vehicles as also the human being, the Road Safety Policy needs to address on a holistic basis, issues covering road engineering, signage, vehicle design, and education of road users and enforcement of traffic safety measures. [135]

Road traffic injuries (RTIs) have a tremendous impact on the public health of a population, and many of the most effective interventions to prevent these injuries require support at the policy level. [136], [137] Road Safety policies generally function by establishing personal, vehicle, and environmental standards, and by creating statutory controls on risks related to roads [4].
Tried and tested interventions such as minimum age requirements for licensure, the use of safety helmets, enforcement of speed limits, and designation of separate motorcycle lanes are some of the many examples of public health interventions for the prevention of RTI that necessitate the involvement of the policy sector. [139], [140]

Government can create Policy to apply a lot of programs which could improve road safety performance. These programs range from the dissemination of road safety messages, road safety towns, campaigns for the wearing of seat belts and against drink driving, the improvement of road signs, to the maintenance of good road surfaces. The road safety strategies that they feature all aim to improve three major factors, such as below: [141].

- The behavior of road users including drivers and pedestrians.
- Vehicles.
- The road environment.

As much effort has been spent on improving road safety in the implementation of these strategies, it is of great importance that policy makers know whether they have actually reduced traffic accidents. Road safety authorities elsewhere have evaluated the effectiveness of such strategies. [142].

The relationship between effectiveness and equity is very important as objectives of road safety policy. The term effectiveness refers to the efficient use of all road safety measures. Road safety measures are used efficiently if the priority given to them is based on the criterion that marginal social benefits should be at least equal to marginal social costs. To use road safety measures efficiently therefore means that the priority given to each measure is set strictly according to cost–benefit analyses. [143]

These analyses conclude that road safety could be improved substantially if policy priorities were based on cost–benefit analyses to a greater extent than they are today. The use of cost–benefit analysis to set priorities for road safety policy is controversial. At least two arguments are often made against the use of cost–benefit analyses to set priorities for road safety. Arguments are as below: [144]

- Cost–benefit analysis is based on the assumption that road safety ought to be provided only to the extent that there is a demand for it (i.e. willingness-to-pay for reduced risk). But, critics claim that one of the major problems of road safety policy is that there is no demand for road safety. Hence, providing for road safety only to the extent that monetary benefits exceed costs will not result in a large improvement in safety.
- It is unethical to reject proposals for improving safety simply because monetary benefits are believed to be smaller than monetary costs.

Road safety policy making at the national level of government in Norway and set the national transport plan to remove the road fatality as called "*Vision Zero*". The plan for the 2010–2019 terms is currently in the final stages of preparation. *Vision Zero*, stating that the long-term objective for transport safety is that nobody should be killed or permanently injured in transport accidents, has been adopted as the basis for transport safety policy in Norway (like in Sweden). *Vision Zero* applies to all modes of transport. A set of more specific policy objectives, possibly a quantified road safety target, may be set in addition to "*Vision Zero"*. [143]

The national level road safety policy rest on an extensive information system (covering accidents, risk exposure, speed, utilization of mobile phones) and on analyses of road risk (the risks attributable to alcohol, speed and the use of mobile phones). This statistical information and these risk models are integrated in risk management tools such as monitoring, ranking and policing. Monitoring makes it possible to track the development of road safety, bench-marking to compare the performance of the country's different departments with each other, and policy making to refine the details of a policy. [145]

A co-ordinate national, regional and local approach to implement the Road safety Strategy between all stakeholders, particularly local government, Police, industry, road user groups and voluntary organizations. The provision of adequate resources for road safety linked to the implementation of national and local road safety strategies. The continued development of a national road safety research strategy to provide evidence from which national and local road safety initiatives can be developed and evaluated, and to ensure that cost-effective and best practice measures should be adopted. [146]

5.3 How to Formulate and Implement Road Safety Policy:

Formulating and implementing policies is necessary for improving road safety. Policies will have no effect on road safety unless they are implemented. This unit examines the importance of road safety policy, and then describes the basic steps and issues to consider in formulating and implementing road safety policy. Objectives are as below: [147]

- Explain the importance of developing policies for road traffic injury prevention,
- Describe the process of developing a policy for road traffic injury prevention,
- Discuss the role of a national lead agency in developing and implementing policies for road traffic injury prevention.

The term policy can be interpreted in a variety of ways. Here we consider a national policy on road safety to be a written document that provides the basis for action to be taken jointly by the government and its non-governmental partners. A policy is necessary to —

- raise awareness and create mutual understanding about a situation;
- articulate ethical and other principles that should justify and guide action;
- generate a consensus vision on the actions to be undertaken;
- provide a framework for action;
- define institutional responsibilities and mechanisms of coordination;
- secure or raise political commitment;
- engage a variety of partners;
- identify measures which are likely to produce good results;
- Monitor progress and effectiveness of strategies.

5.3.1 Policy formulation process:

Policy formulation and implementation is a continuous process. This process is often presented as taking place in phases or stages, in order to make it easier to identify key elements. However, it should be noted that this process is complex and it does not necessarily move in a smooth manner from one step to another. For the sake of systematic presentation and clarification of key issues, we present the process of developing a national policy as taking place in three phases (shown in below figure). In Phase 1 the policy development process is being initiated. In Phase 2 the policy document itself is being formulated. [148]

PHASE 1: INITIATING THE POLICY DEVELOPMENT PROCESS

Step 1: Assess the situation

Step 2: Raise awareness

Step 3: Identify the leadership and foster political commitment

Step 4: Involve stakeholder and create ownership

↓

PHASE 2: FORMULATING THE POLICY

Step 1: Define a framework

Step 2: Set objectives and set interventions

Step 3: Ensure the policy leads to action

↓

PHASE 3: SEEKING APPROVAL AND ENDORSEMENT

Step 1: Stakeholder approval

Step 2: Government approval

Step 3: State endorsement

Figure 5.1: The three phases of the policy development process.

Finally, in Phase 3 official approval and endorsement of the policy is being sought. Each of the three phases is composed of a number of steps. Important points to note about the process presented in ***Figure 5.1*** are as follows:

- In real life, a policy development process can be much more chaotic than the best-case scenario portrayed here. It may be necessary to jump ahead and come back to a step that ideally should have happened earlier on in the process.
- This process is influenced by social, economic and political factors.
- Political will and commitment are necessary for effective policy formulation and implementation.
- The process takes time, consultation, negotiation and effort.
- Ensure that key stakeholders are involved in the entire process.
- Consultation should be conducted with all stakeholders in an open, fair and transparent manner.
- Ensure that all the stakeholders approve and endorse the policy document.
- The very act of developing a policy document can bring about significant changes in attitudes and perceptions that can go a long way towards tackling a problem.
- Implementation of policy is essential once a policy has been formulated.
- Implementation of road safety measures requires coordinated action. Responsibilities at different levels need to be clearly spelled out.
- Financial and human resources need to be provided for implementation.
- Evaluating policy implementation is necessary. Evaluation provides feedback on how well the policy is working and can lead to improvement of the policy itself.
-

5.3.2 Policy implementation process:

Road safety work is a complex process involving different sectors. There is thus a need for a functional and effective institutional framework for the development and implementation of policies and programs to prevent road traffic injuries.
At first we have to check is there a national road safety policy and action plan in the country where we are interested to reduce fatalities? If yes, then we have to prepare summary of the aims, targets and activities that have been implemented. What are the strengths in the policy and plan? What are the weaknesses in the policy and plan? If there is no policy, what steps do you plan to take to initiate the process of developing a national road safety policy or action plan?

An exercise could be done that is meant to assist trainees with reviewing their national road safety policy and action plan. If possible, the trainees should be given above question in advance of the training session so that they have time to gather the relevant information. If this is not possible, allow them answer based on their previous knowledge and experience. This exercise is meant to get trainees to think much more deeply about the road safety policies and action plans in countries, and especially about whether or not these policies and plans are being implemented. [149]

5.4 Road Safety Policy in Europe:

Now a day, Road safety is a major societal issue. In the year of 2009, more than 35,000 people died on the roads of the European Union, i.e. the equivalent of a medium town, and no fewer than 1,500,000 persons were injured. The cost for society is huge, representing approximately 130 billion Euros in 2009. [150]

In its Communication "Europe 2020 – A strategy for smart, sustainable and inclusive growth", the Commission has underlined the importance for Europe of social cohesion, a greener economy, education and innovation. These objectives should be reflected in the various aspects of European transport policy which should aim at ensuring sustainable mobility for all citizens; "de-carbonizing" transport and make full use of technological progress. Road safety will play an important role in the upcoming White Paper on transport policy 2010 – 2020, as lowering the number of road users' casualties is key to improving the overall performance of the transport system and to meet citizens' and companies' needs and expectations. [151]

An integrated and coherent holistic approach is therefore needed, taking into account synergies with other policy goals. Road safety policies at local, national, European or international level should integrate relevant objectives of other public policies and vice versa.

The proposed policy orientations takes fully account of the results obtained during the 3rd road safety action program 2001-2010, showing that in spite of important progress made on road safety, efforts needed to be continued and further strengthened.

The European road safety policy orientations up to 2020 aims to provide a general governance framework and challenging objectives which should guide national or local strategies. In line with the principle of subsidiary, actions described should be implemented at the most appropriate level and through the most appropriate means.

In the framework of these policy orientations, the Commission considers that the three following actions should be undertaken as a priority: [150]

- The establishment of a structured and coherent cooperation framework which draws on best practices across the Member States, as a necessary condition to implement in an effective manner the road safety policy orientations 2011-2020,
- A strategy for injuries and first aid to address the urgent and growing need to reduce the number of road injuries,
- The improvement of the safety of vulnerable road users, in particular motorcyclists for whom accidents statistics are particularly worrying.

The maximum injuries and fatalities on the EU's roads are due to human error or misbehavior. The European Commission has thus identified improvements to education and training of road users as a key objective of its road safety policy for the period 2011-2020 and a vital factor in achieving the target of halving the number of road deaths in the EU by 2020. [152]

The importance of EU legislation related to driving licenses and training of professional drivers is already in place. However, the approach to driver training remains fragmented and an integrated view of road safety education and training is required. This should encompass not only the driving test but also preen post-test learning as part of a lifelong process. Initial training received by a learner driver can have a considerable effect on their subsequent road behavior. The potential positive impacts of such training could be enhanced by tailoring it to the learner's individual characteristics. This could in turn be strengthened by aspects such as inclusion of accompanied driving in the process leading up to issuing of licenses and introduction of harmonized requirements for instructors.

The driving test scope could also be widened to evaluate broader skills or aspects such as risk awareness and energy-efficient driving. Continuous post-test learning for groups such as professional drivers is a key element in reinforcing education and training. It may also be useful to extend this to other groups, particularly older drivers given that the ageing of Europe's population is making the issue of maintaining their driving aptitude ever more relevant. As part of its moves to improve education and training, the Commission has granted financial support to a number of projects and studies, details of some of which can be found in this newsletter. The results will be used to draw up a common education and training strategy in coordination with Member States and propose concrete measures in this area. [152]

5.4.1 Ex-post Evaluation of the third European Road Safety action Program:

In the year of 2003, the Commission adopted its 3rd *European action program for road safety* (*RSAP*), including an ambitious target to halve the number of road deaths by 2010 as well as 62 proposals for concrete actions in the field of vehicle safety, safety of infrastructure and users' safety. An ex-post evaluation has been carried out in order to analyses the impact, the level of implementation and the effectiveness of the RSAP. Although the initial target is not likely to be met by the end of 2010, the RSAP has been a strong catalyst of efforts made by Member States to improve road safety. [153]

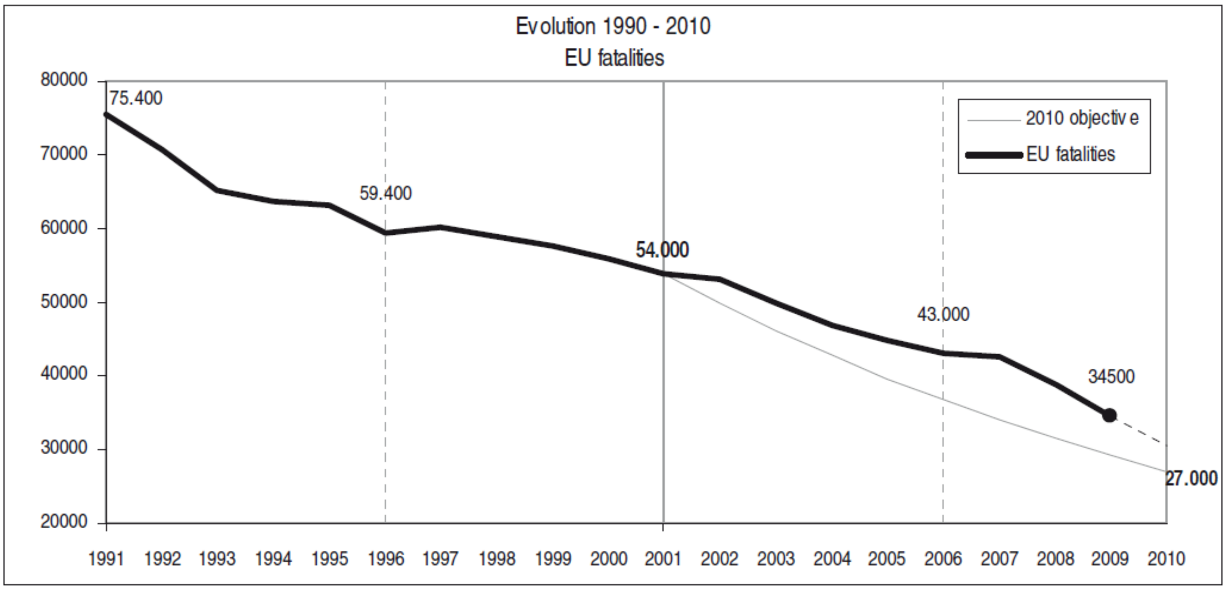


Figure 5.2: Comparison between objective fatalities and actual fatalities up to 2010.

Road safety policy has to put citizens at the heart of its action: it has to encourage them to take primary responsibility for their safety and the safety of others. The aim of road safety policy of the EU at raising level of road safety, ensuring safe and clean mobility for citizens everywhere in Europe. It should foster equity among road users through focused efforts to improve the safety of more vulnerable road users.

The future road safety policy should be taken into account in other policy fields of the EU, and it should take the objectives of these other policies into account. Road safety has close links with policies on energy, environment, employment, education, youth, public health, research, innovation and technology, justice, insurance, trade and foreign affairs, among others.

In view of achieving the objective of creating a common road safety area, the Commission proposes to continue with the target of halving the overall number of road deaths in the European Union by 2020 starting from 2010. Such a common target represents a significant increase of the level of ambition compared to the unmet target of the current RSAP, considering the progress already achieved by several Member States during the past decade, which will give a clear signal of Europe's commitment towards road safety.

5.4.2 Policy Objectives:

The education, training and enforcement are very essential for the road user because they are the first link in the road safety chain. Whatever the technical measures in place, the effectiveness of a road safety policy depends ultimately on the users' behavior. However, the road safety system also has to take into account human error and inappropriate behavior and correct it as much as possible, zero risk does not exist. All components, in particular vehicles and infrastructure, should therefore be 'forgiving', so as to prevent and limit the consequences of these failures for the users, in particular the most vulnerable users.

Seven objectives have been identified for the next decade. For each of these objectives, actions at EU and national level will be proposed. The Commission will ensure continuity with the 3rd RSAP, notably where the ex-post evaluation identified actions to be continued. Seven Objectives are as below: [150]

1. Improve education and training of road users.
2. Increase enforcement of road rules.
3. Safer road infrastructure.
4. Safer vehicles.
5. Promote the use of modern technology to increase road safety.
6. Improve emergency and post-injuries services.
7. Protect vulnerable road users.

1. Improve education and training of road users:

During the 3rd RSAP, important legislation has been put in place as regards driving licenses and training of professional drivers. The impact of such recent measures will be measured in the years to come. However, the need to improve the quality of the licensing and training system, with a special focus on young novice drivers, was stressed during the experts' and public consultation.

The current approach as regards driver training remains indeed too fragmented and specialized. The Commission proposes to promote a wider approach and view education and training as an overall process, a lifelong ‘educational continuum’. Interactive methods and the acquisition of autonomy should be encouraged, while taking duly into account the need to keep the cost of the license at a reasonable level. Three things are very important for the road users (drivers). Such as: [150]

- **Pre-test learning**

The objective is to encourage practice before the test under maximum conditions of safety. The Commission will reflect on several options, in particular the inclusion of accompanied driving in the process leading to the issuing of the license. The introduction of harmonized minimum requirements will be examined for persons involved in learning: such as accompanying persons and instructors.

- **The driving license test**

The driving license test should not be restricted to checking the candidate's knowledge of the Highway Code or his ability to carry out maneuvers. The Commission will consider how to also include broader driving skills, or even an evaluation of values and behavior related to road safety (awareness of the risks) and defensive, energy-efficient driving.

- **Post-license training**

Post-license continuous training for non-professional drivers deserves to be examined, in particular since, with the European population ageing, the question of maintaining older people’s aptitude for driving will become increasingly relevant. Possible actions in this area will have to take into account persons with disabilities and elderly people’s right to mobility and the adoption of alternative solutions.

2. **Increase enforcement of road rules:**

According to the ex-post evaluation of the 3rd RSAP, enforcement remains a key factor in creating the conditions for a considerable reduction in the number of deaths and injuries, especially when it is intensively applied and widely publicized. Public consultation also confirmed that enforcement should be strongly present in the new road safety policy orientations. The full potential of a European enforcement strategy was indeed not reached during the previous program, in particular with the lack of progress on the Commission's proposal concerning cross-border enforcement. Such type of Policy should be built on the following axes: [150]

- **Cross-border exchange of information in the field of road safety**

The work initiated in 2008 on the proposal for a Directive facilitating enforcement in the field of road safety should continue. With the aim to facilitate the exchange of information on road safety offences, the proposed EU legislation is a step towards a more equal treatment of offenders.

- **Enforcement campaigns**

The sharing best practices and increased coordination help make enforcement and controls significantly more efficient. The principle of the targeted control campaigns already organized in and between several Member States should be encouraged and generalized. In addition, the experience shows that the most effective results are obtained by combining control policy with users' information. The Commission will therefore continue to support information actions and awareness-raising, in particular for young people.

- **Vehicle technology to assist enforcement**

Considering technological developments, such as in-vehicle systems providing real-time information on prevailing speed limits could contribute to improve speed enforcement. Since, light commercial vehicles are becoming increasingly numerous on the roads, which also increase the risk that they get involved in accidents, the fitting of speed limiters on such vehicles should also be examined along the lines already identified by the Commission, taking into account also the environmental and climate co-benefits. With respect to drink-driving, penalties should be accompanied by preventive measures. Thus the Commission will examine to what extent measures are appropriate for making the installation of alcohol interlock devices in vehicles compulsory, for example with respect to professional transport (e.g. school buses).

- **National enforcement objectives**

The effectiveness of road safety policies is largely dependent on the intensity of controls on compliance with safety requirements. The Commission encourages setting national control objectives, to be integrated into 'national enforcement plans'.

3. **Safer road infrastructure:**

The highest number of fatalities occurs on rural and urban roads (56% and 44% respectively in 2008, compared to 6% on motorways). Therefore, ways should be found for gradually extending the relevant principles of safe management of infrastructure to the secondary road network of the Member States, taking into account the principle of subsidiary. The Commission will ensure that requests for funding from the EU funds related to road infrastructure within Member States incorporate safety requirements.

4. **Safer vehicles:**

The period covered by the 3rd RSAP has seen considerable progress in vehicle safety. Although the safety of cars has been boosted, thanks partly to the wide use of passive safety devices such as seatbelts and airbags and the implementation of electronic safety systems, other vehicles, in particular motorcycles, have not been subject to the same attention. Moreover, new safety problems will need to be addressed in the years to come to take into account the increasing part of vehicles using an alternative power train. [150]

- **Vehicles of today**

The excellence technical standards and requirements on vehicle safety have been adopted in recent years or are under preparation. Their impact will only be fully visible in the decade to come. After being placed on the market, vehicles should continue to meet safety standards throughout their lifetime. The Commission will evaluate and propose, as appropriate following an impact assessment, actions in the area of harmonization and progressive strengthening of EU legislation on road worthiness tests and on technical roadside inspections. The ultimate objective could be to arrive at a mutual recognition of vehicle inspections between Member States. Currently vehicle data (type approval, registration, results of inspections, etc.) exist in a disparate form in each Member State.

- **Vehicles of tomorrow**

As set out in the Communication of the Commission on "A European strategy on clean and energy efficient vehicles", the development and deployment of alternative power train vehicles constitutes a major priority for the decade to come in order to reduce the environmental impact of road transport. However, some of these vehicles have characteristics which make them radically different from traditional vehicles and which may have an impact on safety. An integrated and coordinated approach is therefore essential with a view to clearly identifying the impact on all factors concerned (such as infrastructure and vulnerable users) and the solutions to be supplied (research, standardization, etc.). A significant contribution to road safety is also expected from the deployment of so called "co-operative systems", where vehicles exchange data and interact with the infrastructure and other surrounding vehicles to have drivers optimally informed, reducing risks on accidents and making traffic flows run more smoothly overall.

5. **Promote the use of modern technology to increase road safety:**

A lot of studies and research activities on Intelligent Transport Systems (ITS) were carried out during the period covered by the 3rd RSAP. ITS have the potential to play a considerable role for the improvement of traffic safety, for example through the adoption of systems to detect incidents and supervise traffic that are able to provide information to road users in real time. Within the framework of the implementation of the ITS Action Plan and of the proposed ITS Directive, the Commission will notably propose technical specifications necessary to exchange data and information between vehicles (V2V), between vehicles and infrastructure (V2I) and between infrastructures (I2I). The possibility of extending the implementation of Advanced Driver Assistance Systems (ADAS) such as Lane Departure Warning, Anti Collision Warning or Pedestrian Recognition systems by retrofitting them to existing commercial and/or private vehicles should also be further assessed. Accelerated deployment and broad market take-up of such safety enhancing applications needs to be supported in order for their full potential to be unleashed. Within the next seven years, ITS should contribute decisively to improving the effectiveness and speed of

rescue, and in particular the adoption of the pan-European emergency call service fitted to vehicles, eCall. The impact and scope for extending the use of eCall should be examined, in particular with a view to improving rescue actions for motorcyclists, heavy duty vehicles and buses.
Finally, in spite of their positive contribution to road safety, the development of ITS, in particular in-vehicle systems and nomadic devices, raises a number of concerns from the safety point of view (distraction, impact on training, etc.) which will require further consideration. [150]

6. **Improve emergency and post-injuries services:**

In the period of 2001 to 2010 the number of fatalities has decreased, the number of injured people is still very high, as illustrated by the figure below. As repeatedly stressed by the stakeholders during the public consultation, reducing the number of injuries should be one of the priority actions within Europe for the next decade. Road injuries have also been recognized as a major public health concern at international level, in particular by the World Health Organization and in the framework of the UN Decade for Action on road safety.

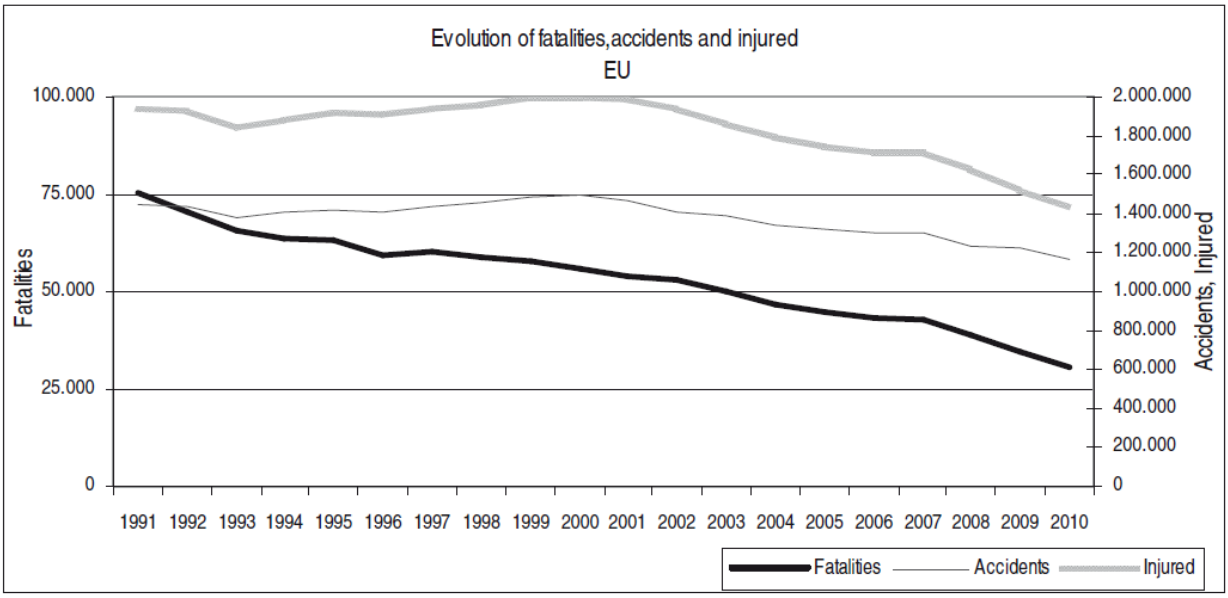


Figure 5.3: Representation of fatalities, accident and injured up to 2010.

Reducing the seriousness of injuries from road accidents requires the introduction of a range of diverse actions, for example on the safety of the vehicle and of infrastructure, ITS, the availability of emergency aid, the speed and coordination of intervention, the efficiency of first aid and rehabilitation, etc. Therefore, the Commission will develop the elements of a global strategy of action concerning road injuries and first aid, with the help of a Task Force bringing together the relevant actors, representatives of international and non-governmental organizations, government experts and the Commission. Initially, it would seek to find a common understanding of definitions and concepts relating to casualties and to identify courses of action to improve prevention and intervention, including their socio-economic impact. On this basis, precise actions could be identified, such as exchange of good practices, development of intervention guides, a common approach to the definition of major and minor injuries, promotion of the creation of mixed rescue units between Member States, etc. [150]

7. **Protect vulnerable road users:**

The large number of fatalities and serious injuries faced by vulnerable road users such as riders of motorcycles, mopeds, cyclists and pedestrians are significant and in some European States still increasing. In the year of 2008, they represented 45% of all road deaths and statistics (see graph below) show that they have been given insufficient attention until now.

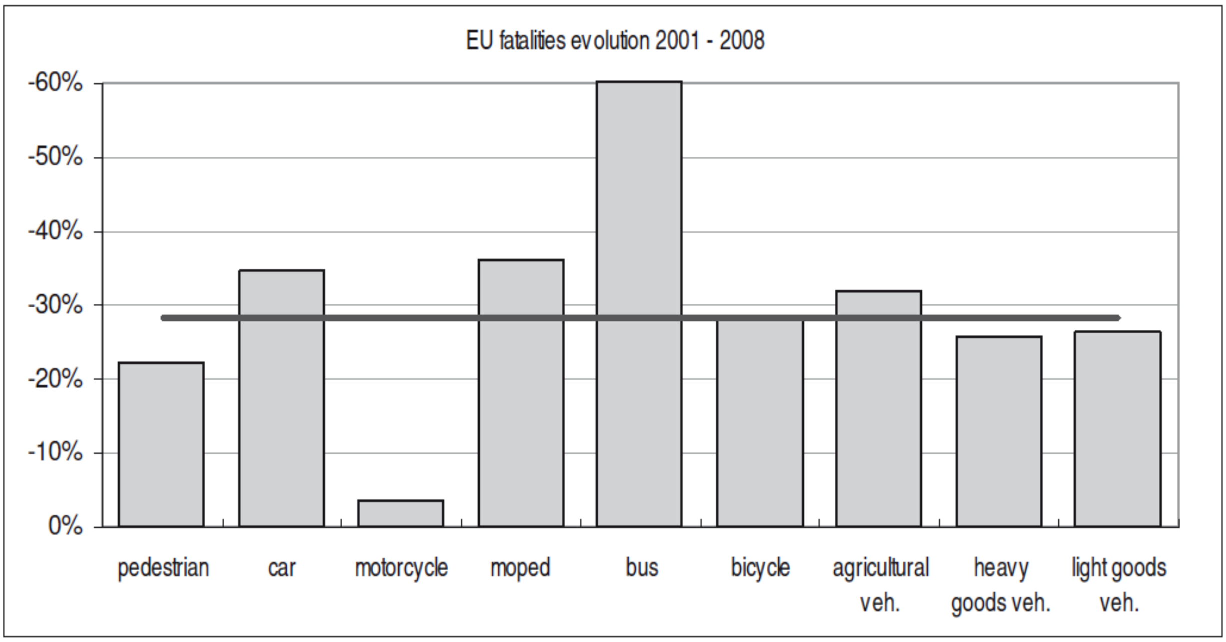


Figure 5.4: Representation of % of fatalities for different vehicle from 2001 to 2008.

Further, other users present an intrinsic "fragility" (e.g. elderly, young children, the disabled), whatever their role in traffic (pedestrian, driver, passenger). Their vulnerability is particularly high in urban areas.

- **Powered-two-wheelers (PTWs)**

This ever growing group of users is the one where it is the most difficult to attain a significant reduction in accidents and fatalities. In particular, as shown by the graph below, the reduction rate of fatalities amongst motorcycle riders is lower than for other road users. [150]

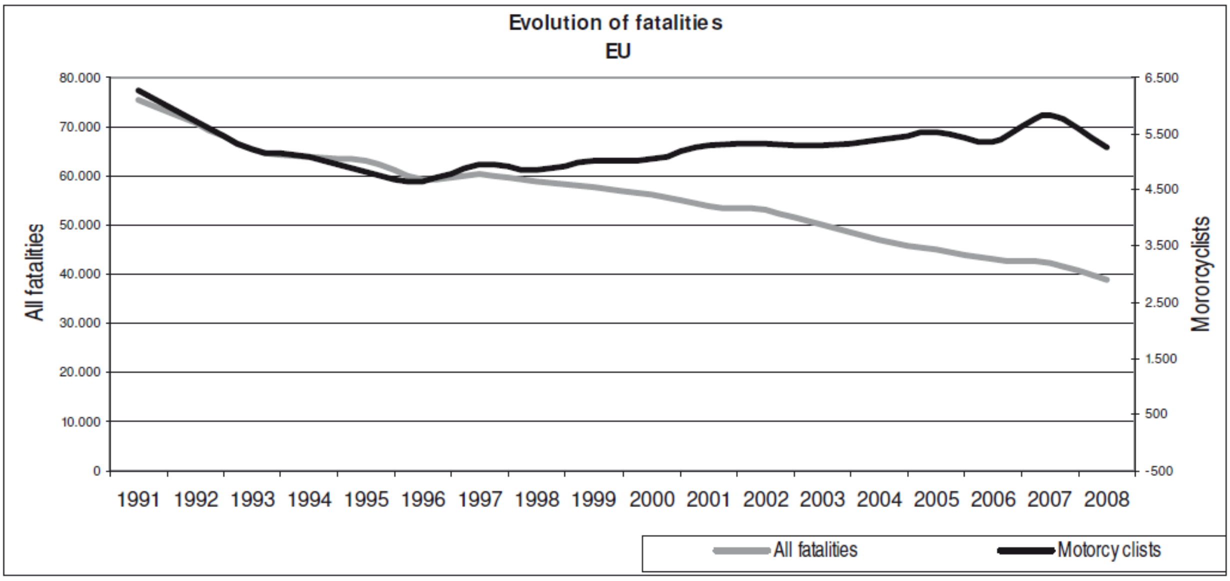


Figure 5.5: Comparison of all fatalities with motorcyclist from 1991 to 2008.

The problem of motorcyclists' safety should be addressed through a range of actions, with a view to:

1. Improving awareness of PTW riders by other road users.

2. Encouraging research and technical developments aimed at increasing PTW's safety and reducing the consequences of accidents, such as standards for personal protective equipment, airbags, the use of relevant ITS applications (e.g. eCall) and progressive installation of advanced braking systems, appropriate anti-tampering measures, etc. The Commission will propose to extend to PTWs the existing EU legislation concerning roadworthiness testing. Finally, on-going efforts to better adapt road infrastructure to PTWs (e.g. safer guardrails) should also be continued.
3. Encouraging Member States to focus enforcement on speed, drink and driving, helmet use, tampering and riding without a proper PTW license.

- **Pedestrians, cyclists**

In the year of 2008, cyclists and pedestrians represented 27% of road deaths (47% in urban areas). For many potential cyclists, real or perceived road safety risks remain a decisive obstacle. National and local governments are increasingly involved in promoting cycling and walking, which will require that more and more attention is paid to road safety issues. Since 2003, legislation has been introduced at EU level to reduce injury risks (e.g. energy absorbing car-front structures, advanced braking systems, blind-spot mirrors, etc.). Further actions will need to be examined (e.g. improved visibility, speed management, adequate infrastructure for non-motorized transport, separation of dangerous mixed traffic, etc). Since the problem is mainly related to urban management, most of the actions will have to be carried out at local level, in accordance with the Commission's Action Plan on Urban Mobility. Given the significant environmental, climate, congestion and public health benefits of cycling, it merits reflection whether more could not be done in this area.

- **Elderly people and people with disabilities**

Elderly people represented 20% of road fatalities (40% as pedestrians) in 2008. Ageing of the population is putting an urgent emphasis on the need to assess older people's vulnerability in traffic. Also, persons with disabilities are at a significant risk. Knowledge is still very limited in this field and focused research efforts are needed, including on medical criteria for the assessment of fitness to drive.

Finally, the proposed policy orientations constitute a plan of possible actions envisaged for the next decade. The actors concerned underlined, in particular during the consultation of stakeholders, the extent to which Europe, by giving a framework for action and ambitious objectives, has stimulated efforts at all levels and enabled the achievement of significant results. The proposed policy orientations provides a general framework under which, at various European, national, regional or local levels concerned, concrete initiatives could be taken. Individual measures would be subject to proper impact assessment in line with established EU better regulation principles. The role of the Commission will be to make proposals on matters where the EU is competent and, in all other cases, to support initiatives taken at various levels, to encourage the exchange of information, to identify and promote the best results obtained and to follow carefully the progress achieved.

5.5 Road Safety Policy in USA:

The primary means of transport is motor vehicle in the United States, providing an unprecedented degree of mobility. Yet for all its advantages, injuries resulting from motor vehicle crashes are the leading cause of death for people of every age from 3 through 5, 8, 9, and 11 through 33 (based on 2007 data). The main objectives of the National Highway Traffic Safety Administration are to reduce deaths, injuries, and economic losses from motor vehicle crashes. [154]

In the year of 2009, 33,808 people were killed in the estimated 5,505,000 police reported motor vehicle traffic crashes; 2,217,000 people were injured; and 3,957,000 crashes involved property damage only. Compared to 2008, this is a 10% decrease in the number of fatalities, and a 5% decrease in the number of police reported motor vehicle traffic crashes, people injured, and crashes involving property damage. Daily an average of 93 people died in motor vehicle crashes in 2009, an average of one every 16 minutes.

Fortunately, much progress has been made in reducing the number of deaths and injuries on our Nation’s highways. In the year of 2009, the fatality rate per 100 million vehicle miles of travel (VMT) fell to a historic low of 1.13. The 2000 rate was 1.53 per 100 million VMT. The National Occupant Protection Use Survey (NOPUS) reported an 84% seat belt use rate nationwide for 2009. Data has also shown a decrease in the number of fatalities in alcohol impaired driving crashes, from 13,324 in 2000 to 10,839 in 2009. Fatalities in alcohol impaired driving crashes when compared to the previous year (2008) decreased by 7.4 percent from 11,711 to 10,839.

This overview of motor vehicle fatalities based on data from the *Fatality Analysis Reporting System* (FARS). FARS is a census of fatal crashes within the 50 States, the District of Columbia, and Puerto Rico (although Puerto Rico is not included in U.S. totals). Crash and injury statistics are based on data from the National Automotive Sampling System General Estimates System (GES). GES is a probability based sample of police reported crashes, from 60 locations across the country, from which estimates of national totals for injury and property damage only crashes are derived.

The following terms will be used to define motorcycle occupants: a motorcycle rider is the operator only; a passenger is any person seated on the motorcycle but not in control of the motorcycle; and any combined reference to the “motorcycle rider” (operator) as well as the “passenger” will be referred to as motorcyclists.

The fatality rate per 100 million VMT in 2009 was 1.13, a decrease of 10% from 1.26 in 2008. The injury rate per 100 million VMT in 2009 was 74. The fatality rate per 100,000 populations was 11.01 in 2009, a decrease of 10% from the 2008 rate of 12.30.

Vehicle occupants accounted for 72% and motorcyclists accounted for 13% of traffic fatalities in 2009. The remaining 14% were pedestrians, pedal cyclists, and other non occupants. Males accounted for 70% of all traffic fatalities, 69% of all pedestrian fatalities, and 87% of all pedal cyclist fatalities in 2009. [154]

5.5.1 Policy Objectives:

Policy making and implementation is very crucial for reducing road fatalities. The United States was at the forefront of traffic safety for most of the 20th century. Unfortunately, that is no longer the case. According to Evans (2004), "by 2002 the United States had dropped from first to 16th place in deaths per registered vehicle, and from first to 10th place in deaths for the same distance of travel". [155]

Lot of policy objectives could be apply to improve road safety but Five objectives have been identified which are significantly improve the road safety. Such as below: [156]

1. Exceeding Speed Limit
2. Use of Safety Belt
3. Driving while intoxicated
4. Night time driving
5. Young drivers

1. Exceeding Speed Limit

Speed limit is very important for the road safety problem. In the year of 2003, 13,380 people (31.4% of all road traffic fatalities) were killed in speeding related crashes in the United States. [157] The relationship between speed and crashes is not only statistical but also causal. The risk of injury in an accident increases by the second power of the mean speed, and the risk of a fatal accident increases by the fourth power of the mean speed. [158].

The posted speed limit exceeding is probably the most common traffic law violation. For example, the proportion of drivers exceeding the posted speed limit by more than 5 mph (8 km/h) ranged from 10% to 68% on U.S. rural and urban interstates in five states. [159] On urban interstates in four cities with the posted speed limit of 55 mph (88 km/h), the proportion of drivers exceeding the limit by more than 15 mph (24 km/h) ranged from 11% to 78%. These results are in line with the findings from a recent national driver survey: more than 60% of drivers admit they drove over the speed limit within the past week. [160]

Speeding is a complex issue. However, for example, determination of whether speeding was involved in a crash is no simple task, which implies that we probably underestimate the number of speeding related fatalities. [155] This case is very crucial because a crash is considered speeding related only if a driver is charged with a speeding related offense, and that requires strong evidence. On the other hand, speeding related crashes also include behaviors other than exceeding the posted speed limit, for example "driving too fast for conditions". Nevertheless, given the above proportions of drivers exceeding the posted speed on U.S. roads and the strong evidence of the effects of speed on accidents and fatalities, it is assumed that the above number of fatalities provides a reasonable estimate for demonstrating the magnitude of the problem. As a result, exceeding posted speed limits is a major problem that should be addressed. This is not to say that "racing" or "driving too fast for conditions" are of no importance, but, according to the basics of safe driver behavior, careful and prudent speed is never faster than the posted speed limit. [161]

Year	Speeding		Not Speeding	
	Number	Percent	Number	Percent
2000	12,552	30	29,393	70
2001	12,924	31	29,272	69
2002	13,799	32	29,206	68
2003	13,499	31	29,385	69
2004	13,291	31	29,545	69
2005	13,583	31	29,927	69
2006	13,609	32	29,099	68
2007	13,140	32	28,119	68
2008	11,767	31	25,656	69
2009	10,591	31	23,217	69

Table 5.1: Fatalities in Motor Vehicle Traffic Crashes by Speeding Involvement, 2000–2009

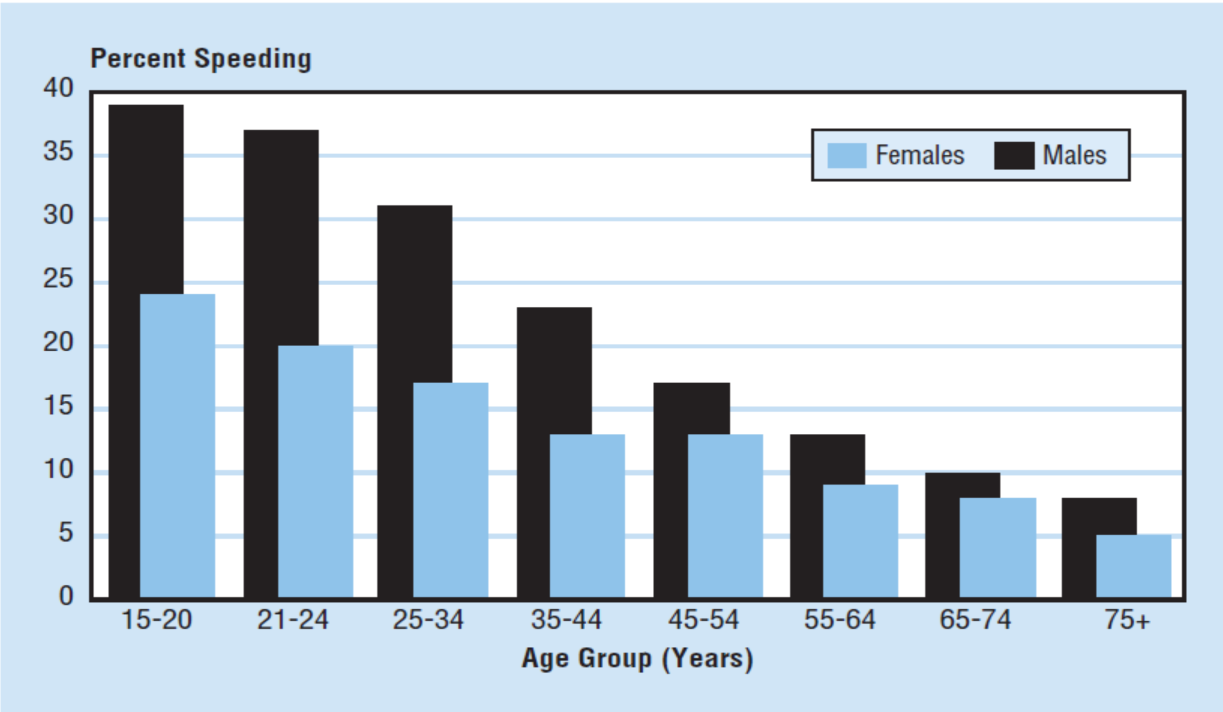


Figure 5.6: Speeding Drivers in Fatal Crashes by Age and Sex, 2009

Traditional countermeasures could be taken for reducing fatalities due to over speed which cover three broad areas. Such as:

- Education,
- Enforcement,
- Engineering.

- **Education.**

The education of the driver should be designed to ensure that every licensed driver knows that the posted speed limits must be obeyed. In addition to driver education, information and publicity campaigns regarding the impacts of speed have been used. However, these measures have had no major success. This is the case because lack of information and attitudes toward speed and speed limits are not the main problems. Indeed, the results of a national survey showed that most drivers indicate that it is important to reduce speeding on all types of roads: the highest support was for streets (90%), followed by two-lane roads (86%), non-interstate multilane roads (81%), and multi-lane interstate highways (77%). [160] Almost all drivers (98%) indicated that speeding by others is a threat to themselves and to their family. In addition, only a small minority (8–35%, depending on the road type) stated that the speed limits were too low. However, drivers do not appreciate that speed is associated with risk in their own driving. [28] In particular, driving only slightly above the speed limit is not considered risky or socially unacceptable. Other important factors are that drivers overestimate other drivers' speed, believe that other drivers think they are driving too slowly, and want to drive like others. Consequently, there are several complex factors that result in speeding, and thus presenting simple information to drivers cannot solve the problem. [163]

- **Enforcement.**

The policy offers involves traditional speed enforcement, usually in police vehicles. However, only a small proportion of all speeding violations are detected: more than 70% of drivers admit exceeding the speed limit, but only 10% report having been stopped within one year. The probability of detection is low because police surveillance is time consuming and expensive, and there is no reason to assume that public funding for enforcement will increase in the near future. In addition, there are many occasions' and sites, such as high volume roads, where traditional speed enforcement can never operate effectively. [160]

- **Engineering.**

The road design should be involves with the basic engineering. Specifically, the design elements of the road should consistently reflect the road category and thus encourage appropriate choice of speed. However, the necessity of other engineering countermeasures, such as speed limits and speed bumps, demonstrates that the design of roads is challenging and does not provide any easy solution to the speeding problem. [164]

2. **Use of Safety Belt**

Using seat belt is the most effective technology to reduce severity in a motor vehicle crash. Depending upon the vehicle type, has estimated that use of three point safety belts reduces the risk of fatality by 45–60%. [165] Safety belts are only effective, however, if they are used. Of all the U.S. passenger vehicle occupants killed in 2004, 55% were not restrained by an occupant protection system. The problem is more significant when certain subgroups are considered. In 2004, 68% of passenger vehicle occupant fatalities aged 13–15 years were not restrained, and in 69% of pickup truck fatalities, the occupant was not restrained. If all passenger vehicle occupants used safety belts, estimates that 5,839 lives would have been saved in 2004. This equates to about a 14% reduction in motor vehicle related fatalities. [166]

The United States reached safety belt use all-time high of 82% in 2005. Despite this achievement, use of safety belts in the United States still lags behind many other developed countries. [167] For example, Australia has an estimated use rate of 96%, Within the United States, statewide belt use rates vary from 61% to 95%. [168]

Comparatively motor-vehicle occupants are significantly less likely to use safety belts than others. Direct observation studies in the United States consistently find that belt use is lower for males; increases with age after the mid teens and is quite low for pickup truck occupants and heavy truck drivers. Use of safety belts also varies by situational factors, with belt use lower on rural than urban or suburban roads on local roads than freeways and during the daytime. [169]

The below countermeasures could be taken for improving use of safety belt.

- Legislation
- Reminder systems
- Interlock systems

- **Legislation**

In the year of 1980, statewide mandatory safety belt use laws began to be enacted at the urging of the federal government, with New York passing the first mandatory safety belt use law in 1984. While these laws were initially unpopular in many states, every state except New Hampshire has now passed a safety belt use law. It is clear that implementation and enforcement of mandatory safety belt use laws increase safety belt use. The increase in the national safety belt use rate from approximately 15% in the early 1980s to the current rate of 82% can be attributed in large part to the introduction of mandatory safety belt use laws. [170] In general, such type of laws produce a dramatic increase in safety belt use immediately after implementation, followed by a decline in belt use to a level that remains substantially higher than pre law levels.

It is very important that how this safety belt use legislation will be enforced. As states began to discuss adopting safety belt use laws, citizens, in particular minority groups, voiced concerns that these laws were in violation of their individual rights and that these laws could be used by police as a way to single out and harass citizens. To address these concerns, legislators in New Jersey included a "secondary" enforcement provision in their safety belt use law that stated that an officer could issue a safety belt citation only if the vehicle were stopped for a different violation. [171] By including this provision in their law, New Jersey legislators created a distinction between such secondary and "standard," or primary enforcement, where an officer can stop a vehicle and cite an occupant solely for failure to use a safety belt. Direct observation studies show that states with standard enforcement have use rates that are about 10% higher than states with secondary enforcement. In recognition of this fact, many states that originally had secondary enforcement have begun to enact legislation to strengthen belt use laws to standard enforcement. Changing a law from secondary to standard enforcement can be a significant and cost-effective way for states to increase their safety belt use rate, with increases found to be on the order of 10% to 15% immediately following a change to standard enforcement. [172]

- **Reminder systems**

In the year of 1970, reminder systems were introduced into vehicles by federal mandate with a requirement that all new vehicles in the United States produce a 4 to 8 second signal if the driver does not use a safety belt after starting the vehicle. [173] The signal could be a light, a sound, or both. Analysis of belt use before and after the buzzer light systems were installed showed no statistical increase in safety belt use, as the benign reminder signal was easily ignored. In 1995, the Swedish Road Administration and Swedish vehicle manufacturers began to examine the potential of improved reminder systems. Following this initial work, the European New Car Assessment Program (Euro NCAP) developed a reminder system protocol that defined the minimum acceptable features of an advanced system, including a loud and clear audible signal of at least 90 seconds if the driver is unbelted. [174] An observational study in Sweden has shown that, compared to vehicles without NCAP protocol compliant reminder systems, belt use is significantly greater (by as much as 16%) in vehicles with an advanced reminder system. A more advanced reminder system has recently been implemented voluntarily in the United States by the Ford Motor Company. Ford's system involves intermittent flashing lights and chimes for five minutes if the driver is not buckled. A direct observation study of patrons arriving at Ford dealerships found that belt use was 5% higher for drivers with the reminder system installed than for those without the system. [175]

- **Interlock systems**

The important link between safety belt interlock system with some vehicle function, such as the ability to start the vehicle. In the year 1973, the federal government mandated that all new vehicles sold in the United States must be equipped with a safety belt ignition interlock system that prevents the vehicle from starting if the driver and front right passenger are not using safety belts. [176] Despite the fact that these interlock systems increased safety belt use by as much as 30%, public opposition to them led Congress to rescind the legislation in 1975. More recently, vehicle manufacturers have begun to evaluate the effectiveness and acceptability of interlocking safety belt use with the ability to use the entertainment or environmental control systems. A nationwide telephone survey of part-time safety belt users in the United States found that the perceived effectiveness of interlocking belt use with either the entertainment and heating/cooling system was high. [177]

3. Driving while intoxicated

The United States, alcohol-impaired drivers were involved in 14,968 fatal crashes, 168,000 injury crashes, and 247,000 property-damage-only crashes, resulting in 16,694 fatalities and 248,000 injuries shows in the year of 2004. [178] All told, the economic cost to society for medical care, insurance premiums, lost productivity, and other indirect costs due to alcohol impaired driving exceeded $51 billion in 2002. [179]

It is very clear that alcohol involved driving increased likelihood of crash occurrence and severity. Alcohol contributes to impaired driving by slowing responses and interfering with the safe execution of driving maneuvers. Furthermore, the effects of alcohol on driving are not limited to its physiological effects on the brain. Psychological characteristics of drivers, such as antisocial personality, aggressiveness, psychopathology, impulsivity, sensation seeking, and biological characteristics relating to alcohol metabolism, appear to act as moderators of the likelihood that alcohol involved driving will result in a crash. Alcohol consumption pattern also plays a role, with higher consumption contributing to increased likelihood of driving after drinking. [180] However, contrary to some claims, when other factors, including blood alcohol concentration (BAC), are controlled, there is inconsistent evidence linking an alcohol abuse or dependence diagnosis with alcohol related crash severity. [181]

Alcohol impaired driving is also associated with age and sex. Young adults ages 20 to 24 have the highest rates of alcohol impaired driving and alcohol involved fatal crashes of any age group. Teenaged drivers are less likely than young adults to drive while impaired by alcohol, and drivers over age 65 have the lowest rates of alcohol impaired driving. At all ages, men are more likely than women to drive while impaired by alcohol. On the positive side, alcohol impaired driving and alcohol involved fatal crashes have been decreasing for the past decade. [182]

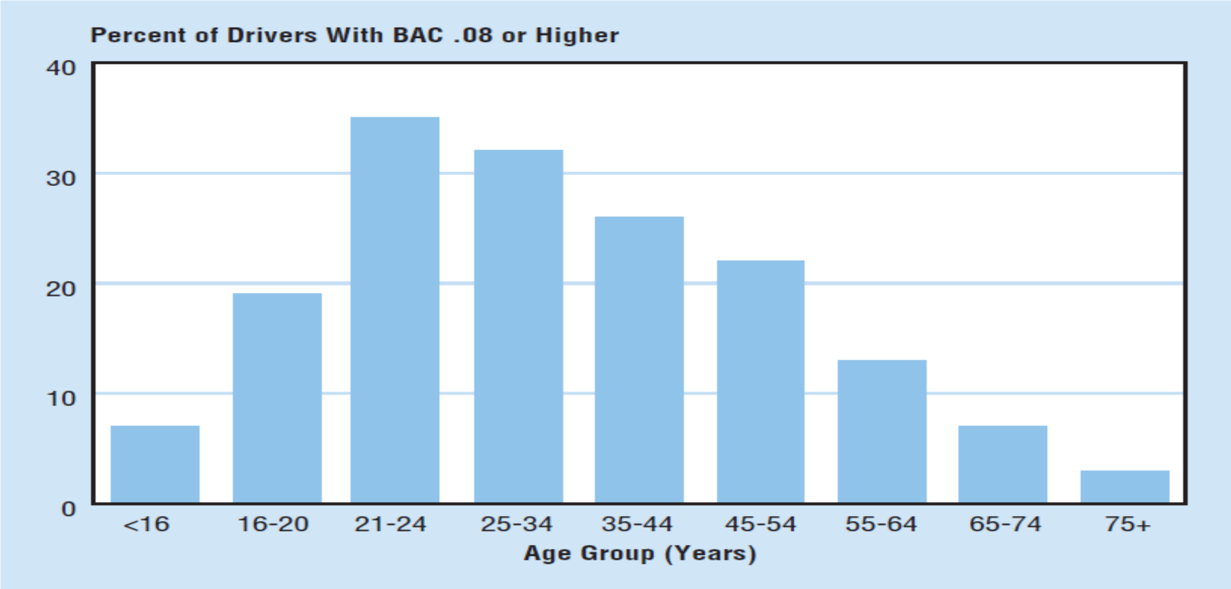


Figure 5.7: Drivers with BAC Levels of .08 or Higher Involved in Fatal Crashes by Age Group, 2009. (NHTSA, 2009)

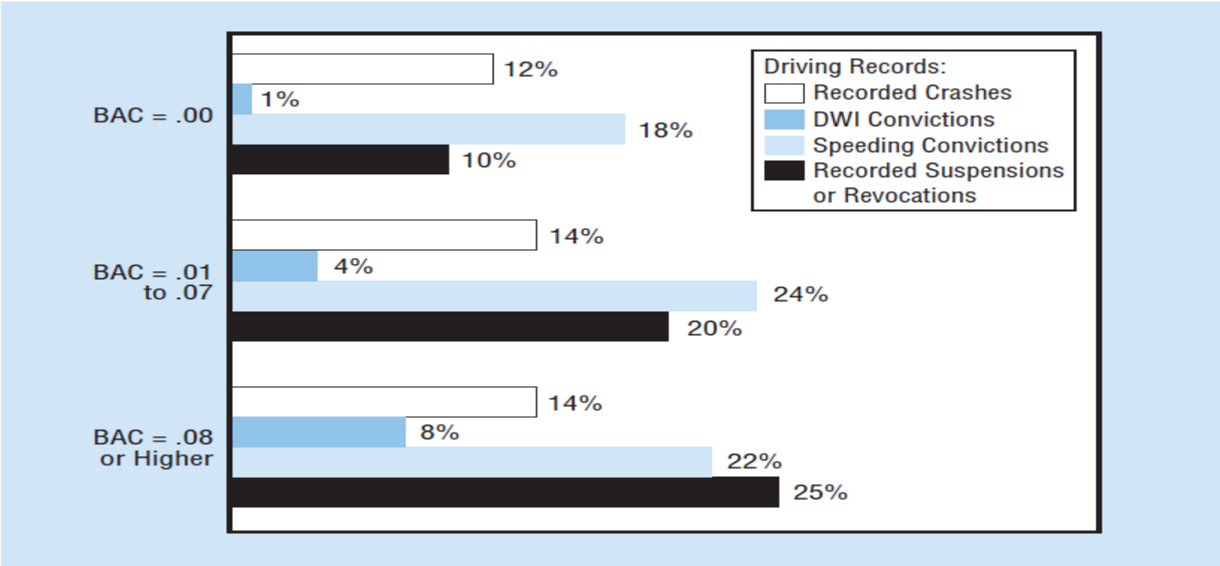


Figure 5.8: Previous Driving Records of Drivers Involved in Fatal Traffic Crashes by BAC, 2009. (NHTSA, 2009)

Countermeasures could be taken likely; Alcohol impaired driving stands out in comparison to other threats to driver safety in that there is a large alcohol beverage industry whose interest it is to encourage alcohol use. Although the alcohol industry is not overtly supportive of alcohol impaired driving, this industry has exerted effort against the passage of laws that might decrease alcohol consumption, and that might indirectly discourage alcohol impaired driving. The interests and efforts of the alcohol industry in opposition to interventions, programs, and policies to limit alcohol use is in contrast to similar efforts to increase other aspects of driver safety and makes the reduction of alcohol impaired driving unique. An additional factor that sets alcohol impaired driving apart is that adjudication is often quite poor, with many ticketed offenses being poorly adjudicated. [183]

There are many policy and program measures that reduce heavy alcohol consumption and behaviors that are unacceptably risky when combined with alcohol, such as driving. [184] A few examples of effective programs targeting the person directly are self-help and 12-step programs, such as Alcoholics Anonymous one on one or group Cognitive Behavioral Therapy, Motivational Interviewing, and brief interventions. These treatments can target at-risk alcohol consumption in general or alcohol impaired driving in particular. [185]

Public health programs explains an important lesson (both failed and successful) is that relevant information is necessary, but not sufficient, to cause behavior change. Effective programs must include an incentive in addition to information so that there is adequate motivation to change behavior. Some of the most effective motivations come from laws, policies, and enforcement. For example, the passage of per se laws (laws that declare it illegal to drive above a certain alcohol level, as measured by a blood or breath test) resulted in immediate decreases in alcohol impaired driving, and random breath testing in New South Wales, Australia, produced one of the largest changes (a reduction of 19%) in alcohol impaired driving specific to a single intervention [186]. Other factors that can be influenced by policy, laws, and enforcement include alcohol availability, minimum drinking age laws, cost of alcohol, and alcohol sales and advertising. Evidence from Finland shows that the imposition and enforcement of severe penalties for alcohol impaired driving results in substantially fewer drivers exceeding the legal BAC limit. Enforcement is vital to program success, and aggressive enforcement strategies should be considered in the formulation of alcohol-related driving laws and policies. Another set of countermeasures could deal with curtailing alcohol consumption in general. As pointed out by, an increase in the federal excise tax on alcohol in general and beer in particular (beer represents a majority of all alcohol sales), and a prohibition on beer advertising on TV, would likely lead to major reductions in alcohol consumption. In turn, reductions in alcohol consumption would likely result in reduced frequencies of alcohol impaired driving. [187]

4. Night time driving

Day time driving is less risk than night time driving. For example, the current fatality rate per 100,000,000 vehicle miles is 2.27 times higher at night than during the day (2.68 vs. 1.18). Given that about 25% of the distance traveled is at night, if the night rate per vehicle mile had been as low as the day rate, 10,282 fewer deaths (24% of the total of 42,636) would have occurred in 2004. [188]

As with many major problems that can be regarded, at a certain level of analysis, as unified and homogeneous, the problem of increased risk at night can also be viewed as a collection of related but separable mechanisms. For example, nighttime risk is influenced by a number of factors that are not unique to nighttime including alcohol, fatigue, and the proportion of young drivers. Each of these factors has a stronger influence at night, but also accounts for some amount of risk throughout the day. The defining characteristic of night driving, lack of natural light is the only major factor that is unique to nighttime. Recent studies of crash data have been reasonably successful in isolating the component of increased risk at night that is attributable to darkness itself rather than the other factors that vary between day and night. For fatal crashes, it appears that about 3,855 fatalities per year in the United States can be attributed to darkness, with the largest single component of that total being pedestrians, estimated to be about 2,334 per year. [189]

In addition to quantifying the overall importance of the darkness of night as a risk factor, this line of research has produced evidence about the nature of that risk, and that evidence corresponds closely to well establish circumstances concerning head lighting and driver vision. The primary countermeasure for darkness is vehicle head lighting. It has been recognized for a long time that low-beam headlamps, which are used vastly more often than high beam headlamps, usually do not provide adequate seeing distance to unexpected, low-contrast objects (most importantly, pedestrians). For example, in summarizing a variety of studies, estimated that the maximum safe speeds with low-beam headlamps was about 70 km/h. [190] As would be expected from that assessment, the relative risk for fatal pedestrian crashes under dark versus light conditions varies greatly with posted speed limits, being particularly high on higher speed roads. Such findings suggest that the majority of the safety problem related to darkness involves inadequate seeing distance with typical headlamps. [191]

The most obvious, if perhaps impractical, countermeasure for the increased risk of driving at night is to restrict driving to daytime. Although this may be unrealistic as a general solution, it may in fact be reasonable in a variety of ways as a partial solution. Some older drivers, for example, self restrict their driving at night. Some graduated licensing programs include restrictions on night driving by young drivers. At a societal level, analyses have shown that it would be possible to reduce road crashes by shifting driving toward light hours by means of extended daylight saving time. Because such restrictions involve potentially complex changes in drivers' daily activities, it is unclear how much they would reduce the risk of nighttime crashes that are unrelated to darkness itself (such as crashes attributable to alcohol and fatigue). However, it is likely that they would at least reduce darkness-related crashes. [192]

There are lot of options exist to reduce the risk of darkness related crashes in night driving. Some of these involve improved equipment, and some could be accomplished through education or changes in policy. Because of the dominant role of pedestrians in darkness related crashes, some of the simplest options involve changes in pedestrian exposure to traffic. For example, if pedestrians stayed out of traffic lanes at night, darkness-related crashes would be greatly reduced. Although it is notoriously difficult to improve safety by attempting simply to increase compliance with safety guidelines, there is some reason to expect that in this particular case it would be effective. This is because pedestrians' behavior near traffic at night may be influenced to a great extent by a particular misunderstanding about how visible they are to drivers. [193]

A variety of changes in infrastructure could reduce pedestrian exposure to traffic at all times of day, or increase pedestrian visibility at night. These include improvements in sidewalks, crosswalks, and separate pedestrian walkways. Improved street lighting, especially by concentrating efforts on areas in which pedestrians are more likely to be encountered, would help. It has been established that high beam headlamps are substantially underused, even in situations in which a vehicle is isolated from other vehicles, and there is therefore no cause for concern about glare from high beams. Current laws never require the use of high beams; they only prohibit their use under certain circumstances. Changes in laws, and public education in general, could promote the use of high beams, which would probably reduce pedestrian crashes at night. Automatic switching between high and low beams is an old idea, but recent improvements in artificial sensing technology offer greatly improved performance. Use of this equipment would probably increase the use of high beams under appropriate circumstances. [194]

The light output of low-beam headlamps is restricted relative to high-beam headlamps because of glare to oncoming drivers. However, it appears to be possible to improve the visibility provided by low beams while still taking into account concerns about glare. For example, although headlamps with high intensity discharge sources have caused public concern about glare, there is evidence that they actually improve the situation with respect to the objectively important aspects of glare, as well as providing more light in important areas. Better evidence about the effectiveness of these lamps may increase their acceptance. [195]

Adaptive head lighting may offer improved visibility without creating the glare concerns that have been raised by HID lamps. By changing head lighting in response to roadway, environmental, and traffic conditions, adaptive head lighting offers a more favorable tradeoff between visibility and glare than can be achieved with traditional, fixed head lighting. Some recent work on crash data has attempted to identify the highway geometries and traffic maneuvers (such as curves and turns at intersections) that might benefit most from adaptive lighting. [196]

Infrared night vision systems have been used on the road in a small number of vehicles for a number of years, and such systems are becoming available on more vehicles. Technical development of these systems has been rapid, and further improvements appear to be likely. The design of the optimal driver interface for these systems is still unresolved. With an appropriate interface, these systems may be very effective in reducing risk at night. [197]

5. Young drivers

The fatal crash rates are very high for the young driver compare to any other age groups. While in most U.S. states, a license to drive unsupervised requires a driver to be at least age 16, there is some variation, from 14 years and 3 months (with driver education) in South Dakota to 17 years in New Jersey. [198] Age limits on driver licensure in the United States are based historically on the need for young drivers to manage trucks in agricultural areas, and to provide teens with the means of getting to their places of employment. These continue to be common arguments for maintaining the current age limits in the United States. Insurance companies have for a long time charged higher rates for drivers under age 25, based on their overall poor driving records Recently, however, this has changed somewhat, as some insurance agencies have begun to provide discounts for youth who agree to some degree of on-road monitoring. [199]

According to the National Highway Traffic Safety Administration (NHTSA), 7,709 drivers of motor vehicles (including motorcycles) who were ages 16 to 20 were involved in fatal crashes in 2004 (a rate of 61.8 per 100,000 license drivers), among whom male drivers were more than twice

as likely to be involved in fatal crashes as female drivers. Drivers ages 21 to 24 had the next highest rate of any age group, at 46.5 per 100,000 licensed drivers, with 6,382 drivers involved in fatal crashes. In this age group, male drivers were more than three times as likely to be involved in fatal crashes as female drivers. In comparison, fatal involvement rates for other age groups ranged from 18.7 for 65 to 74 year-old drivers to 31.0 for 25 to 34 year old drivers, clearly demonstrating the excess risk presented by drivers 16 to 24 years old.
In 2004, there were 14,977 road fatalities of all ages in crashes involving drivers between 16 and 24 years old, or 35% of the total U.S. fatalities, even though drivers under age 25 comprised only 13% of all U.S. licensed drivers. Unfortunately, there has been no substantial decrease in the last decade. Among 15 to 20 year old drivers, there was only a 1% decrease in involvement in fatal crashes, with fatally injured drivers actually increasing 5%. More than half (7,672) of the 2004 deaths involving 16 to 24 year old drivers were in single vehicle crashes, of which the most common types were rollovers (1,442 deaths) and hitting a tree (1,310 deaths). Finally, unintentional injury is the leading cause of death for 15 to 24 year olds, with 70% of those deaths from motor vehicle crashes (10,736) in 2003. [200]

Several countermeasures have been adopted to address the particular crash characteristics seen among young drivers. Most of these are policy based. High rates of alcohol related fatal crashes led to changes in states' minimum legal drinking age laws, and by 1988 all states had raised their drinking age to 21. During the changeover, states with a minimum legal drinking age of 21 were found to have substantially fewer single vehicle, nighttime (proxy for alcohol related) fatal crashes among drivers under age 21. [201] By 1998, all states had also adopted lower legal blood alcohol concentration limits for drivers under age 21 ("zero tolerance" laws). During that changeover, states with a zero tolerance law were found to have further decreased their rates of single vehicle, nighttime fatal crashes. [202]

In the year of 1990, the high rates of teen driver fatal crashes, particularly at night, led to the adoption of graduated driver licensing (GDL), which is now in place in most states. [203] GDL programs for drivers under 18 years old vary by state, but typically have three licensure stages: a learner stage requiring extended supervised practice, an intermediate stage of at least six months that allows independent driving only with specific restrictions (night especially), and a full privilege stage following a clean driving record. Several GDL program evaluations have demonstrated reduced crashes among 16-year-olds. The longer learner or supervised driving phase in GDL addresses the presumed need for more practice driving, which was shown to reduce crashes in Sweden. Ideal GDL programs also include an intermediate stage restriction on carrying teen passengers, which addresses the high fatal crash rates among teen drivers who are carrying passengers. Positive results of passenger restriction have been reported from California. The most comprehensive programs tend to have the greatest benefits. Compliance with GDL, however, is less than ideal. [204]

Other potential policy approaches exist. An older age of driver licensure is one approach. Indeed, in New Jersey, the only state where for years teens had to be 17 to be licensed to drive, teen fatal crash rates were lower than in states with a lower licensing age. In most developed countries other than the United States, the licensing age is 18. [205] While an older age of licensure does not eliminate novice drivers' crashes that are due to inexperience, it does contribute somewhat to reducing the risk. Another policy related area of concern is the especially low rate of safety belt usage among young drivers and their passengers. In states with primary safety belt laws, higher belt use is also seen among teens. [206]

Policy and practice in the United States do not fully utilize the potential of other existing approaches that could help to reduce young driver fatalities by certain and swift enforcement of behaviors known to lead to crashes. Speed limit enforcement cameras reduce both speeding and the incidence of crashes. Red light running cameras have been shown to reduce intersection violations and crashes. Alcohol sobriety checkpoints are effective but underutilized in the United States. Policy approaches such as these would reduce fatalities for drivers of all ages, but offer particular benefit for young drivers because of their higher incidence of the unsafe behaviors involved. [207]

Another countermeasure targets the parents of young, novice drivers, enhancing their awareness of teen drivers' especially high risks in the early months of licensure, and encouraging them to restrict their teen's initial driving, increasing driving privileges only as they are earned. This "Checkpoints Program" promotes parent involvement in teen driving through the use of a parent/teen agreement and monitoring of teens' behavior, and results in increased parental limitations, and decreased risky driving and traffic violations among teen drivers. [208]

5.6 Road Safety Policy in Country Level:

5.6.1 SWEDEN:

- **National Road safety policy in Sweden:** [98]

'Vision Zero' is the basis of Swedish road safety work, a strategic approach towards a safe system where no one is at risk of being fatally or severely injured while using road transport.

In traditional sense there is no safety plan. However, a number of other agencies and stakeholders, representing municipalities, the police, the insurance industry, the car industry and others, along with the Swedish Transport Administration, have adopted a management by objective approach to road safety in order to achieve the new interim target towards Vision Zero. All the stakeholders (including the SRA- the Society for Risk Analysis) have agreed upon objectives for a number of performance indicators, such as speed compliance and seat-belt usage. These objectives are supposed to guide the road safety work towards the interim target of 2020 and towards *Vision Zero*.

Safety targets

The Swedish parliament decided in may 2009 on a new road safety target for 2020 of a 50% reduction in fatalities from the base year 2006-2008, as well as the new management by objectives approach to road safety work. The core of the new system is the collaboration of different stakeholders. To reach the target, an annual reduction of about 5 % is required.
The Parliament also decided on a 25% reduction target for severely injured persons, as defined by functional capacity after the injury, rather than police reports.

Figure 5.9: Progress towards road fatality target.

Infrastructure
Roads with median barrier. At the end of 2009, more than 2 000 kilometers of roads had median barriers, mostly the wire type (2+1, 1+1). Research has shown that the risk of fatal or severe accidents on these roads has dropped by 75-80%, which is higher than expected.

Speed
A new speed limit system was adopted in 2008 and includes a larger number of speed limits (10 steps, ranging from 30 km/h to 120 km/h). A review of all Swedish roads began in autumn 2008, and speed limits have been changed on 17 000 kilometers of the road network. By the end of 2009, more than 30 000 km of road had undergone a control of its speed limit due to the new criteria and many speed limit changes were made.

Road user behavior, enforcement
Installation of road-safety cameras enforcing speed limits continued in 2009, and there were 1030 cameras by the end of 2010.

Licensing, regulation
In the year 2010, the Swedish Transport Administration presented a new national strategy on motorcycle and moped safety. The main result is to focus on ABS (anti lock brake system) brakes for motorcyclists and proper helmet use for moped drivers. Speeding should be reduced for both groups.
The Parliament has decided that Class 1 mopeds will continue to be allowed for 15-year-olds (Contrary to an EU directive), but they will be required to have a specific driving license and education is compulsory. A driver’s permit is compulsory for Class 2 mopeds. The new rules were introduced on 1 October 2009.

5.6.2 NORWAY:

Swedish project '*vision zero'* has adopted by Norway due requirement of minimize road fatalities as much as possible which target are very close to zero fatalities and injuries. The project is part of the National Plan of Action for Traffic Safety 2002-2011. The Government has decided that *Vision Zero* provides the basis for traffic safety activities in Norway. *Vision Zero* was first discussed in parliament when the National Transport Plan 2002-2011 was introduced and also featured in discussion of the National Transport Plan 2006-2015. As stated in the document "*Road Traffic Safety 2002-2011*":

The Government views the large number of killed and injured in road traffic as a serious national concern. Therefore, a vision of no-one being killed or permanently disabled has been established as a basis for the long-term traffic safety effort. The vision means that the Government, in addition to conducting a policy with the goal of reducing the total number of accidents, will focus strongly on measures that can reduce the most serious accidents.

The Norwegian *Vision Zero* involves the entire transport system. The intention is to reduce the total number of accidents, but the main emphasis is put on serious accidents that can lead to fatalities and serious injuries.
As part of its 2010-2019 National Transport Plan, Norway adopted a target of reducing the number of people killed and seriously injured by 33% between 2009 and 2020. [98]

Recently safety measure taken in major issue like speed and drink driving to minimize road fatalities and injuries. Such as:

Speed:
Norway is seeking to make speeding socially unacceptable the authorities have adopted a strategy with a special focus on people aged 16 to 24. A national campaign for 2009-2012 was launched, targeting drivers who consider themselves responsible even though they exceed the speed limit. The goal is to improve drivers' knowledge of the relationship between speed and crash risk and reduce the number of fatalities and seriously injured by changing speeding behavior.

- In 2009-10, speed section control (to measure the average speed between two points) was implemented on three sections, selected according to their crash risk. Evaluation is on-going and decisions will be taken on whether or not to expand their implementation.
- Automatic cameras are progressively being replaced with digital cameras.
- Speed limits (30-100 km/h) are being reviewed on the whole network.

Drink-driving
The police have invested in Alco-meters to detect intoxicated drivers. A working group (appointed by the Ministry of Transport and Communication) has delivered a report from a study of Alco-lock as an alternative to suspending the driving license of those apprehended for driving while intoxicated.

5.6.3 GERMANY:

National road safety strategies:

The Federal Road Safety Action Plan of Germany launched in 2001, is called the "Program for more safety in road transport". A new program, currently in development, will soon replace it.
The new program is expected to be launched in 2011 and will contain many road safety measures under all the main categories ("human related safety", "vehicle safety" and "infrastructure safety"). The principal aim of the planned program is to enable safe, ecologically sensitive and sustainable mobility for all road users in Germany.

Safety targets and its progress:
Germany has no national target in terms of numbers but instead aims at reducing fatalities and injuries as much as possible. The federal Road Safety Action Plan is entitled "*Program for more safety in road transport*". It includes the following priorities:

- to improve the transport climate in Germany (e.g. aggressiveness);
- to protect vulnerable road users (children and the elderly, pedestrians, cyclists and motorcyclists);
- to reduce the accident risk among young drivers;
- to reduce the potential danger of heavy goods vehicles;
- to improve road safety on rural (interurban) main roads.

Germany is making good progress towards the overall ECMT target of a 50% reduction in the number of fatalities between 2000 and 2012.

Figure 5.10: Progress towards road safety target.

The Safety Program (2008- 2010) for more Safety in Road Transport has provided a good basis for a positive decade of road safety development on German roads. The success of the program provides a good example of efficient road safety implementation without setting a specific numeric target. Regarding recent road safety developments, Germany benefits from an excellent road network, with over 12 000 km of highways which are among the safest roads worldwide without a general speed limit; an optimized legal framework with a highly sophisticated penalty point system; and impressive progress in passive safety technology, as well as, increasingly, active safety as the vehicle industry strives to meet customer demand.

- In recent years, further promising measures that have been introduced include:
- Spending more than EUR 9 billion to build more than 900 km of new highways since 2001;
- Construction of more than 3 000 parking devices for heavy goods vehicles (by 2012, 11 000 further parking devices are planned);
- Augmenting the number of crossing devices for animals on interurban roads;
- Reducing the legal BAC limit from 0.08% to 0.05% and to zero for novice drivers;
- Increasing sanctions for main offences (enhancing of penalties for speed, right-of-way and red-light violations, and for driving under the influence of alcohol and drugs);
- Higher standards for road safety and mobility education in secondary school education through implementing evaluation instruments;
- Recommending the application of day-time-running lights;
- Carrying out nation-wide safety campaigns;
- The wide introduction of ESP in the vehicle fleet, while other active safety systems, such as ACC, are on the brink of market penetration;
- Developing and implementing a new assessment procedure for Euro NCAP (before: separate stars for "passive safety for adult passengers on front seats", "protection of children" and "of pedestrians"; now: a one-star system considering all aspects). [98]

5.6.4 FRANCE:

National road safety strategy
In the year 2010, the Interdepartmental Committee for Road Safety (chaired by the Prime Minister), determined 14 new measures under six main objectives which showed in below.

Targets
In the year 2007, President set a national target for reducing the number of road fatalities to 3 000 by 2012. This corresponds to a reduction of 35% over the 2007 level; that is, an average annual reduction of 8.3%. There are no quantitative sub targets. In 2009, there was no improvement in

comparison to 2008. An average annual reduction in fatalities of 11% in 2010, 2011 and 2012 will be required to reach the target set for 2012.

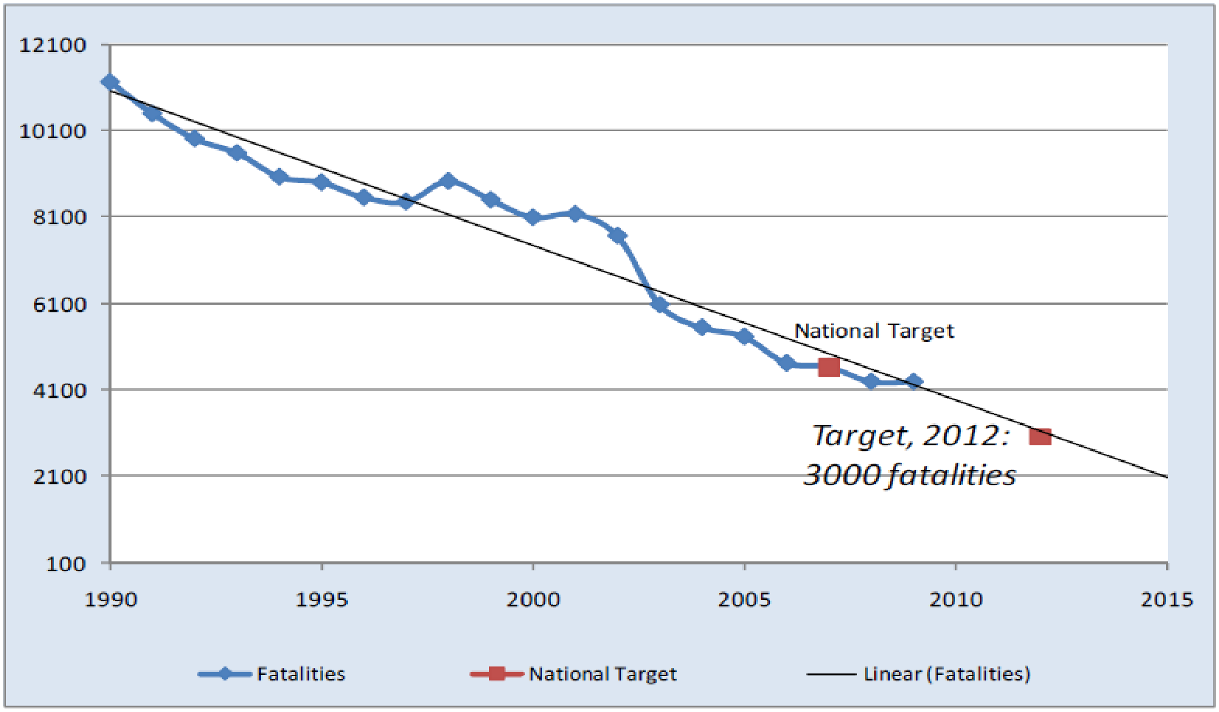


Figure 5.11: Trend in progress towards road fatality target.

Recently taken safety measure (2008-2010) as below: [98]

Alcohol and drug abuse
New measures adopted in 2010

- Equipping police and gendarmerie units with 5 000 electronic breathalysers to augment roadside alcohol tests;
- Raising roadside drug tests to 10 000 a year;
- Charging the cost of drug tests to the offenders instead of tax-payers;
- Making breathalysers available in bars.

Continuous implementation of previous measures:

- Preparation of a law allowing judges to oblige a driver testing with a positive BAC to install an alcohol interlock in his car, or to confiscate the vehicle in case of recidivism under the influence of alcohol or drugs. This law will be presented to Parliament at the end of 2009;
- Mandatory alcohol interlock in school buses (September 2009).

Speed management: fighting speeding
New measures adopted in 2010

- Signposting large, automated speed-control sections, instead of individual radar locations;
- Installing 100 control devices on mean speed throughout large sections (control section).

Continuous implementation of previous measures:

- The implementation of automatic speed cameras continued in 2009 and will continue until 2012 (500 devices per year, including red light or headway cameras).

Enforcement
New measures adopted in 2010

- Immediate clamping of vehicles involved in a major road offence;
- Sentencing to three years of jail and a 5 000 euro fine in cases of failure to report an accident.

Continuous implementation of previous measures:

- First implementation of red light cameras started at the beginning of 2009.

Safety of motorized two-wheelers:
New measures adopted in 2010

- Making moped power-restraining devices fully respected;
- Imposing compulsory moped anti-derestriction checks every two years;
- Compulsory prior training before driving all light motorcycles;
- Promoting new roadside fittings and signposts, less aggressive to motorized two-wheelers.

Increasing awareness of future drivers
New measures adopted in 2010

- Organizing road safety events in high schools

Preventing occupational road risks

- Developing occupational road safety plans

Vehicle standards and equipment

- July 2008, compulsory reflecting jacket and triangle
- Cyclists must wear a reflecting jacket outside urban areas at night.

5.6.5 ITALY:

National road safety strategies
In Italy, the Road Safety National Plan covers the period 2001-2010. The Plan set a target to reduce the number of road fatalities by 50% between 2001 and 2010 (in line with the EU target). The Plan is structured according to a two-level action strategy: [98]

- The first-level actions support, also economically, the implementation of immediately feasible measures in high-risk situations.

- The second-level actions aim at the implementation of a new and efficient system made up of techniques and tools for the analysis of risk factors, road safety monitoring and of methods and criteria for road safety management.

Road safety strategies beyond 2010

The revision of the Road Safety National Plan is expected in 2011.

Safety targets and sub targets

The 2010 targets identified in the Road Safety National Plan are:

- to reduce the number of fatalities by 50% compared to 2001;
- to reduce the number of injuries by 20% compared to 2001.

The figure below shows the progress made towards the ECMT target, approved by Transport Ministers in 2002, of a 50% reduction in the number of fatalities by 2012 compared to the level in 2000.

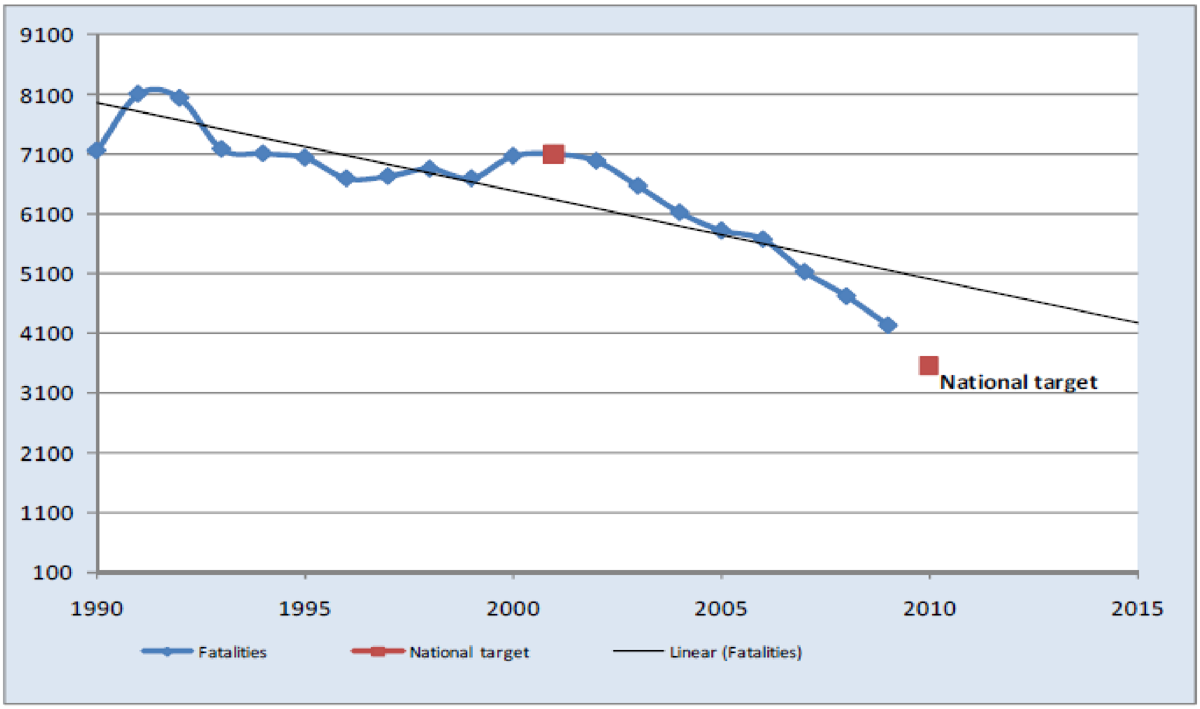


Figure 5.12: Progress towards road safety target.

The main safety measures taken in 2009-2010 are:

- Zero BAC limit for young drivers, novice drivers and professional drivers;
- Lower speed limits for young drivers;
- Compulsory use of safety-belts in micro cars;
- Alcohol cannot be sold between 2 and 7 a.m.; and between 10 p.m. and 6 a.m. on motorways.

5.6.6 SPAIN:

National road safety strategies

In the year 2003, Spain adopted a Road Safety Strategic Plan for 2004-2008. The plan has three axes:

- In 2004, the *Dirección General de Tráfico* (DGT) introduced a group of special road safety measures for 2004-2005 in order to achieve quick results. These measures were: implementation of the penalty points driving license; creation of the National Road Safety Observatory; promotion of the Road Safety Council; a significant increase in the number of traffic agents; and the introduction of speed cameras on highways.

- Development of the 2005-2008 Key Strategic Action Plan, with active involvement of civil societies and other administrations.

- An Urban Road Safety Master Plan was developed to define a methodology for interventions in this specific area. A Strategic Infrastructure and Transport Plan were also approved in 2004.

Safety targets and sub targets

Spain's objective for 2008 was to reduce by 40% the number of road accident fatalities compared to 2003. The target was reached, with a 43% reduction in fatalities. In relation to the EU target (reduction by 50% in the number of fatalities between 2000 and 2010), Spain has achieved a 44% reduction. If the trend continues, achieving the European target seems feasible.

Road safety strategies beyond 2010

A new Road Safety Plan 2010-2020, with new targets, is under development and will be ready at the end of 2010.

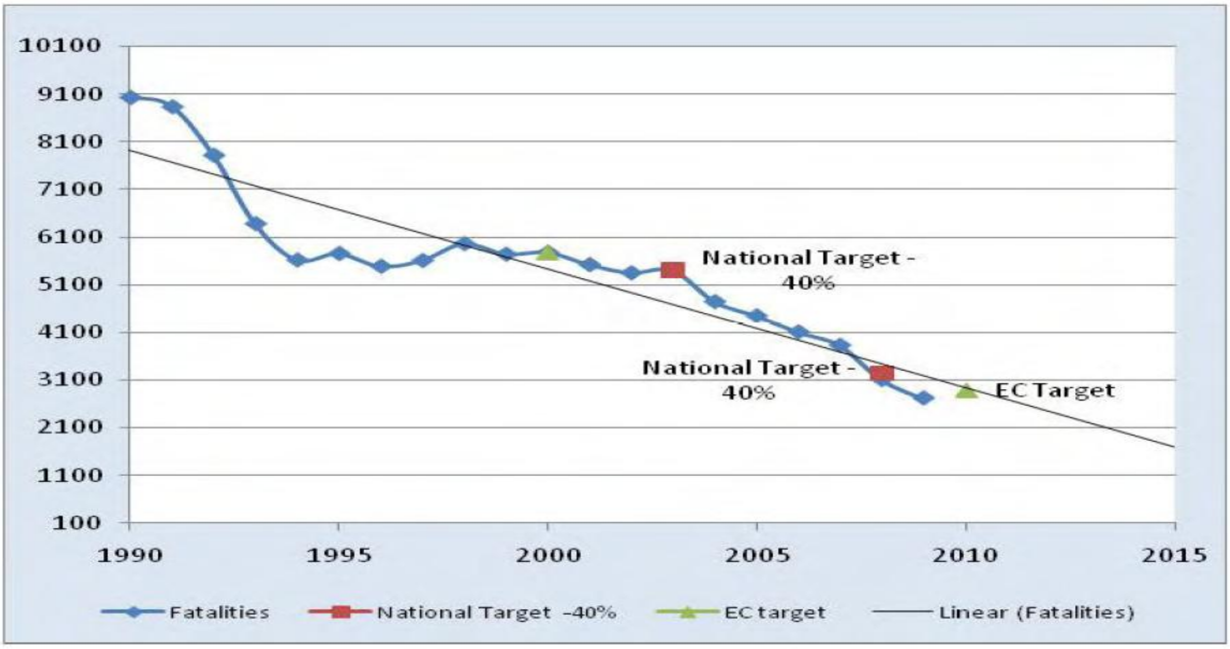


Figure 5.13: Trend in progress towards road fatality target.

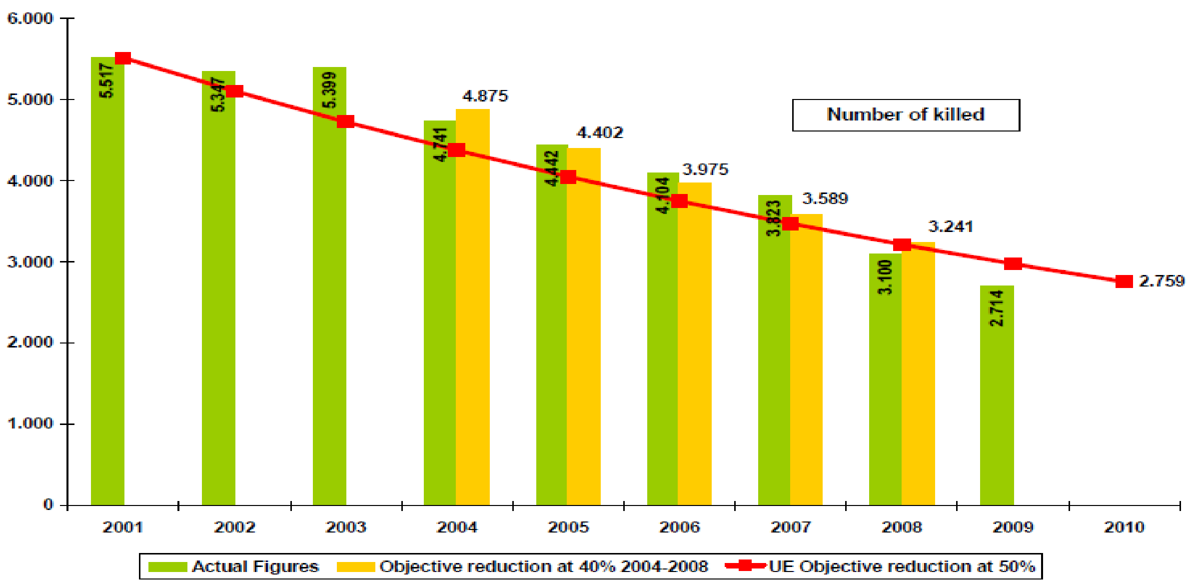


Figure 5.14: Trend in progress towards road fatality target.

Recent safety measures taken in the year between (2009-2010) as below:

Institutions

- In 2009, signature of the Collaboration Agreement between the Spanish Federation for Municipalities and Provinces and the General Directorate for Road Traffic (DGT), for the purpose of developing more effective participation of town/city councils in road safety policy development.

- There will be signed agreements with town/city councils in which DGT will provide speed and alcohol-measuring devices, and fund the development of urban road safety plans.

Licensing

- Implementation of the Driving License Directive 2006/126/CE, which came into force in December 2009.

Road safety plans

The Strategic Plan on Road Safety for Motorcycles and Mopeds, launched in November 2007, is being monitored within the Spanish Road Safety Council. The Plan's following actions have been selected as the most relevant so far:

- A specific mass-media communication campaign on PTW safety in 2008 and 2009;
- Protection of guardrails with biker-friendly systems, according to a specific regulation issued by the Spanish Central Administration. The Ministry of Public Works has already protected 1 600 kms and plans to additionally protect another 1 600 kms;

- Ensuring road safety for PTW users in urban areas. DGT is promoting the adoption of PTW-friendly measures by Spanish cities. Barcelona and Madrid have already implemented a PTW Safety Plan;
- Special multi-agent campaign for the enforcement and promotion of the use of helmets in southern Spain;
- Research program on PTWs;
- Specific Working Group for the development of a voluntary training market for motorcyclists.

Speed

- Increase in the number of speed cameras on roads outside urban areas, from 465 in 2008 ton540 in 2009.
- Increase in the number of speed checks by fixed speed cameras, from 305 185 in 2008 to 473 337 in 2009. Refer to Section 4 for information on the evolution of speed violations.

Drink-driving

- Increased enforcement for drink-driving. The number of controls has doubled in five years.
- Promotion of non-alcoholic beer: 10% of consumption is now non-alcoholic.
- Promotion of designated drivers.

Use of safety devices

- Increased enforcement of safety-belt and helmet use.
- Specific campaigns for the use of helmets in the South of Spain.

Enforcement (general)

Special road surveillance and control campaigns in 2009:

- Speed controls on secondary roads from 13 to 27 May.
- Control of safety-belt use from 9 to 22 February.
- Control of motorcycle and moped crash-helmet use from 4 to 18 June.
- Special campaign on alcohol from 6 to 19 July and from 7 to 20 December.
- Mobile phone use from 9 to 22 November
- School buses from 15 to 28 October.

Infrastructure. [209]

- Signposting of black spots on the central government network, as a temporary measure.
- A road safety master plan for built-up areas has been developed to serve as a guide for local authorities.

5.6.7 JAPAN:

National road safety strategies and targets:

Since 1971, the government sets up a National Traffic Safety Program every five years. The 8th Program covers the period 2006 to 2010. It initially included the target to have less than 5 500 deaths (within 24 hours) and one million casualties, by 2010. This target was achieved two years earlier than expected; therefore, the Prime Minister set new targets: [98]

- To reduce the number of fatalities to less than 5 0002 by 2012 and to less than 2 500 by 2018;
- By 2010, pedestrian and cyclist fatalities to be reduced by 20% compared to 2005;
- Also by 2010, fatal accidents caused by drivers (70+) to be reduced by more than 10% compared to 2005.

The 8th National Traffic Safety Program has four strategic objectives and eight pillars. The four strategic objectives are:

- Coping with the declining birth rate and an ageing society;
- Improving safety for pedestrians;
- Encouraging citizens to improve their awareness;
- Utilizing new technologies.

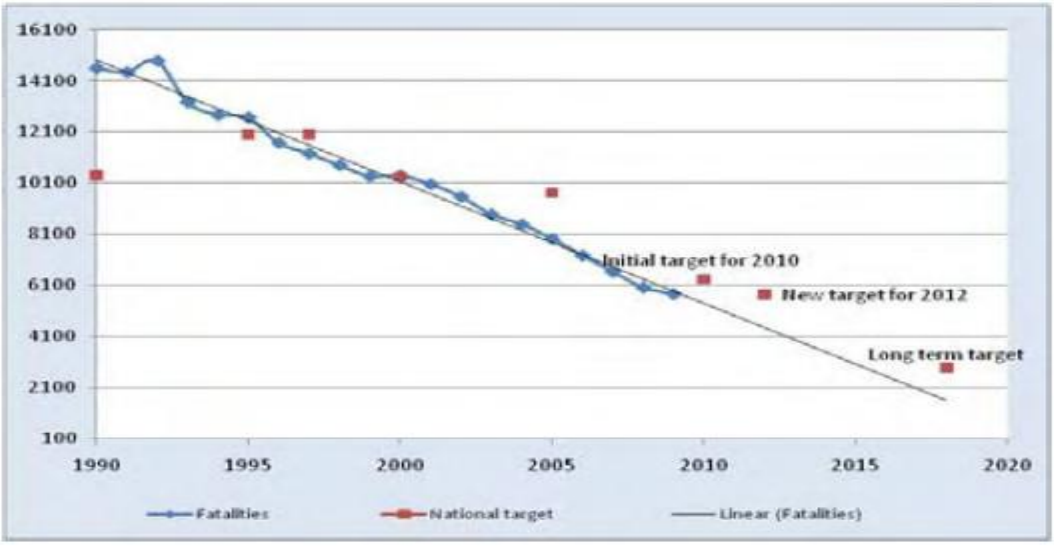


Figure 5.15: Trend in progress towards road fatality target.

Road user behavior, enforcement, regulation:

- The Road Traffic Law was revised in June 2009 and is now in force.
- Drink-driving :

- Since 2007, a fine is imposed not only on drivers (up to 8 800 EUR) but also on their passengers and the alcohol providers (up to 4 400 EUR);

- Drunken driving (drive not in a condition to drive, whatever the level of alcohol) is subject to 35 penalty points and drink-driving (BAC above 0.3g/l) to 13 or 25 penalty points;

- For serious drink-driving offences, the penalty points and maximum suspension period of the license have been raised: for example, if a drunken driver causes a fatal crash and runs away, his driver's license is revoked for ten years.

- Older drivers (+75) are required to take a cognitive function test before their license is renewed. If they are diagnosed with dementia their license is cancelled.
- Two infants may be carried on a bicycle only if the bicycle follows the newly prescribed safety measures.

Education and communication

- Pedestrians are being educated to wear reflective clothing.

Infrastructure

- As from April 2010, exclusive parking spaces have been designated near administrative and health services for the elderly aged 70 or over and for pregnant mothers.
- A traffic signal control system has been introduced which separates cars from pedestrians.
- Barrier-free signals have been installed using sound displays.

5.6.8 SWITZERLAND:

National road safety strategies

An action plan, "*Via Sicura*", has been drawn up and is being discussed by the Swiss Government. Among its measures, all of which have undergone cost-benefit analysis, are: [98]

- BAC for young drivers and professional drivers;
- Treatment of black spots;
- Road safety audits;
- Compulsory helmet use for cyclists up to 14 years old;
- Limitation of the validity period of the driving license (regular checks of ability to drive).

In the year 2010, the Swiss Federal Council submitted the '*Via Sicura*' program to Parliament for consent. Some measures require legal amendments. The process will therefore still take time and implementation is not expected before 2012.

Safety targets and sub targets:

The current target in Switzerland is to halve the number of fatalities and seriously injured by 2010 in comparison to 2000. Based on preliminary results for 2010, it seems unlikely that the target will be reached, especially regarding the number of seriously injured. However, overall the last decade has recorded much progress.

Type	Targets (% and absolute figures)	Base year	Target year	Base year figure	Current results (figure in 2009)
Fatalities	-50% (300)	2000	2010	592	-41% (349)
Seriously injured	-50% (3 000)	2000	2010	6 191	-24% (4 708)

Table 5.2: General road safety targets.

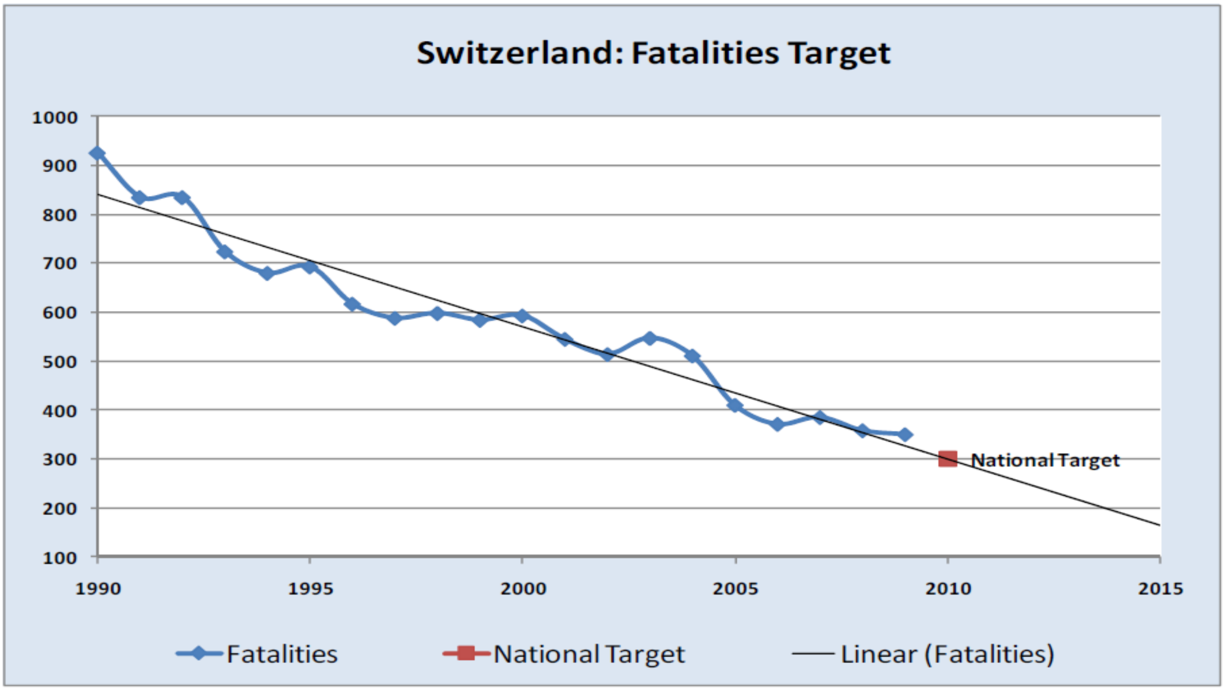


Figure 5.16: Trend in progress towards road fatality target.

Few road safety measures (2007-2010) taken as below:

Cars
Starting from 1 April 2010, new regulations were applied for the transport of children in cars: children between 7 and 12 and smaller than 150 cm must be restrained with a certified child restraint system. Until 2010, this only concerned children younger than 7 years.

Speed
The first two section control systems (control of average speed between two points) were installed in 2010.

Traffic law
The Swiss Federal Roads Office started a project with the aim of simplifying the regulations concerning road traffic and signal systems.

Education, communication and safety campaigns

- Upcoming (2011-13) campaign on driver fatigue;
- Continuation in 2011-13 of the head-rest campaign (www.kopfstuetzen.ch);
- Third seat-belt campaign, see http://www.sicherheitsgurt.ch/indexflash.html;
- Campaign by bfu and insurance companies on driver assistance systems, http://www.autoiq.ch/;
- Campaign on speeding, see http://www.slow-n-easy.ch/.

5.6.9 INDIA:

Lot of factor involve in road accident such as roads itself, motor vehicles as also the human being, the National Road Safety Policy needs to address on a holistic basis, issues covering road engineering, signage, vehicle design, and education of road users and enforcement of traffic safety measures. It is also recognized that regardless of jurisdictions, the Central and State Governments have a joint responsibility in making a dent on the incidence of road accidents and fatalities.

In the light of this, the Government of India has considered it relevant to frame a draft National Policy on Road Safety covering both preventive and post-accident aspects of Road Safety encompassing initiatives of public policy as well as implementation aspects, as also the responsibilities of various stakeholders. [135]

1. **Raising Awareness about Road Safety Issues:**

Policy Statement:

The government will make increased efforts to promote awareness about the seriousness of the road accident problem, its social and economic implications and the necessity to curb the rising menace of road accidents. This will facilitate various stakeholders to play their rightful role in promoting road safety.

Strategies to Implement Policy:

- Raising awareness among key decision-makers, stakeholders and **NGOs** to facilitate them for planning and promoting road safety.
- Raising awareness about the gravity of road safety issues amongst all citizens of the country and particularly the young, elderly and the infirm.
- To enlighten various road user groups with respect to their roles and responsibilities.

Providing Enabling Legal, Institutional and Financial Environment For Road Safety:

Policy Statement

The government will spell out the institutional responsibilities of the various stakeholders of road safety and take appropriate measures to ensure that the required legal, institutional and financial environment for road safety is put in place. The reforms in these areas would take into account an active and extensive participation of the community at large and of private and business sector as well as of NGOs for raising awareness about the road safety issues like behavioral pattern, the human factor, issues of risk perception is also building up of an environment for a minimum acceptable level of safe behavior on roads etc. [135]

Strategies to Implement Policy:

- To strengthen the legal framework for road safety at various levels.
- To strengthen the institutional framework for managing road safety.
- To strengthen the financial framework for road safety.

Road Safety Information Database:

Policy Statement
The government will significantly increase help and assistance to enhance data collection and analysis systems in states, union territories, districts, metropolitan cities as the components of a national road safety information system. [135]

Strategies to Implement Policy

- Improve the reporting of important details at the scene of accident shortly after the occurrence of the accident.
- Improve the storage and accessibility of all data relevant to an accident such as vehicles involved, road environment etc.
- Development of a comprehensive road safety information database needed for operating effective safety management systems/programs at National, State and City levels.

Safer Road Infrastructure:

Policy Statement

The government will undertake additional steps to promote road safety practices at national, state and local levels. Safety conscious planning and design of roads and road networks will be encouraged whilst undertaking new as well as up gradation and rehabilitation road schemes through application of road safety audits. Continuing application of ITS to achieve safe and efficient transport system will be encouraged. [135]

Strategies to Implement Policy

- Require all proposed new and rehabilitation road schemes to be checked from a safety perspective for all types of road users during the planning and designing stages through Road Safety Audit and adopt accident reduction strategies for existing roads through black spot improvement programs.
- Review design standards, codes, guidelines, recommended practices, access control and development control procedures to ensure best global practices for road safety are incorporated wherever appropriate.

- To facilitate quality improvement of practicing highway engineers on various road safety aspects through training and dissemination of appropriate road safety knowledge.

2. **Safer Vehicles:**

Policy Statement

The government will take steps to strengthen the system to ensure that safety aspects are built in at the stage of design, manufacture, usage, operation and maintenance of vehicles in line with prevailing international standards in order to minimize adverse safety and environmental effects of vehicle operation on road users and infrastructure. [135]

Strategies to Implement Policy

- To promote safety conscious design of vehicles to ensure safe transport for passengers, drivers and other road users.
- To promote the statutory periodic inspection as an essential check on the road worthiness of vehicles.
- To minimize impact of vehicle operation on roads.

3. **Safer Drivers:**

Policy Statement

The government will strengthen the system of driver licensing and training to improve the competence and capability of drivers. [135]

Strategies to Implement Policy

- To facilitate the development of systems which ensure that trained and competent new drivers are permitted to come on the roads.
- To improve the manpower both quantitatively and qualitatively, to test and evaluate the driving ability of all license applicants. This would be done by a system of accreditation of the quality of testing and evaluation of drivers.
- To assist and encourage setting up of model driving schools with adequate infrastructure and tools in partnership with automobile manufacturers, other private sector participants and NGOs.

4. **Safety For Vulnerable Road Users:**

Policy Statement

The design and construction of all road facilities will take into account the needs of vulnerable and physically disadvantaged in an appropriate manner. The government will seek to disseminate 'best practices' in this regard to town planners, architects, and highway and traffic engineers

Strategies to Implement Policy

- Recognize Vulnerable Road Users (VRUs) as being equally important as the motorized vehicle, in the planning, designing, construction and operation of roads and to provide for their special needs and requirements.
- To update existing and develop new standards, guidelines and recommended practices in line with accepted international practices to facilitate safe accommodation of VRUs.
- To encourage NGOs to work with Vulnerable Road Users, to increase their awareness of the dangers.

5. **Road Traffic Safety Education And Training:**

Policy Statement

Road safety knowledge and awareness will be created amongst the population through education, training and publicity campaigns. Road safety education will also focus on school children and college going students, while road safety publicity campaigns will be used to propagate good road safety practice among the community. The government will encourage all professionals undertaking road design, road construction, road network management, traffic management and law enforcement to attain adequate knowledge of road safety issues. [135]

Strategies to Implement Policy

- Encourage inclusion of road safety awareness as part of educational curriculum for students of various age groups.
- To develop and implement road safety publicity campaigns by using the creative resources of both Government and, professional agencies and NGOs for various target groups as per their respective requirements.
- Also Planning and implementing community based road safety programs to engage local as well as non-governmental partners in the areas of road traffic safety that most affect their daily lives.
- Planning, designing and implementing training programs for various specific groups involved in road safety management tasks e.g. Traffic Personnel, Highway Engineers, School Teachers, Town Planners, NGOs etc.

6. **Traffic Enforcement:**

Policy Statement

The government will take appropriate measures to assist various state and other governments to improve the quality of their enforcement agencies. Government will actively encourage the establishment and strengthening of Highway Patrolling on National and State Highways taking the help of the State Government and Union Territories as appropriate. [135]

Strategies to Implement Policy

- To take appropriate measures to improve the capacity of concerned state agencies, to affect improvement in their driver testing and vehicle testing to the required standards.

- To take appropriate steps to ensure that the enforcement authorities are adequately manned, trained, and equipped and empowered to carry out their function ensuring safe road use and orderly traffic flow including the traffic situation, land use and road network planning etc.
- To setup a national level Traffic Police Training Institute to serve, motivate and provide incentive and necessary help to each State to set up modern police training schools within their jurisdiction.

7. **Emergency Medical Services For Road Accidents:**

Policy Statement

The Government will strive to achieve its target that all persons involved in road accidents benefit from speedy and effective trauma care and health management. The essential functions of such a service would include the provision of rescue operation and administration of first aid at the site of an accident, the transport of the victim from accident site to an appropriate nearby hospital. [135]

Strategies to Implement Policy

- To improve communication system available with police and other emergency services as a means to reduce response times and to assist in planning and implementation of Traffic Aid Post Scheme.
- To train police, fire and other emergency service personnel such as those on ambulances and paramedics in basic first aid for road crash victims.
- To develop local and regional trauma plans based on study of post accident assistance and consequences for road traffic accident casualties.

8. **HRD & Research For Road Safety:**

Policy Statement

Government will encourage the current road research activities and programs of road safety research. Priority areas will be encouraged by increased funding. Government will facilitate dissemination of the result of research and identified examples of good practice through publication, training, conferences, workshops and websites. [135]

Strategies to Implement Policy

- To set up a system for identifying new areas for research and for extension to ongoing research projects that are likely to be most rewarding with a special attention to safety of the vulnerable road users.
- To develop arrangements for the allocation of funds for research projects to be carried out by Research Institutes, Universities, NGOs.
- To consolidate the results already available from research projects and resource material for widespread dissemination among road safety professionals.

5.7 Conclusion:

In every year a lot of people killed by road accident all over the world. Day by day road fatalities become a major global problem for every nation. Some countries of the world are achieving their road safety targets. On the other hand lot of country could not reach their targets due to lacking of proper making policy and implement it. Policy has a crucial role to improvement road safety fatalities. Policy implementation is very important because it is not possible to achieve road safety target without implementation.

Over the world, the policy is not same for every country. It varies country to country even nation to nation but the few basic policies are same all over the world. As mentioned in this chapter The European Union emphasizes to make policy in seven objectives. Such as: Education and training of road users, enforcement of road rule, safer road infrastructure, safer vehicle, modern technology and protect vulnerable road user. The education, training and enforcement are very essential for the road user because they are the first link in the road safety chain. Exceeding speed limit for the young driver should monitor properly by road police to reduce fatalities. Not only in Europe, whole over the world, the fatal crash rates very high for the young driver compare to any other age groups.
In U.S.A, they emphasized five policy objectives to reduce road fatalities such as Exceeding speed limit, Use of safety belt, Drink driving, Night time driving and young drivers. Statistics shows that the highest numbers of male and female young drivers whose age limit within 15 to 20 years are killed by road accident in U.S.A. While in most U.S. states, a license to drive unsupervised requires a driver to be at least age 16, there is some variation, from 14 years and 3 months (with driver education) in South Dakota to 17 years in New Jersey. If U.S.A will make a new policy to getting license for young drivers considering age limit such as 17 years for all states then it could be reduce road fatalities all over the United States.

In Asian region, considering developing country like India which make policies to improve road safety that are not fully similar to EU and U.S.A. In developing country the main problem is lacking of safer road infrastructure and people education. Due to poor road structure and illiterate people who don't want to respect the traffic rules and regulations properly as a result every year lot of people killed by road accident in India. Some Important policy objectives also important to reduce fatalities such as: safer vehicle, safer driver, vulnerable road user, traffic enforcement which are emphasized by Indian policy maker. In Asian developing country could make policy in use of safety belt and emergency medical service like Europe and America, because it a passive safety measure which could improve road safety.

CHAPTER 6

TECHNOLOGIES IN ROAD SAFETY

6.1 INTRODUCTION:

It did not take rigorous scientific research to achieve major improvements in traffic safety in the early stages of motorization. Instead, early traffic-safety countermeasures were often based exclusively on common sense. Since then, scientific research has gradually increased in importance as the basis for developing successful interventions. This shift was not made by choice but mostly by necessity: Many of the “easy” problems have already been addressed, and the remaining problems are generally too complex for an approach based solely on common sense. Fortunately, our understanding of the complexities involved in traffic safety has recently made major gains, and common sense can now be supplemented, to some degree, by valid technical analysis. Approach: This chapter discusses major conceptual issues that should be considered in guiding the future development of effective, science-based traffic-safety countermeasures and applications of modern advanced technologies addressed to cope with the emerging complexities prevalent in the road safety realm.

The conceptual considerations to advocate the proper envision of the road safety technological advancement and to better understand the phenomenology and the extent of the safety problem are discussed as an approach to total harm proposed by Thulin and Nilsson [210] and amenability. Total harm is conceptualized as a product of exposure, risk, and consequences (figure 6.1). For each event, the values along the three dimensions (exposure, risk, and consequences) define a three-dimensional space. The volume of this space is the total harm for this particular event. By the term exposure means the probability of a particular, potentially risky event (condition, situation) per distance traveled or per unit of time. Risk is the conditional probability of a crash, given the event in question. Consequence is the conditional probability of undesirable outcomes (i.e., fatality, injury, and property damage), given a crash that was precipitated by the event in question.

The implications of this approach can be several. First, a high value of total harm can be a consequence of a high value along any of the three dimensions. This is illustrated in Fig. 6.2, which shows annual mileage (exposure), likelihood of a crash per distance driven (risk), and likelihood of a fatality per crash (consequences) by driver age. The fatality aspect of total harm for different age groups is carried primarily by different dimensions: risk for young drivers, exposure for middle-aged drivers and consequences for older drivers. For injuries the pattern will be the same.

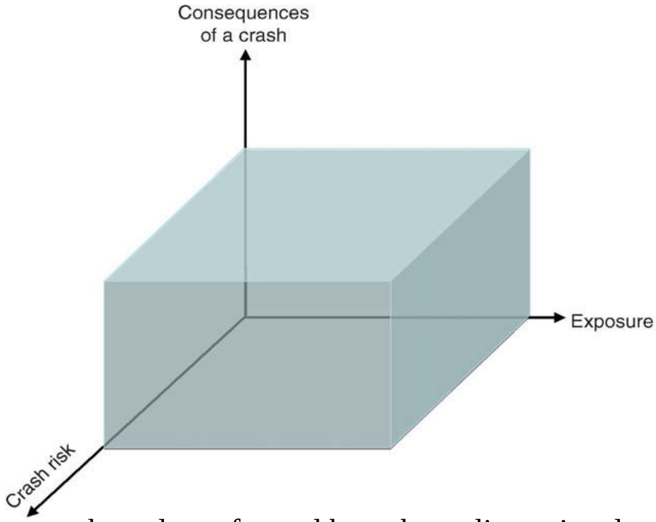


Figure 6.1: Total harm as the volume formed by a three-dimensional space of exposure, risk, and consequences. [210]

The 2nd important implication of this approach is that proportional changes in any of the three dimensions are equivalent in terms of the resultant changes in total harm. For example, a 25% decrease in exposure is functionally equivalent to a 25% decrease in risk or a 25% decrease in consequences. The 3rd implication, and a corollary to the previous one, is that effective interventions are not necessarily those that address the most dominant dimension of the problem. Let's again consider the age effect example in Fig. 6.2. As indicated earlier, the total harm for young drivers is carried primarily by risk. Nevertheless, a 25% reduction in risk is no more effective than a 25% reduction in either exposure or consequences. Above all the consideration of this approach is viable if whole the three dimensions of total harm are judged.

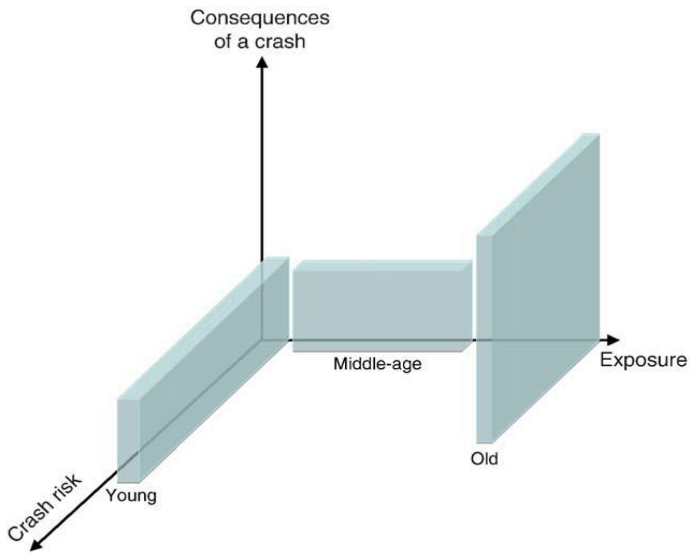


Figure 6.2: A schematic illustration of the total harm of road crashes in developed countries by driver age. Total harm for each age group is the volume of the corresponding three-dimensional space. [210]

By the approach amenability of total harm means the amenability of any of its three components: exposure, risk, or consequences (Fig. 6.3). Let us consider an example of total harm from crashes due to making unprotected left turns across traffic. The total harm here could be reduced by interventions along any of the three dimensions of the space. For example, exposure could be reduced by increasing the frequency of locations where left turns are not allowed or by installing more left-turn arrows. Risk could be lowered by installing collision-warning systems, collision avoidance systems, by reducing the posted speed, intelligent vehicle and infrastructure systems. Finally, consequences could be minimized adopting passive measures by installing side-impact and curtain airbags, or by installing technology that would reduce the likelihood of a rollover after an initial impact which may triggers severe consequences.

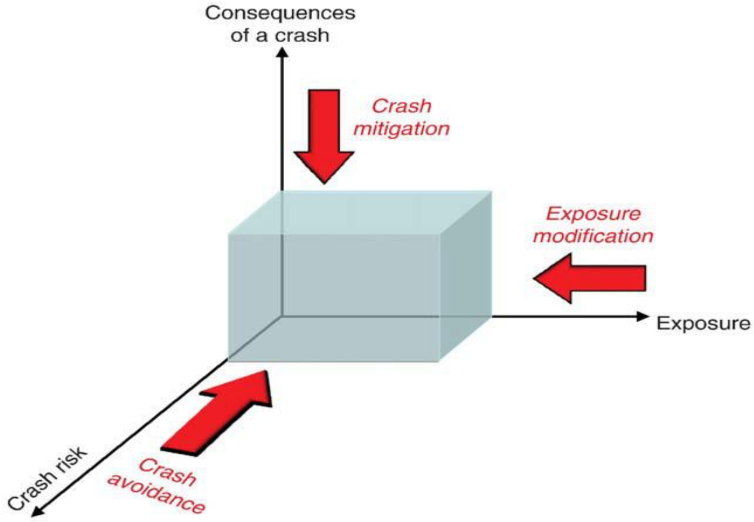


Figure 6.3: Amenability of total harm as a consequence of amenability of exposure, risk, or consequences.

The Effective development of science-based countermeasures need the following recommended points are to be noticed [211]:

(1) Concentrate on total harm (as opposed to exposure, crash risk, or consequences).
(2) Deal with the most amenable of the three underlying dimensions of total harm (exposure, crash risk, or consequences).
(3) Consider the multiple sources of uncertainty in estimating costs and benefits.
(4) Be sensitive to current and expected societal trends.
(5) Pay attention to the law of increasing returns.
(6) Take into consideration micro and macro adaptation on the part of traffic participants.
(7) Consider the complex effects of most countermeasures.
(8) Be aware of interactions among contributing factors.
(9) Take advantage of interactions among countermeasures

The prediction of any accident happening is not possible and the risk of happening may not be totally avoided. Risk of the road traffic accident causation is the convolution of probability of any crash, exposures exposed to that event and the propensity to be damaged or vulnerability of the systems. Human interaction with vehicles, vehicles interaction with guided and surrounding infrastructures, driver's perception and stimulant, quality of the services etc are significant elements of a traffic mobility system. Improvement of the road safety requires the development of all of the above factors in a holistic way. The systematic components of each of the interacting element are needed to be integrated for future interventions and sustainable safety. The infrastructures and the transport modes are essential to tackle in a intelligent way for the rapid, quickest, easiest, economical and rational decision making for the users' of the whole systems.

In the following passages of this chapter, this concept is envisaged for the intervention of emerging road safety techniques.

6.2 SELF-EXPLANATORY ROADS AND FORGIVING ROADS ENVIRONMENT:

The self-explaining road and forgiving road are two often cited concepts deemed to be able to reduce the number of accidents due to infrastructure-vehicle-human fault management.

6.2.1 Self-Explanatory Roads:

Self-explanatory road (SER) is defined as one that is designed and constructed to evoke correct expectations from road users and elicit proper driving behaviors, thereby reducing the probability of driver errors and enhancing driving comfort. SER implies is the interaction between the infrastructure (including the road, the road equipment and the whole roadside environment) and the road users. The key issue in this case is that the road succeeds (either by its layout, or by adequate signing) to communicate correctly to its users the necessary "messages" (figure 6.4), so that they would be able to use it effectively, in the least distracting and risk-generating manner. There are two main issues regarding self-explanatory roads (SER)[212]: the first issue is related to the degree to which the total design of road environment, including road layout, contributes to creating a SER environment (through a process of prioritizing road accidents, followed by designing, choosing alternative measures to prevent these types of accidents and prioritizing, using multicriteria analysis – MCA). The second issue is related to the readability and understandability of VMS messages (through an analysis of existing VMS, the design of alternative VMS, as well as the design of new VMS. Mantena [213] suggested the application of SER to the following roads (figure 6.5).

Figure 6.4: VMS in SER road environments.

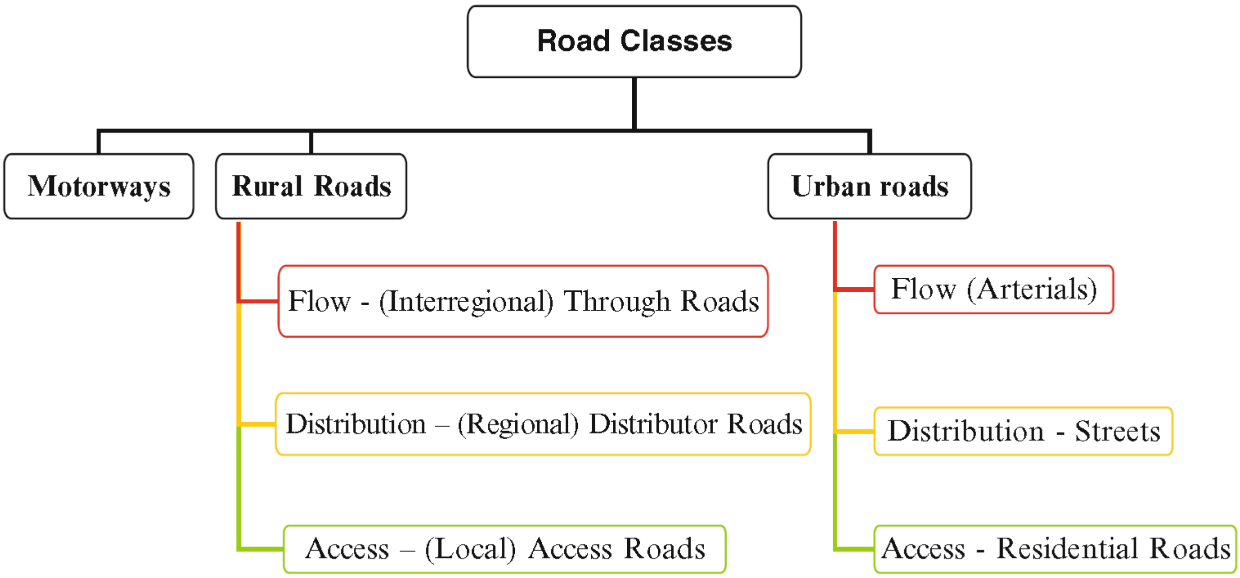


Figure 6.5: Suggested road classes for self-explanatory roads. [213]

All the users' have to cope with increasingly complex traffic environments, including different types of road layout and all kinds of signposting, of which an increasingly amount are already supported by telematics. The cases may impose a critical workload to the driver, as he/she may be:

- Striving to read the VMS (Variable Message Sign) message, while seeking the route in an unfamiliar environment (often in a foreign language and even with unfamiliar signs).
- Attempting to detect the required relevant piece of information among an abundance of information sources (like in-car navigation system, messages from traffic management and information centre (TMIC) or radio announcements, VMS signs, road signs, in-vehicle messages, etc.).

Thus, there is a considerable need for a self-explanatory road environment, preferably at a personalized level, which would offer intuitive guidance to the driver and information when this is needed, related to the driver's particular needs (route, disabilities, preferences, etc.) and, if possible, in the driver's own language of every nation.

6.2.2 Forgiving Roads:

By definition a forgiving road is that which is designed and built in such a way as to interfere with or block the development of driving errors and to avoid or mitigate negative consequences of driving errors, allowing the driver to regain control and either stop or return to the travel lane without injury or damage.

As everybody makes mistakes, drivers will eventually keep doing erroneous maneuvers or actions. Over 80% of accidents are related to driver's error. The Forgiving road environments constitute a basic tool in preventing or mitigating an important percentage of road accidents related to driving errors. More specifically, statistics show that about 25–30% of fatal accidents involve crashes with fixed roadside objects. Those accidents are mainly caused due to driving errors that lead to lane/road departure. The existence of a forgiving road environment would have prevented accidents of this type (and generally accidents that involve driving errors) and/or reduced the seriousness of the consequences of such accidents.

To develop a forgiving road environment certain characteristics must be included and measures should be taken, involving either the infrastructure itself or the use of telematic and in-vehicle systems, which will support the driver in case of an error. Those systems, in contrast to traditional and autonomous ADAS (Advanced Driver Assistance Systems), will not only support the driver by providing an adequate warning, but will supplement the road infrastructure. This, for example, can be achieved by simulating a rumble strips sound or using other haptic warnings, when the driver involuntarily crosses the road marking, over speeds or initiates an erroneous overtaking.

IN-SAFETY project (http://www.insafety-eu.org/) of Europe from 1/01/2005 until 31/12/2007 devised the measures for forgiving road environments (FOR) aiming to avoid or mitigate the negative consequences of driving errors, starts with listing possible driving errors to be supported. IN-SAFETY project [214], where four levels of driving errors have been identified and relevant measures (table 6.1) have been proposed for each error category:

1. Accident type errors: result of the execution of an error (e.g. collide with other vehicle).
2. Driving errors: action that leads to an accident (e.g. inappropriate speed).
3. Human error: psychological process that forms the basis of a driving error (e.g. incorrect evaluation of speed and distance).
4. Psycho-physiological condition: condition that can influence the underlying psychological process (e.g. fatigue).

Measure error	**In-vehicle**	**Infrastructure**	**Co-operative (based on vehicle infrastructure and vehicle-to-vehicle communication and cooperation)**
Speeding in an unexpected bend on rural roads	Navigational aid	Variable message sign (VMS)	Electronic beacons, providing in-car info, merged into on-board navigation.

Over-speeding (in general)	Speed alert system by speed sign recognition	Vehicle detection systems (VDS)	Speed alert, based on digital maps, updated by road beacons.
Wrong use of road	Lane departure warning system	Audio lane warning delineation	Adaptive Lane departure warning systems (LDWS)
Violation of priority rules	In-vehicle traffic sign recognition	Electronic traffic signs	Traffic light status emitted to the car
Overtaking failure	Blind spot detector	Rumble strips	Vehicle-to-vehicle communication
Insufficient safety distance	A frontal warning system	VMS with fog warning	Adaptive frontal warning systems

Table 6.1: Errors and measures for FOR and SER measures [215]

It is obvious that for the FOR and SER environment, the application of emerging technologies is striking task to integrate human-vehicle-infrastructure interface. To warn and better guide of the drivers are also important to avoid the imminent dangerous situation. Now-a-days Information and communication technology (ICT) applied in transportation engineering and this system of transportation is called Intelligent Transportation System (ITS).ITS is a much diversified arena. The detailed application of ITS in road transportation safety will be addressed next.

6.3 ITS - THE ADVANCED TECHNOLY OF ROAD SAFETY:

6.3.1 Definition

In the 1980s, a small group of transportation professionals recognized the impact that the computing and communications revolutions of the Information Age could have on surface transportation [216]. The idea of ITS—originally intelligent vehicle-highway systems—was born Intelligent Transport Systems (ITS) is considered as an umbrella term for a number of electronic, information processing, communication, and control technologies that may be combined and applied to the transport domain. Intuitively any ITS must show at least some form of information processing, computing, or vehicular or road network control to be considered intelligent. ITS may refer to a single technology, an integrated system, or a network of systems. "ITS is neither a monolithic system, nor the integration of systems rather ITS is a multi-faceted approach for addressing transportation needs". [217]

ITS serves a lot functions in a number of ways. They may interact with a single user or vehicle, or influence an entire road network. ITS can be used to improve traffic safety, traffic flow and capacity, public transport and commercial vehicle efficiency and productivity, and reduce vehicle emissions and resource consumption. While the potential for ITS to enhance the environment and economic productivity is promising, perhaps the greatest impact ITS has is in the improvement of the safety of road users. For the specific aim of enhancing occupant protection, or the protection of vulnerable road users many systems have been developed.

In literature it has been estimated the potential for ITS to enhance safety. For example, McKeever [218] estimated that 26% of fatal and 30% of injury crashes could be prevented with total system wide deployment of in-vehicle, infrastructure-based and cooperative ITS systems in the US. A report of OCED (2003) [234] conservatively predicted that full deployment of ITS in OCED countries could result the prevention of up to 47,000 fatalities, the reduction of fatal and injury crashes by up to 40%, and estimated annual crash cost savings of $194 billion US. The savings from fatal crashes alone were expected to be $73 billion US. Likewise, Intelligent transportation system in Eupore, ERTICO (www.ertico.com) (1997, cited in Rumar, et al. [219]) proposed a future vision of ITS in which the following predictions were made:

- ITS will significantly contribute to a 50% reduction in road fatalities.
- 25% reduction in travel times for the application of ITS.
- 50% reductions in city centres due to traffic management systems
- 15% reduction in fatalities due to Automatic Crash Notification.
- 40 hours per road user saved due to automated tolling systems.
- 50% delay reductions due to public transport priority systems.
- In case of fleet management systems, 25% reductions in commercial vehicle operations costs due to application of ITS .

Others have estimated the potential of ITS to influence certain crash types. For example, it has been suggested that systems which address lane-change, rear-end and off-path crashes have the potential to prevent 1.1 million crashes (17% of all crashes) in the US annually (FHWA) [220]. European Communities (2000) [221] reported that a reduction in the magnitude of 120,000 fatalities and serious injuries per year can be expected with occupant protection (passive) systems. McKeever [218] estimated that system-wide deployment of infrastructure-based ITS systems in the US has the potential to reduce the total number of fatal crashes by 11.2% and injury crashes by 14.4%. The systems included in this analysis were traffic (freeway) management systems, incident management systems, automated enforcement (speed and red-light cameras), signal control, rail crossing systems and weather information systems. Cooperative systems were estimated to have the potential to reduce the total number of fatal crashes by 4.3% and injury crashes by 1.7% with system-wide deployment in the US. The systems included in this analysis were in-vehicle navigation systems, automatic crash notification, intelligent speed adaptation, and electronic screening, which are cooperative systems.

While the overall effects of ITS on road user safety are difficult to assess at this early stage, it is possible to investigate the impact of individual systems or small classes of ITS. However, given the large number of ITS systems that are currently commercially available, there is a disproportionate lack of evaluative literature regarding their actual safety benefits. As most ITS are relatively recent developments in transport safety, in most instances there has not been sufficient time or market saturation to accurately assess their impact. At present, numerous studies have estimated the potential of ITS to reduce crash risk and severity, while others have investigated their benefits is simulator studies, test-track trails or naturalistic driving studies. The current study will report these findings.

6.3.2 Taxonomy of Intelligent Transport Systems

Intelligent transport system (ITS) can be divided into nine subject fields [222]:

•*Traveler Information*: Facilities to support traveler decision making before and during a trip: which travel mode to use, starting time, specific route, etc.
•*Traffic Management*: Management of traffic flow on roads.
•*Demand Management*: Services to reduce traffic demand on roads and congestion in city centers by charging for road use and promoting use of other travel modes.
•*Road Management*: Physical maintenance of roads and pavements, including repairs, snow clearance, etc.

•*Advanced Driving Assistance*: Automated systems to improve the performance of the vehicle and the driver to make driving safer.
•*Electronic Financial Transactions*: Services to allow automatic electronic payment of tolls and fees, primarily on roads and bridges, but also to enter restricted city centers and sometimes to pay for parking charges, drive through meals, etc.
•*Commercial Vehicle Management*: Services to support fleet and freight management, including fleet management and automatic safety and credential checking at borders
•*Public Transport Management*: Services to improve the convenience and performance of public transport, such as schedule management and common fare payment mechanisms
•*Incident and Hazard Response*: For the better respond to accidents and other emergencies such as dispatch of ambulances, fire trucks, etc services are provided by ITS.

According to the application the need for ITS may differ from event to event. The flexible application of ITS is important. A series of approaches to meet the needs of the operators and end users of the transportation system – meeting these needs responsively is more important than adhering to strict categories above. Considering the application perspectives, ITS may be categorized several ways, referring either to the physical location of the system, the timing of the effects of the system, the means by which the system enhances safety, or the transport domain to which it is applied. One of the broadest and most common classifications regards the positioning of the system, which are: whether system is in-vehicle, infrastructure-based or cooperative given below:

Vehicle-based systems: These refer to technologies based within the vehicle. In-vehicle safety technologies primarily include on-board sensors that collect data and on-board units (OBUs) (figure 6.5) 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. Excessive reliance on the OBUs of drivers is sometimes lead worse conditions, which may be avoided by proper awakening of the extent of the system is able to reduce the dangers.

Infrastructure-based systems: The essential components of Infrastructure-based safety systems are 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 related to infrastructure-based systems is that the supplied data should be standardized to improve understanding of drivers.

Co-operative systems: Co-operative safety systems utilize both infrastructure-based and vehicle-based systems with communication links between them. This communication may be one way, e.g., where the vehicle receives information(*e.g.* speed limits, traffic and road conditions) from the infrastructure but does not transmit information in return, or two-way where the vehicle both sends and receive information to another vehicle or infrastructure-based system. 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.

Figure 6.6: On Board units (OBUs) in Car

1"On Board Units" (OBUs) includes mini-computers, which are the size of a car radio, supply all relevant data via a GPS-supported satellite tracking system, e.g. the exact position of the respective vehicle. This provides drivers with the maximum possible transparency and the good feeling of always knowing about traffic related information.

ITS applications are considered also from the safety point of view as follows:

Active Safety Systems: ITS may be considered crash avoidance technologies. That is, they serve to prevent a crash from occurring. Active systems continuously monitor an aspect of the performance of the user, vehicle, road environment or transport network, and either alert the user/s to potential danger, intervene with the driving task to avoid danger, or automate part of the driving task.

Passive Safety Systems: Passive systems may be considered crash mitigation or minimization technologies. They serve to enhance the safety of the driver or other road users by minimizing the severity of a crash once it has already occurred. A clear example of passive systems is airbags, pretensioner etc.

Combined Passive and Active Systems (CAPS): This is relatively a new concept. It describes systems that monitor the road environment, vehicle and/or driver for potential danger (the active components), and then applies passive safety measures when a crash has been deemed to be unavoidable. At this point, CAPS systems are only in-vehicle and vehicle to vehicle.

The above classifications described are able to encapsulate all currently available ITS systems. They are not mutually exclusive – indeed they can be combined to further distinguish ITS, e.g., in-vehicle active systems, in-vehicle passive systems and in-vehicle CAPS systems.

6.4 ITS - ENABLING TECHNOLOGIES:

An intelligent transportation system (ITS) encompasses a wide range of emerging technologies to advocate the current and future needs in traffic safety and management. Here some of the basic technologies are overviewed only as their subjective features not in detail mechanical and functional architectures. Digital maps, Sensors and communication technologies are the heart of the ITS technologies and discussed below.

Digital Maps

Map is a graphical representation of natural and man-made objects that surround us. As such it provides a "natural" mechanism for the visual presentation, and quick assimilation by the viewer, of situational information such as traffic density and speed, and travel routes.

The use of maps spans many centuries and their availability is responsible for the exploration of the World by the Portuguese, the Spanish, and other European nations during the 15th, 16th and 17th centuries. Early maps were drawn on clay tablets, and in some cases engraved in stone, e.g., the Yii Chi Thu of llth century A.D. China. Later they were drawn on softer and lighter materials such as papyrus, vellum, and parchment and, more recently, on paper. With the advent of digital computers came the creation of digital maps. [223]

The contents of a digital map can be categorized into two fundamental data types: (1) graphic data and (2) nongraphic data. Graphic data are digital descriptions of map features used to re-create the map either on a display device or on paper. Six types of elements are typically used to depict map features and their associated annotations, namely points, lines, areas, grid cells, pixels, and symbols. Nongraphic data on the other hand are representations of the characteristics, qualities, or relationships of map features and geographic locations, often referred to as feature attributes.

Graphic data can be stored as either vector data or raster data. Vector data represent geographic features as points, lines, or polygons stored as a series of *x*, *y* coordinates. Points may be used to represent building locations; lines may represent roads or boundaries; and polygons may represent states or counties. To record and manipulate the logical relationships of map features and geographic information, use is made of a topological approach. The descriptive attributes of the vector data features are stored in a feature attribute table. The data are usually available in coverages, a coverage being a digital representation of a single layer in a map, such as streets, buildings, or counties. Two types of coordinate systems are typically used: Cartesian and latitude/longitude. The projection system used Universal Transverse Mercator (UTM) in U.S. and Europe. The latitude/longitude coordinate system records angular measurements relative to the equator and the Greenwich Prime Meridian, and is compatible throughout the world. Raster data divides a geographic area into a uniform, rectangular grid of rows and columns. The intersection of a row and a column is referred to as a cell. Each cell corresponds to a geographic area on the surface of the Earth. Two types of raster data are available: grids and images. Grids are typically used to store elevation data in the form of digital terrain models (DTM) or digital elevation models (DEM). In the case of image data, the cells are called pixels.

Vector data in general requires considerably less computer mass memory for storage than raster data does, and with recent improvements in graphic display hardware, it is enjoying considerably more use in ITS applications than raster data. Digital maps find application in traveler information systems, traffic management systems, commercial vehicle operations, public transportation systems, and rural transportation systems. In these areas, they are used for data display, navigation, and fleet management.

Sensors

Critical to the implementation of each technology area of ITS is sensors. Three key sensor technologies in particular will be exploited that owe their development to the defense industry, viz., GPS, image processing and radar. Sensor applications that relate to their use on board the vehicle for such items as driver assistance, vehicle health and safety to those sensors used outside the vehicle for controlling and monitoring traffic flow, and measuring environmental conditions are shown below:

In-Vehicle Systems	**Off-Vehicle Systems**
<u>Driver Health</u> Drowsiness Detection-Capillary Pulse Line of Fixation-Image Processing <u>Driver Assistance</u> Roadsign Reading-Image Processing <u>Driver Awareness</u> Collision Avoidance Obstacle Avoidance Lateral Location <u>Vehicle Navigation</u> Water Temperature/Pressure Oil Temperature/Pressure Fuel Level, etc. Emission Detection Acoustic Emission Detection <u>Vehicle Security</u> Vehicle Location Smart Wheels <u>Law Enforcement</u> Electronic Tachographs and In-vehicle recorder	<u>Traffic Flow</u> Inductance Loop Detectors Magnetometers Microwave Ultrasound Video Image Processing <u>Environmental Conditions</u> Road Surface-Capacitance, Temperature Visibility <u>Heavy Goods</u> Weight-Fibers, Load Cells License Plate-Image Processing <u>Automatic Toll Collection</u> Smart Cards <u>Law Enforcement</u> Speed Sensors - RF Image Processing <u>Driver Assistance</u> Pavement Bar-Codes(PBS)

Table 6.2: Sensor needs in intelligent transportation systems [223]

All the on board sensor needs relate generically to safety, navigation, vehicle security and vehicle health. In the area of driver's health, research in Japan is on going to use capillary pulse sensors as an indication of the driver's attention, and they are exploiting the driver's line of fixation to not only sense the driver's state but also to integrate it into other traffic awareness sensors as a safety measure.

A special section is reserved later for image processing working with a TV camera or an Infra-red (IR) camera, because that sensor technology offers the potential to be exploited in many areas both in on board vehicle and off vehicle applications.

Radar technology applied to vehicles fall into three categories, (1) forward looking, (2) side looking, and (3) rear looking. The forward looking radars can be used for either intelligent or simple cruise control or as a safety device to warn of rear-end type crashes with the vehicle in front. The side looking radar is useful for forewarning of objects in the vehicles blind spot while lane changing. The rear looking radar is similarly useful for forewarning of obstacles in the path when the vehicle is in reverse.

The proposal of ***Harmonic Radar System*** is widely accepted now-a-days. The system involves the fitting of passive harmonic reflector “tags” to the target objects which are to be detected by the “search” vehicle. These objects may be roadside hazards or the rear of other vehicles. The “search” vehicle has an antenna fitted at its front which emits radar signals and receives reflected signals from “tags”. By measuring certain characteristics of the returned signal the unit is able to compute the distance ahead to the “tag” and the differential speed between the ‘search” vehicles and the object being detected. In the context of driver behavior concept, the harmonic radar system can be used as:

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

In the area of vehicle navigation, the biggest single impact sensor is the GPS system and the development of the inexpensive GPS receivers. It is one of the most enabling sensor technologies that is applicable to many facets of the ITS program is the Global Positioning System (GPS). GPS was a US$l0 billion program pioneered by the Department of Defense to provide worldwide position, velocity and time data to military forces around the globe. GPS was envisioned, from the very first, to be a dual use technology and is regarded as the epitome of that model. It has been so successful a program that it has changed the way we navigate and determine location forever.

The impact of GPS on navigation systems throughout the world is marked. Krakiwsky [224] notes that of all the techniques used in 136 navigation systems identified between 1975 and 1993, GPS is the first with 56%, dead reckoning is second with 49%, and then comes map matching with 25%, terrestrial 19%, sign post 15% and inertial 2%.

The ***electronic tachographs*** have been developed which are more versatile, reliable and tamper proof than the earlier paper tape devices. Advocates stricter controls of the trucking industry have looked to these devices as a means of policing driver observance of regulations. The underlying assumption in proposal to use tachographs is that stricter enforcement of regulations will result in fewer crashes. Tachographs are often used in Germany to investigate and punish speeding. This practice was approved by the German high regional court in the 1990s. Also, after an accident, the discs are often examined with a microscope to discover the events that took place at a collision site.

The ***in-vehicle recorders*** have been advocated as a means of gathering information about the events leading up to crashes. These devices would operate in the same manner as the in-flight recorder box in modern aircraft. The assumption is that drivers would be less inclined to ignore speed limits if they know that their driving is being recorded.

Sensor technologies outside the vehicles are exploited principally to measure traffic flow, roadway conditions, monitoring of the commercial vehicles and emergency operations. Inductance loop detectors and magnetometers have dominated this field. These sensors are inexpensive but costly to install and replace. They are embedded in the asphalt of the road. Apart from the cost of the installation, there is an associated cost of the traffic delay while the device is being installed. To estimate the condition of road surfaces, capacitance and thermal sensors are being embedded in the road. From the capacitance, a measure of the salt content on the road can be estimated leading to an estimate of the freezing point of the road surface. When this is coupled to the temperature measure, an estimate of the potential slippery nature of the road can be established. Another application of image processing can yield estimates of visibility. Visibility and condition of the road surface will provide warning of hazardous driving conditions. In the area of aiding commercial vehicles, experiments are on-going to measure their weight while the vehicle is in motion, so-called WIM or weight in motion. The success of such experiments will reduce the number of hours such commercial vehicles waste standing in line at weigh stations as well as the fuel they waste, and the pollution they generate. Such “weight” sensors exploit either piezoelectric, bending plate technology, or fiber optic principles. As an adjunct, automatic license plate recognition or automatic vehicle identification (AVI) and automatic vehicle classification (AVC) again exploiting image processing will reduce the need for weigh station delays.

The radio frequency (RF) smart card appellations are growing almost daily in all areas of our life. These cards are either active or passive according to whether they carry their own power source or whether they are powered by rectifying the RF from the interrogation source. They consist of a small antenna, an electronic integrated circuit (normally complementary metal–oxide–semiconductor, CMOS) and a battery (for active cards). They are physically small of the order of a credit card or smaller, and have a normal range of around a few meters. Information can be transferred to the interrogator remotely and at high speed. In large quantities, these electronic RF cards are inexpensive. We will see them used for automatic toll collection again obviating the, need for toll booths which slow traffic causing loss of time, fuel and increase in pollution levels.

Many applications are now using radio frequency (RF) technology to automatically identify objects or verify the identity of people. These RF-enabled applications range from tracking animals and tagging goods for inventory control to enabling secure payment and identification. While these applications all use radio waves to communicate information, the RF technology used for each has different operational parameters, frequencies, read ranges and capabilities to support security and privacy features. For example:

RFID tags and labels: These are used to add value in manufacturing, shipping and object-related tracking. They operate over short to long ranges (e.g., from inches to 25 feet), were designed for that purpose alone and have minimal built-in support for security and privacy. (Figure 6.7A)

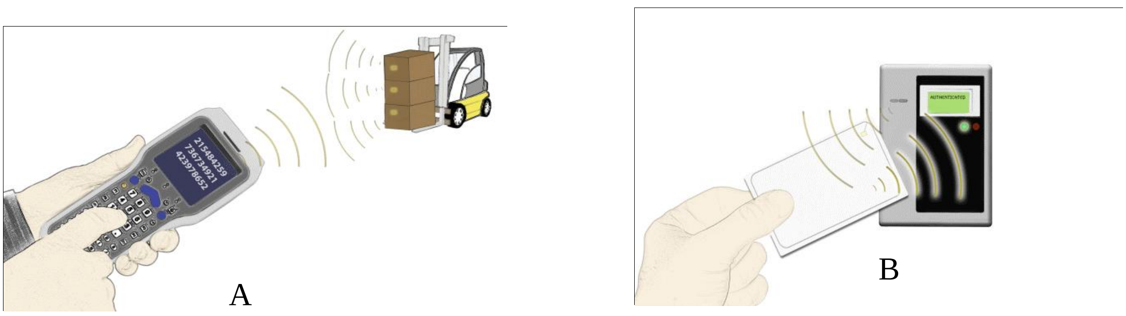


Figure 6.7: RF Smart Cards

RF-enabled smart cards: On the other hand, this card use RF technology, but, by design, operate at a short range (less than 4 inches) and support a wide variety of security features for critical applications (figure 6.7B). This technology is also referred to as "contactless smart card technology."

Another important technology is the use of ***Pavement Bar codes (PBC)*** painted on the roadway was first proposed by Tasani Pty. Ltd, provides a means of transferring information to a vehicle for display to the drivers. This system requires a scanner under the vehicle to read the bar-code painted on the road pavement. An alternative approach would be to place the bar-code marking on the vehicles and to use roadside scanners to record the identification number – from the bar code- of vehicles found. Potential applications for PBC are to:

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

Communication technologies:

Communication is the "glue" that will hold ITS together. Traffic counts may be taken, vehicle locations established, and road conditions detected, but if this data cannot be disseminated to interested parties, then all the sensing and data gathering effort is of no value. At opposite ends of the communication-alternatives spectrum, we find two options for disseminating the data, namely:

(1) the sensors can transmit the data collected directly to the end-user, and
(2) the data can be collected at some central location, where it may be processed and then disseminated to the end-user.

The communication framework would accommodate both wide-area and short-range data transfer. Wide-area communication includes either wireline or landline and wireless two-way communication technology. Short-range communication would be wireless. A simple broadcast capability would be used for one-way dissemination of highway traffic advisories. These public service broadcasts would be via radio, TV, and highway advisory radio (HAR). Variable message signs (VMS) would inform drivers of alternate routes. Telephone, cellular and personal communication services (PCS), as well as computer networks, would be used to disseminate travel information. The land lines include telephone and fiber optic cables. Mobile elements, i.e., vehicles, would use a wide range of options that allow l-way and 2-way communications. Wireless broadcasts would provide a low cost means for the uniform distribution of limited traffic data over a wide area. Cell-based communication would offer l-way and 2-way information exchange. Beacons, which are short range communication devices, would offer l-way and 2-way communication between the vehicles and the road infrastructure to convey position or location specific data. These beacons would be based on the use of infrared, millimeter wave, and microwave communication technologies.

Two types of mechanisms are in use for delivering data over a network, be it land-based or wireless. They are circuit switching and packet switching; see Figure 6.8. Circuit switching is exemplarized by the common telephone call, i.e., a connection is established first, and then data is transmitted over the connection. This is referred to as a *connection mode* of operation. In this mode the network establishes a session, monitors its progress, and when completed it terminates the call.

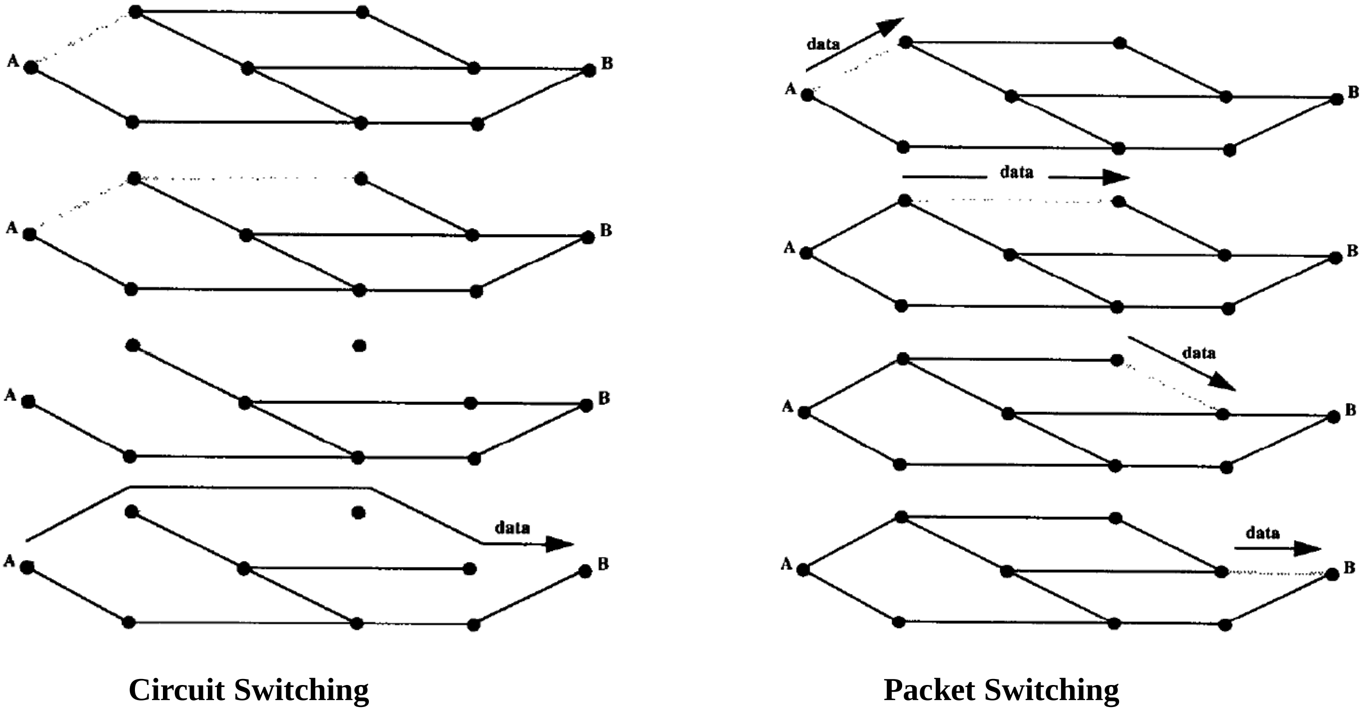


Figure 6.8: A connection oriented (circuit switching) network needs an end-to-end connection before data is sent; a connectionless oriented (packet switching) network sends data packets from node to node until they reach their destination.[223]

Packet switching, on the other hand, can be compared to sending a letter by mail, a page at a time. The letter is first separated into individual pages at the origin, mailed, and then reassembled at the destination. In the terminology of networks, a message is broken into data packets, the packets are then sent across the network perhaps following different paths depending on the link congestion, and finally the packets are collected and reassembled. This is referred to as a *connectionless mode* of operation. In this situation the network is also responsible for addressing the packets and packet flow control.

In general & communications for ITS can be classified into three broad categories: local, regional and wide-area. The media used may be land-based or wireless. In most cases it is a combination of both technologies.

At the local level the communication technologies found are: inductive loops, infrared (IR) beacons, microwave beams, and radio frequency transmission. Inductive loops provide a coupling between the underside of a vehicle and the road surface. These systems operate typically in the range of 50 to 150 kHz, using a two-way full duplex communication link. The amount of data that can be transmitted is typically small due to the short communication range of the system and the vehicle speed. An example of this type of communication is the HAR used by many cities in U.S. to convey traffic information to the driver via the in-vehicle radio unit.

Regional communication coverage ranges from several hundred feet to several miles, and operate at very high frequency (VHF) and ultra high frequency (UHF). Examples of these are the pager and cellular networks. Route guidance systems such as SOCRATES [225] use cellular radio data transmission.

Wide-area communication services distances in excess of ten miles from the transmitter, typically in a broadcast mode of operation. One example of this type of communication is the radio data system (RDS) which uses an FM subcarrier frequency to transmit data to the vehicle. The information sent may be traffic updates similar to those provided by a HAR system, or GPS corrections for use by a differential GPS (DGPS), vehicle navigation system. Satellite communication is the ultimate example of wide-area communication.

Hybrid Communications which integrate land-based and wireless communication technology so as to provide the user with both mobility and high data transfer rates. The result is colloquially known as wireless digital networks. These networks operate in the 900MHz region of the spectrum. However, they have special attributes of their own. To ensure proper transmission of the data to and from a vehicle that is constantly moving from cell site to cell site, the network requires the use of protocols which break large amounts of data into data packets. The data packets are reassembled at the receiving end. The RAM Mobile Data network use the MOBITEX (www.mobitex.com) system developed by Ericsson, and the ARDIS network uses a system developed by Motorola. The MOBITEX system is a public, trunked, land-based, mobile radio system originally developed as part of a mobile alarm system for the Swedish Telecom Radio field personnel [226]. The network was first placed into operation in Sweden in 1986, and since then similar systems have been built in Norway, Finland, the Netherlands, the United Kingdom, the United States, and Canada; Australia and France have systems under development. The network is a packet switching or connectionless network consisting of radio base stations, local and regional switches, and a network control center. The radio channels are shared by all the network users.

A common architecture of vehicular networking is shown in figure 6.9. It consists of (1) on-board units (OBUs) built into vehicles and (2) roadside units (RSUs) deployed along highways/sidewalks, which provide facilitates both vehicle-to-vehicle (V2V) communications between vehicles and vehicle-to-infrastructure (V2I) communications between vehicles and RSUs. Via wireless communication links, each vehicle communicates with nearby vehicles in a highly dynamic ad hoc networking environment. Traffic-related information can be exchanged via V2V communications (e.g., through periodic beaconing) to allow drivers to be better aware of surrounding traffic conditions. In case of emergency, event-driven messages can be generated and disseminated to the vehicles in the zone of danger (or zone of relevance, ZOR) [227]. Information sharing and gaming can also be supported through V2V communications.

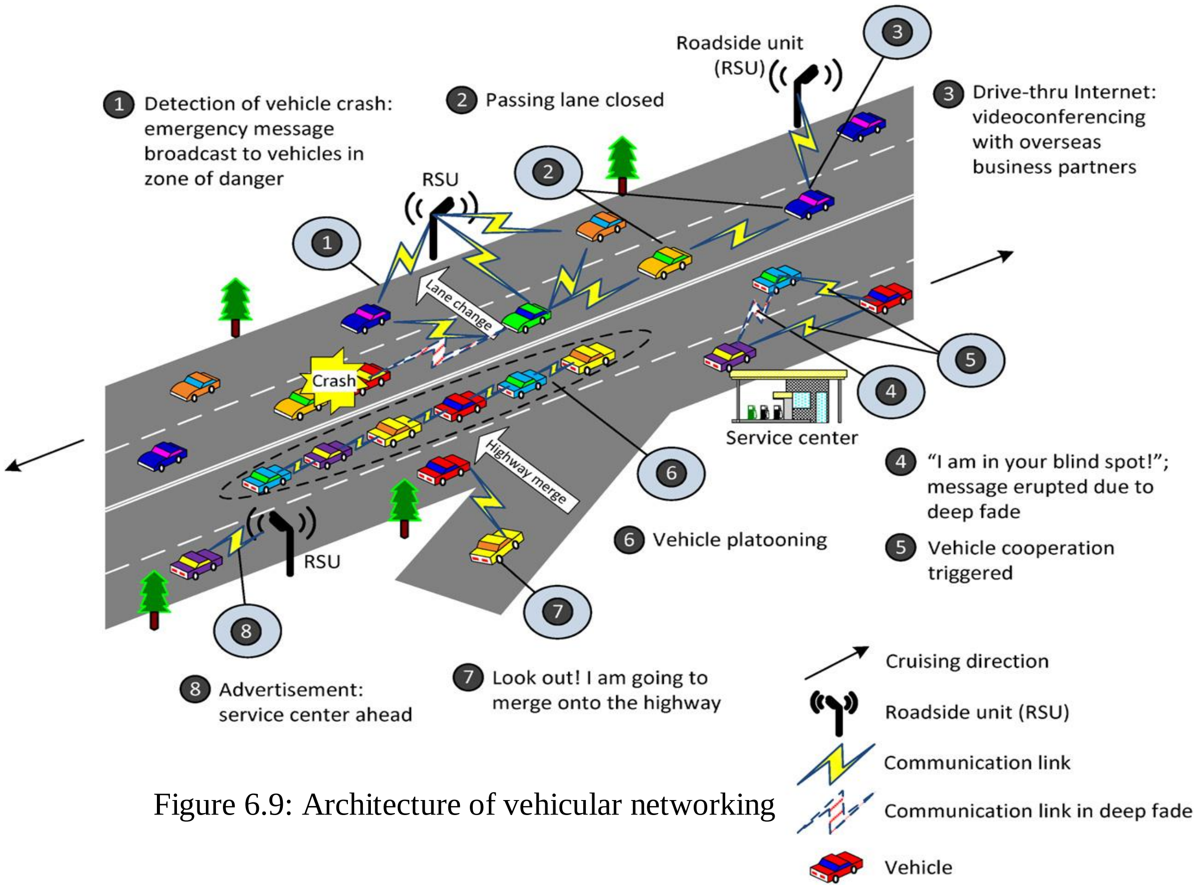


Figure 6.9: Architecture of vehicular networking

In U.S. for communication-based safety and infotainment services, the Federal Communications Commission (FCC) has allocated 75 MHz of licensed spectrum at 5.9 GHz as the dedicated short range communication (DSRC) band for ITSs [19]. In Europe, different frequency bands are used for vehicular communications, for instance, unlicensed frequency band at 2010–2020 MHz is used in Fleetnet [229]. Recently, the European Telecommunications Standards Institute (ETSI) has also allocated a radio spectrum of 30 MHz at 5.9 GHz for ITSs. To increase spectrum utilization and improve quality-of-service (QoS) (e.g., network throughput, packet dropping rate, end-to-end delay, fairness, etc.), multiple channels are expected to be employed in vehicular communications. Location information of vehicles is generally available, thanks to the global positioning system (GPS). End-to-end paths for information delivery can then be established via location-aware V2V and/or V2I transmission. In short, this emerging vehicular networking paradigm is expected to enable a plethora of communication- based automotive applications in the near future, ranging from seamless inter-vehicle video streaming to road traffic monitoring to collision warning/avoidance.

6.5 APPLICATIONS OF ADVANCED TECHNOLOGIES IN ROAD SAFETY

For the improvement of both active and passive safety, the application of modern technologies is very important. Those technologies relate both vehicles and infrastructures independently and as a whole.

6.5.1 In-vehicle systems

Advanced Vehicle Control Systems (AVCS) involve the use of a variety of sensors, computers, and electromechanical actuators to control the engine/transmission, brakes, and steering system of a vehicle. The concept of an automated vehicle was first displayed at the General Motors' Futurama exhibit during the 1939 World's Fair in New York where it attracted considerable interest [223]. Now-a day's extensive works are continuing to enhance in-vehicle systems related to road safety.

6.5.1.1 Active Systems

6.5.1.1.1 Active Front Steering (AFS)

AFS is advisable for both of Commercial and passenger type of vehicles. Active front steering (AFS) automatically adjusts the steering input required from the driver to suit the current speed and road conditions. The system adjusts the ratio of the steering transmission depending on the speed and geometry of the road. At low speeds, the ratio is ratio is lower, or more direct, so that the vehicle is more 'agile' when maneuvering. At high speeds and when cornering, the steering system becomes stiffer, so that the vehicle is more responsive to less driver input. AFS reduces the need to cross the arms over when cornering, and reduces steering effort by up to one third while increasing vehicle stability and responsiveness while driving. (www.delphi.com).
AFS system involves a mechanical link between the front and rear wheels. Vehicle factors such as steering input, speed, yaw rate, lateral acceleration are constantly monitored to determine the appropriate steering ratio for the current driving conditions. AFS works in conjunction with hydraulic or electric power steering systems. AFS also augments Electronic stability control (ESC), reducing the need for ESC action and giving more control over the vehicle trajectory to the driver. In this sense, ASF has an intervening function, where the system corrects over steering situations of drivers. Off-path on straight crashes, off-path on curve crashes, maneuvering crashes are effectively minimized [230].

Figure 6.10: Active Front Steering

6.5.1.1.2 Active Rollover Protection (ARP)

The system of Active rollover prevention (ARP) serves to avoid rollover crashes by adjusting the braking pressure and engine torque distributed to the vehicles individual wheels. Rollover situations are imperceptible to drivers until the rollover has actually begun, in which case a crash is largely unavoidable. ARP augments the electronic stability control (ESC) by monitoring the tilt of the vehicle. As in ESC, vehicle speed, traction and yaw rate are continuously monitored, plus the vehicles centre of gravity. ARP is typically only applied to vehicles with a higher centre of gravity, such as vans, sports utility vehicles (SUVs) etc. When the vehicle approaches a rollover threshold of lateral acceleration, i.e. when cornering rapidly, the system applies additional torque and/or braking pressure to each wheel individually. This maintains contact between all wheels and the road surface. The system may also include an in-vehicle unit that informs the driver when a near rollover event has occurred [230].

6.5.1.1.3 Adaptive Cruise Control (ACC)

It is sometimes referred as intelligent cruise control. The system of Adaptive Cruise Control (ACC) serves to reduce driver workload in dense traffic. Bishop [231] refers to ACC as a “longitudinal control co-pilot”. ACC aids the user in maintaining a safe headway with the leading vehicle (figure 6.11). As in normal cruise control, the vehicle’s desired speed is preset by the user, and this is maintained by the system if the roadway ahead is unobstructed. Alternatively, a desired time or distance headway from the leading vehicle can be selected in some systems. However, if a leading vehicle is travelling at a lower speed than the user’s vehicle, or is located within the preset time or distance headway, the ACC system intervenes via braking pressure or throttle/engine torque control so that the headway increases. The system only intervenes if the current preselected speed or headway would lead to a likely collision. ACC may employ radar, laser or machine vision to continuously monitor the leading vehicle. Auxiliary detectors also monitor the speed, yaw and cornering rate of the vehicle to maintain tracking of the leading vehicle in the same lane when cornering. ACC prevents the rear-end crashes.

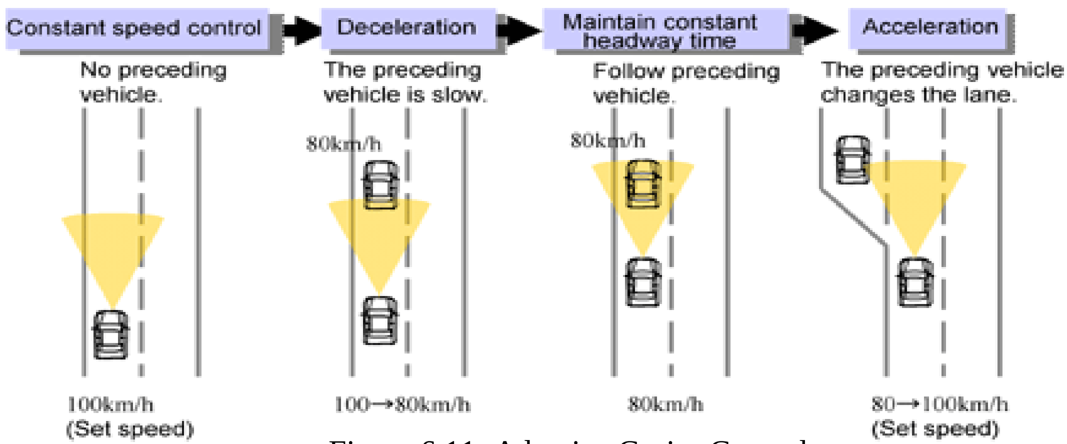


Figure 6.11: Adaptive Cruise Control

According to Abele, et al [23], the benefit-cost ratio is 0.9 for ACC in the year 2010. It was assumed in this study that ACC has the potential to rear-end collisions by 25%. A US study estimated that at speeds of 88 km/h and over, 5.2% of crashes rear-end crashes may be avoided with ACC, while at speeds of 48 km/h and over a 29% reduction was expected [233].

Another research suggests that ACC may reduce the incidence of all types of crashes by 5.9% [234], while in the report of OECD (2003) shows a decrease in all the injuries and fatalities by 1.4% and 0.7% respectively.

The inconsistencies in the effectiveness of ACC were reviewed by HUMANIST (2006) [278]. While some studies showed a reduction in maximum speed and speed variability and an increase in braking and accelerator pedal use, the associated reduction in driver workload was shown to result in driver inattention in other studies. Other negative findings included smaller minimum headways, greater speed, larger braking force, greater lane position variability and longer hazard detection reaction times are sometimes may happen.

Bishop [231] proposed that current ACC systems are only effective at speeds of 40 km/h or above, and do not exert sufficient braking force to prevent a crash should the lead vehicle slow very rapidly.

6.5.1.1.4 Advanced Driver Assistance Systems (ADAS)

ADSA can be applicable for all types of vehicles. It is designed to assist drivers to provide on-board information to avoid head-on, roadway departure, merging, overtaking and turning collisions. ADAS may serve a variety of functions: provide additional information to the user (as in ATIS systems); provide warnings of potential hazards; aid the user in avoiding potential hazards; or provide autonomous intervention to avoid potential crashes [235]. For this purpose, ADAS may deploy a variety of telematics and/or intervening and advisory active safety systems, such as navigation systems, curve speed warnings and forward collision warning and avoidance.

ADSA creates a human-machine interface (HMI) which combines information from in-vehicle devices and communication systems and presents these to the user in an unobtrusive visual and/or auditory form. It reduces the workload of the drivers allowing rapid detection of potentially hazardous situations.

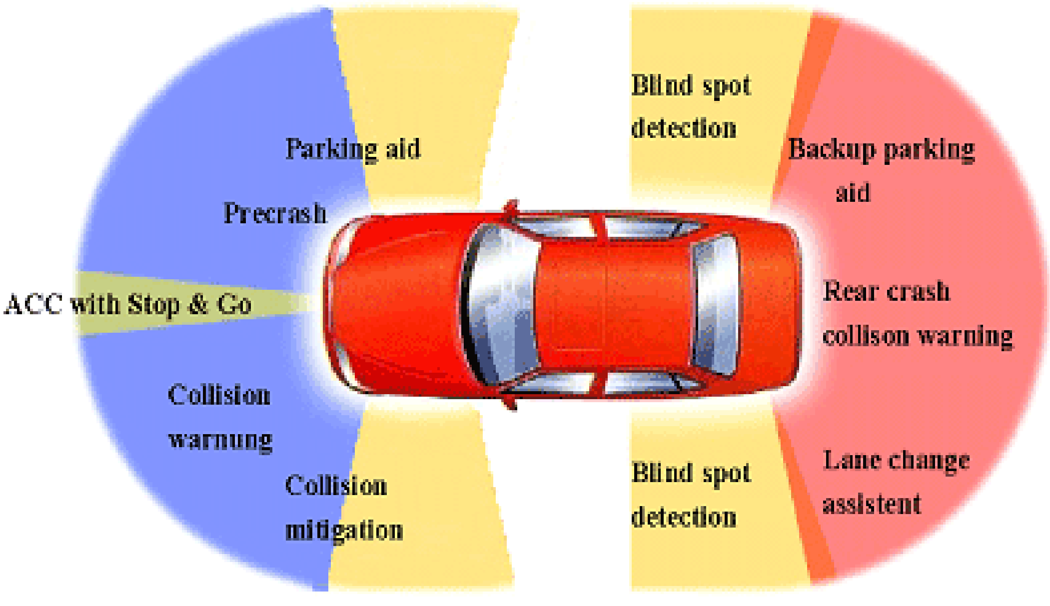


Figure 6.12: Advanced driver assistance systems

Figure 6.12 gives an overview of possible vehicular safety and comfort functions. Short range radar (SRR) is a key enabling technology for advanced driver assistance and safety systems. Vehicular radar systems operating in the 24 GHz range can support a variety of applications and functions to increase traffic safety and convenience. These devices provide exact measurement of distance and relative speed of objects in front, beside or behind the car that can significantly improve the driver's ability to perceive obstacles or dangerous situations.

It has been estimated that systems that provide advanced warnings and automate elements of the driving task, i.e. traffic signal detectors, automated windscreen wipers, have the 'verified' potential (based on the results of other studies) to reduce all road fatalities by less than 0.5%, while the 'full' crash reduction potential (an optimistic estimate based on full deployment) of ADAS was suggested to be 3% [236].

6.5.1.1.5 Alcohol Detection and Interlock (ADI)

It is applicable for all types of vehicles. The level of alcohol intoxication of the user is analyzed by the ADI analyses, and determine the fitness of the individual to operate the vehicle.

Alcohol interlocks are integrated into the ignition system of the vehicle, that's why vehicle is immobilized unless the user passes an alcohol detection test. Some systems may also require re-testing at continuous intervals while travelling [237]. The acceptable blood alcohol content (BAC) of the user may be set at zero, the legal limit for that region, or another predetermined level. Various forms of alcohol detectors and interlocks are available:

In-vehicle breath test: These are the most common interlock systems. The users blow into a tube connected to an in-vehicle unit which contains alcohol sensors, similar to what is used in roadside breath testing. If an excessive BAC is detected, the engine remains immobilized.

Key-based breath test: The breath testing unit is integrated into the fob of the vehicle keys. These systems are functionally very similar to in-vehicle tests; however the testing unit is more subtle, and therefore may be more acceptable to users. The alcohol detector is activated when the user unlocks the vehicle. The user blows into a small mouthpiece in the fob of the key. If the driver is under the prescribed BAC the engine is mobilized otherwise not. In the cold temperature the system is less likely to be activated.

'Sniffer' systems: Within the ambient air of the vehicles cabin, these monitor the level of alcohol. In case of any alcohol detection, the system informs the driver that a breath test is required. If the driver refuses, or the test is failed, the system disconnects the electrical system of the vehicle within a set time frame. For the recidivist drink-driver, the 'Sniffer' methods are not designed. It is also known as 'passive' alcohol detectors. These systems do not require the user to provide a breath test every time the vehicle is being driven. Some systems require additional regular breath tests if the drivers' BAC is below the predefined limit,

Skin contact systems: ADI systems that analyze BAC through the hands in contact with the steering wheel have also been developed. In this system, the blood pressure, glucose and cholesterol are assessed whish eliminates the need for breath-testing. Even drivers wearing gloves comply with the systems. (Ivey & Lightner, 1995)[238].

Figure 6.13: Alcohol detection and Interlock (In-Vehicle breath test)

In the US, Canada and Sweden, show alcohol interlocks reduce the incidence of repeat drink-driving offences by between 40-95%, evidence cited by Kullgren, et al. (2005) [237]. Estimation of eSafety Forum [30], an approximate reduction of 70% penetration of the passenger vehicle fleet in Germany with alcohol interlock systems. It has been estimated that alcohol interlock systems could reduce the number of crashes associated with a BAC>0.05 by 96%, saving approximately $263 million (AU) per year. For males aged 18-24 alone, these systems were estimated to prevent 233 crashes and save $68 million (AU) annually. Depending on the effectiveness and acceptability of the system, it was estimated that up to 9% of all crashes would reduce in severity (i.e., fatal becomes serious injury, serious injury becomes other injury). Regan, et al. (2002) [240]

6.4.1.1.6 Animal Detection Systems

The system is useful to alert users to potential collisions with animals. This system relies on radars, lasers or other visual imaging techniques such as infrared sensors to detect the presence of animals on the roadway. These systems address crashes involving large animals, such as elk, deer, moose, etc. These systems need to be sensitive enough to detect moving objects, but still have a low rate of false alarms. The different characteristics of animals as opposed to pedestrians or vehicles, in terms of height, shape and speed means these systems have different technical specifications to other object-detection systems, such as forward collision warning and pedestrian detection. Another strategy involves vehicle-mounted whistles that emit an ultrasonic noise when the vehicle is travelling at high speeds. These variants of animal detection systems do not employ forward-facing sensors. The following figure 6.14 shows the detection system of Animal:

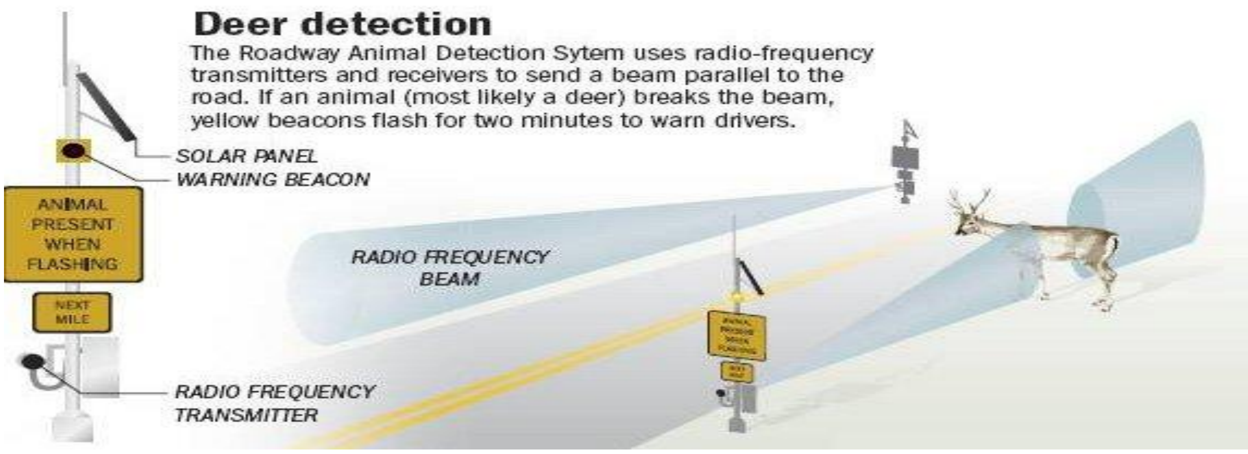


Figure 6.14: Animal detection systems

6.5.1.1.7 Anti-lock Braking System (ABS)

Anti-lock braking systems are applicable for all types of vehicles. ABS optimizes the braking performance of the vehicle, by maximizing the contact between the vehicles tyres and the road surface during forceful braking. ABS ensures smooth and constant braking pressure is applied, where the system continuously monitors and adjusts the braking pressure. ABS monitors the rotational speed of the wheels and releases the braking force if the wheels begin to lock. Braking force is maintained at the maximum pressure just below the threshold of the wheels locking. By preventing the wheels from locking and skidding during emergency braking situations, the driver retains control of the stability and path of the vehicle and stopping distances are shorter than if the vehicle skids.

ABS systems may be four-wheel or rear-wheel only. Rear wheel systems are typically only implemented in light commercial vehicles, while four-wheel systems are installed on passenger vehicles. ABS is applied to both wheels in motorcycles.

Crash relevance shows that ABS may be suitable to off-path crashes, sideswipe crashes, lane departure crashes, rear-end crashes, frontal impact crashes, and jack-knife crashes in commercial vehicles (NHTSA, 2000) [241].

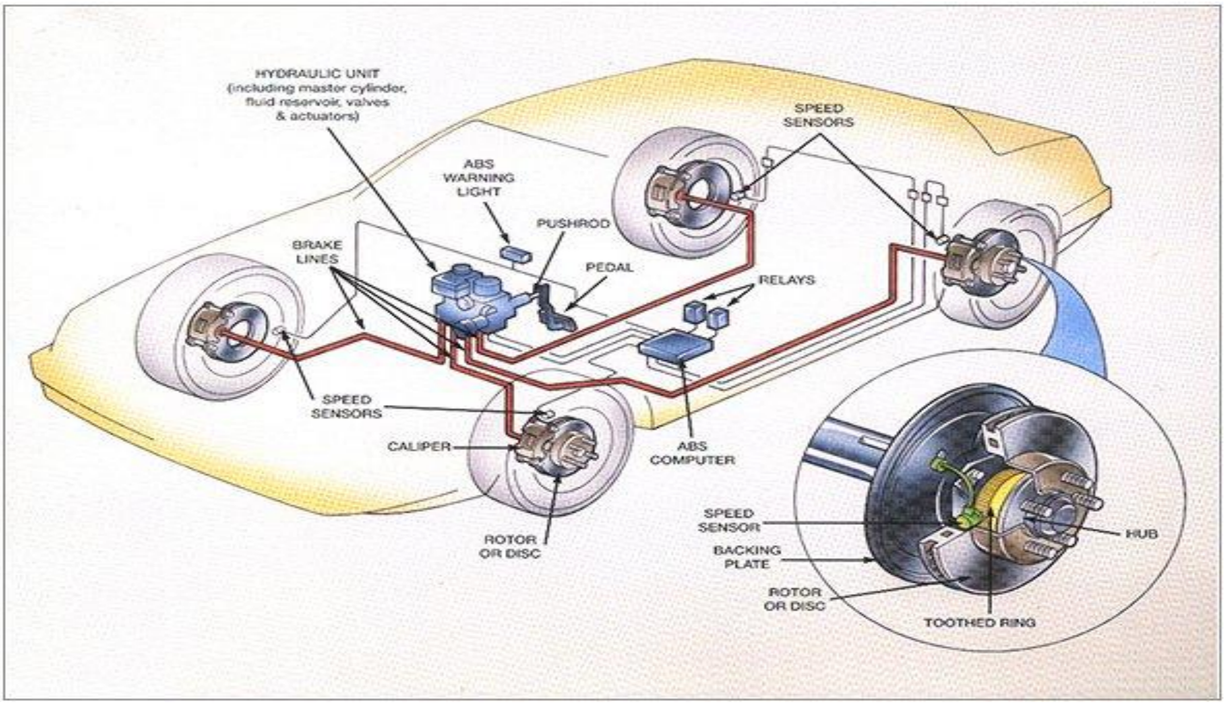


Figure 6.15: Anti-lock braking systems

Figure 6.15 shows the ABS assembly in a car. Paine (2003, cited in Paine, 2005) [242] estimated a benefit cost ratio of 0.83 for ABS in Australia. ABS reduces the multiple-vehicle crashes and pedestrian-vehicle crashes. ABS demonstrates greatest safety-enhancing benefits in wet weather conditions.

6.5.1.1.8 Automated Windscreen Wipers

Automated windscreen wipers activate the windscreen wipers when rain is detected on the vehicle’s windshield. These systems reflect infrared beams onto the external surface of the windshield. In dry conditions the reflection of the beams so maximal. However, when raindrops interrupt the beams, causing diffraction within the raindrops, this reflection is reduced proportional to the amount of water on the windshield. This allows the system to determine not only whether the windscreen wipers need to be activated, but also at what speed. These systems aim to reduce driver workload and eliminate the need for the user to take eyes of the road when activating and adjusting the windscreen wipers.

6.5.1.1.9 Brake Assist

The braking potential of the vehicle is maximized and reducing stopping distances by the Brake assist systems. It ensures user's with maximum braking force in case of an emergency. It provides additional hydraulic pressure to front and rear brakes when rapid and forceful braking pressure is needed. The threshold of what constitutes an emergency brake is predetermined by the system. Brake assist systems may either react to the speed or force with which the brake pedal is applied by the driver. Braking assistance works in conjunction with ABS, where the braking pressure from both the front and rear brakes are assessed, and an acceleration sensing unit automatically intervenes and applies maximum braking pressure in an emergency situation, while also preventing the brakes from locking.

There is also Anticipatory brake assist systems incorporating with forward scanning radar or other forward-facing sensors to detect objects or vehicles on the road ahead. If there is any possibility of imminent crash the system advocates the drivers braking response, brake assist will automatically be applied. These systems may also incorporate an in-vehicle warning that informs the driver when the system is active. Essentially, these advanced brake assist systems are pre-crash system. Indeed, this system can also be incorporated with in-vehicle passive safety measures, i.e. motorized seatbelts.

The system minimizes the crashes where braking is applied by the driver. Brake assist systems will be relevant to loss of control crashes, pedestrian crashes and multiple vehicle crashes (at both intersections and non-intersections) suggested by Page, Foret-Bruno and Cuny (2005) [243].

Busch (2004) [244] estimated that with 100% penetration of the German vehicle fleet, brake assist could result in the following safety benefits for various vehicle types and vulnerable road user (table 6.3).

Vehicle type	Reduction in fatality	Reduction in injury
Passenger vehicles	1.3%	5.1 %
Commercial vehicles	0.8%	1.7%
Motorcycles	1.3%	1.5%
Bicycles	12.6%	5.2%
Pedestrians	7.0%	15.9%
Total	3.0%	5.5%

Table 6.3: Estimated fatal and injury crash rate reductions in Germany for various road user types.

Mercedes-Benz (2004) [245] reported that vehicles with brake assist have 26% less crashes than those without in an emergency brake situation at 50 km/h.

Toyota incorporates the brake application into satellite navigation technology. Using GPS data and a rear-mounted camera, the system will acknowledge an upcoming stop sign and calculate whether the driver has applied enough brake force to stop in time, if not the system takes over bringing the car to a halt (figure 6.16). The typical GPS system in most cars is only accurate to around 15m, presumably this kind of technology would only be implemented on premium Lexus models where the high-end GPS software is accurate to within as little as 30cm.

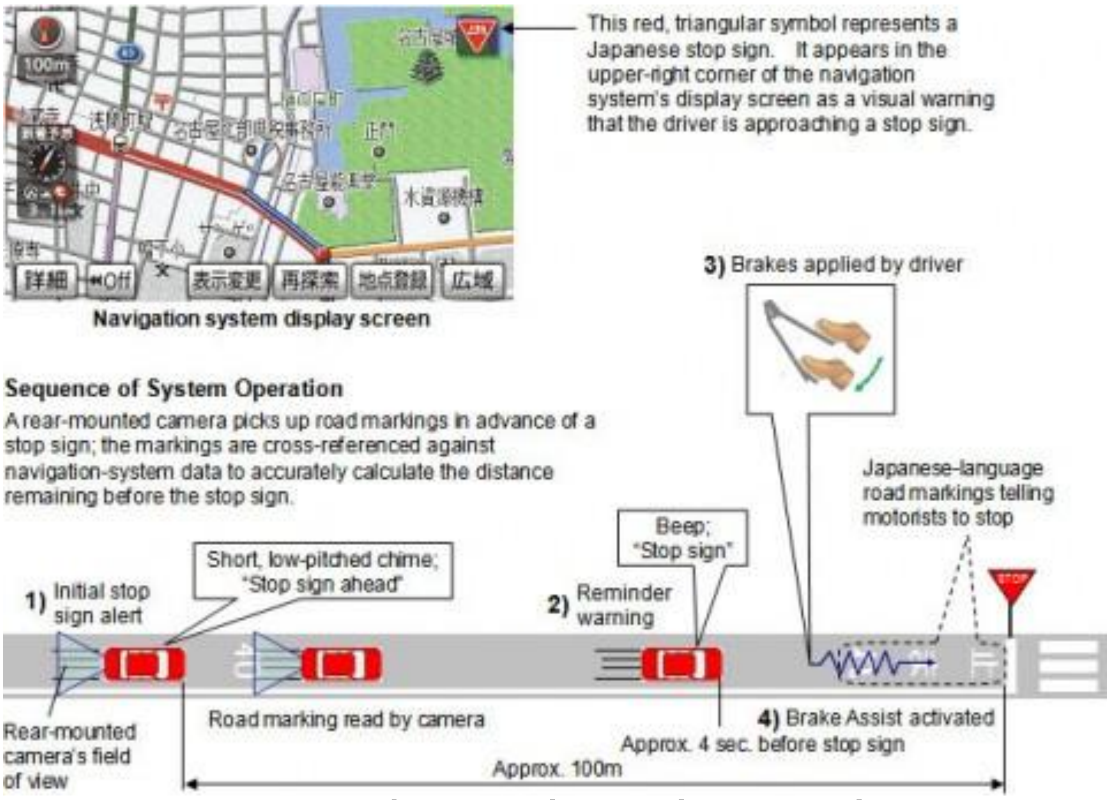


Figure 6.16: Brake-assist with GPS and rear mounted camera

6.5.1.1.10 Driver Vigilance Monitoring

This is also known as the Drowsiness Detection Systems; Fatigue Monitoring Systems; Driver & Vehicle Monitoring. It can be used for passenger and commercial type vehicles. These systems monitor the performance of the driver, and provide alerts or stimulation if the driver is determined to be impaired, and in intervening systems, take control of the vehicle and bring it to a stop. The driver is alerted to their impaired state, either through visual, auditory or haptic stimulus. The systems may monitor driver inattention and/or fatigue in a number of ways involving both the vehicle and the driver. These systems are often referred to as driver and vehicle monitoring systems, as they may monitor both driver and vehicle behaviour. Information can be gathered from driver input and control of the vehicles lateral position and speed, such as acceleration, steering wheel movement and lane position. Likewise, user behaviour such as eye movement, facial feature movement, brain waves (EEG) and steering wheel grip may all be monitored.

More sensitive systems may use a combination of these sensors (Olsson, et al., 2006) [246]. As Bishop (2005) [231] notes, the key to these systems is that they detect the early signs of drowsiness to allow the driver to effectively counteract this impairment. Regan, et al. (2001) [233] suggested that systems that monitor the user's eye movements, such as blinking behaviour, have perhaps the greatest potential to accurately detect drowsiness.

Drowsiness relieving systems are an extension of drowsiness detection systems. They detect and alert the user to fatigue lapses in attention in the same manner as drowsiness detection systems. However, as an additional function they actively attempt to increase the driver's alertness rather than just making the driver aware of their condition. This may be in the form of auditory alerts, vibration of the seat and/or steering wheel, or the release of fragrance into the driving cabin. Heitmann, et al. (2001) [347] suggested that haptic systems may be an effective way to maintain alertness in drivers.

For example, the Drowsiness Warning System equipped on Mitsubishi's Advanced Safety Vehicle (ASV) produces warning sounds, steering wheel and seat vibration, and a 'stimulating' fragrance if drowsiness is detected within the driver (Mimuro, et al., 1996) [248]. Nissan's ASV contains a similar system which emits a buzzing sound and 'refreshing' fragrance in order to alert the driver (Sugasawa, et al., 1996) [249]. The fragrance discharger can also be manually activated by the driver.

The system minimizes the crashes where driver inattention, fatigue or distraction is governing factor. A study of the ROSPA (Royal Society for the Prevention of Accidents) suggests that up to 20% of accidents on monotonous roads in Great Britain are fatigue related and could benefit from the driver drowsiness detection system. Moreover, truck driver fatigue may be a contributing factor in as many as 30% to 40% of all heavy truck accidents (2001). [250]

Estimations of the approximate reductions expected with lane driver monitoring systems in Germany (assuming 70% penetration of the passenger vehicle fleet) were reported by eSafety Forum [239]. It was expected that 50% of fatigue-related crashes would be affected, leading to a 35% reduction in these crashes. This would equate to a 2.9% reduction in all crashes.

By the estimation of Regan, et al. [241], a fatigue monitoring system could reduce 4% of all single vehicle crashes, and result in an estimated saving of $64 million (AU) annually. Depending on the effectiveness and acceptability of the system, it was estimated that up to 24% of fatal crashes would become serious injury and up to 26% of serious injury crashes would become injury crashes as a result of its use. Reductions in other injury and minor injury crashes were predicted to be up to 9.6%.

Acceptability and negative behavioral adaptation are important issues to driver vigilance monitoring systems. There is concern that driver vigilance monitoring systems will actually encourage users to continue to drive even when impaired, due to over-confidence in the system (OECD, 2003) [234]. Road users may be reluctant to accept vigilance monitoring systems unless they are totally reliable (Young, et al.; Regan, et al.) [241].

6.5.1.1.11 Electronic Brake Force Distribution

The system is applicable for both Passenger and commercial vehicles. Electronic Brake-force Distribution (EBD) is an additional component to ABS. EBD serves to prevent the vehicle skidding sideways during an emergency brake by adjusting the braking pressure to each side of the vehicle. This is different to ESC, as EBD is only applied when the user activated the vehicle's brakes. The system applied maximum braking force to the wheels that currently have the maximum grip. Emergency stopping situations that activate the ABS system will also activate EBD. It minimizes the crashes where braking is applied by the driver.

6.5.1.1.12 Electronic License

It can also be done by smart car system. It can be used all types of vehicles. Electronic licenses aim to decrease the occurrence of unlicensed vehicle operation or the use of a vehicle outside the conditions of their license. The license, or smart card, must be inserted into the vehicle to unlock the ignition system. Only valid licenses or cards which have been registered to that particular vehicle, will unlock the ignition of the vehicle. Smart cards are not legal licenses, but can be used to restrict and/or monitor vehicle use. These are commonly used in commercial vehicle operations (COV).

Electronic licenses also have the potential to be used to monitor and record the activity of learner or at risk road users (Faulks, Drummond & Rogers) [251]. Logs of driving/riding conditions, distances and durations could be recorded and collated as a means of ensuring learners gain experience in a variety of situations, or do not drive (or ride) outside their limitations. Electronic licenses can also be combined with a smart card ignition system. A wide variety of information can be stored on these systems, including traffic law violations and medical details.

Crashes involving unlicensed road users, or road users operating outside the conditions of their License are prevented with this system.

Lind, et al. [236] estimated that systems that restrict some individuals from operating vehicles (electronic licenses and alcohol interlocks) have the 'verified' potential (based on other studies) to reduce all road fatalities by 1%, while the 'full' potential (an optimistic estimate based on full deployment) is 5%.

According to Regan, et al. (2002) [240], electronic licenses could reduce the occurrence of crashes involving unlicensed drivers by 98%, with an annual predicted economic benefit of $134 million AU. Depending on the effectiveness and acceptability of the system, it was estimated that up to 8.1% of all crashes would be reduced in severity with the use of electronic licenses (i.e., fatal becomes serious injury, serious injury becomes other injury).

Rumar, et al. [239] suggested electronic licenses have an 'outstanding potential' to enhance road safety, as the issue of authorization and the individual ability of the user to operate the vehicle is addressed.

In Sweden, an electronic license system was developed which functioned as an ignition key. Goldberg [252][253] estimated that this system would prevent all unlicensed driving and reduce the instance of drink-driving by 60% as, in Sweden, 82% of intoxicated drivers that are involved in fatal crashes have been registered for previous offences, and half of these do not have valid licenses. Also, a number of unlicensed drivers may be under the influence of other illicit drugs. Goldberg [254] further estimated that throughout Europe and the US between 5,000-10,000 fatalities and 50,000 injuries could be prevented, saving $30-40 billion annually.

Regan, et al. (2001) [233] noted that acceptability issues associated with this technology should be considered. Road users may see electronic licensing as a 'big brother' device. Some motorists feel that an electronic license system must have additional identification features, such as fingerprint or PIN, and must be difficult to circumvent (Regan, et al.; Young, et al.) [240].

6.5.1.1.13 Electronic Stability Control

The system is applicable for passenger vehicles. Electronic Stability Control (ESC) is a system which serves to maintain control of the vehicle's trajectory when the vehicle looses optimum contact with the road surface. This may occur when cornering too fast, on poor road surfaces, or in emergency stopping situations. ESC continuously monitors traction, lateral acceleration, yaw data, steering wheel position and vehicle speed. Input from these sources is compared to that of normal driving conditions to determine whether the vehicle has, or is about to, loose control. Different braking pressure is applied to the effected wheel to prevent over or under steering. Engine torque to the relevant wheel is also reduced. When the ESC system intervenes, the driver is typically informed via a visual display on the dashboard.

ESC coordinates ABS and traction control systems (TCS) to provide greater control when cornering and braking. Any vehicle equipped with ESC always has TCS and ABS, but the reverse is not necessarily true. These systems control the yaw and tyre spin of the vehicle to prevent skidding and traction-less cornering, and allow maximum contact between the tyre and the road.

ESC uses the following sensors:

- steering angle sensor to detect position of steering wheel
- angular speed sensors to detect speed of each wheel
- yaw sensor to detect the movements on the vertical axis of rotation
- transverse acceleration sensor to detect the centrifugal forces during cornering.

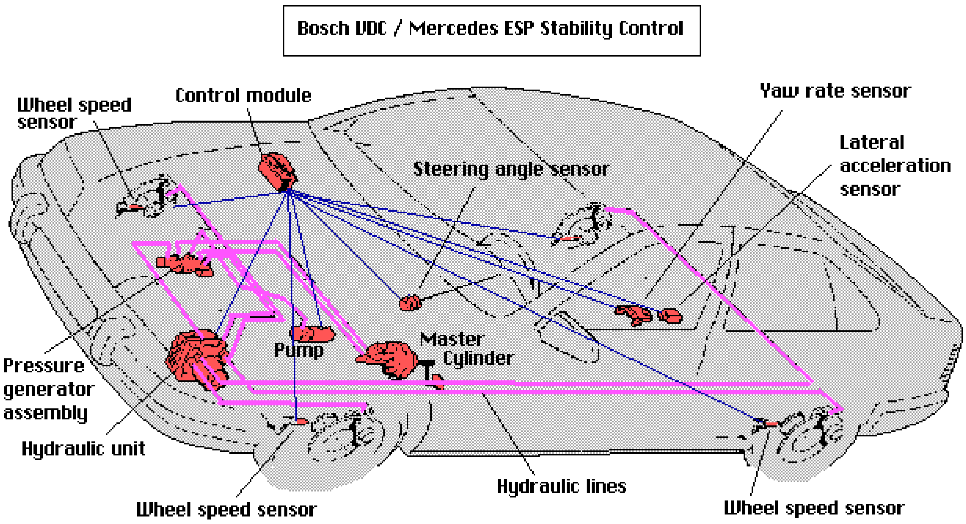


Figure 6.17: Electronic Stability Control (ESC)

ESC can correct under- or over-steering, stabilize the vehicle during emergency evasive maneuvers, and improve traction and handling on unsealed, icy or wet road surfaces (www.vicroads.vic.gov.au). ESC is standard on 40% of 2006 models of passenger vehicles and optional on a further 15% (IIHS) [255]. The proportion of SUVs with ESC as standard is growing more rapidly than in passenger vehicles. ESC has not been applied to motorcycles.

The Off-path on straight crashes; off-path on curve crashes; rollover crashes; crashes where speed and poor road surface are contributing factors are avoided by ESC.

The IIHS [255] has recently updated an earlier evaluation of ESC, suggesting that ESC has the potential to prevent almost one third of fatal crashes, and 80% of rollover crashes for SUVs and 77% for passenger cars. More than 40% of single vehicle crashes could be avoided with ESC – including 56% of all fatal single vehicle crashes. Multiple vehicle crashes were reduced by 59% for SUVs and 53% for passenger vehicles. Overall, ESC was associated with a 43% reduction in fatal crashes.

In a similar study, Lie, et al. [256] estimated that up to 20% of fatalities in Sweden could be avoided if all cars featured ESC. Even greater benefits were predicted by Sferco, et al. [257], who suggested that ESC would positively affect 18% of injury crashes and 34% of fatal crashes. Risk of loss of control crashes alone were predicted to reduce by 42% for injury and 67% for fatalities.

An extensive review of studies of the effectiveness of ESC estimated that, with full deployment in all cars, the number of fatal and injury crashes in Germany would reduce by 15-20% and 7-11%, respectively (Langwieder, cited in eSafety Forum) [239].

Farmer [258] investigated the effectiveness of ESC in the US over several. The following crash risk reductions were found for ESC equipped vehicles compared with non-ESC equipped vehicles. These reductions are presented in Table 6.4.

Crash type	Fatal crashes	All crashes
Single-vehicle	56%	41%
Multiple-vehicle	17%	3%
All types	34%	7%

Table 6.4: Expected crash risk reductions attributable to ESC for various crash types.

In Japan the application of ESC in Toyota reduces 35% in all single vehicle crashes, 50% reduction in ‘severe’ single vehicle crashes, a 30% reduction in head-on crashes, and 40% reduction in severe frontal crashes (Aga & Okada) [259].

6.5.1.1.14 Emergency Brake Advisory System

The system is applicable for both passenger and commercial vehicles. Emergency brake advisory systems serve to rapidly alert drivers when a leading vehicle is braking forcefully. A number of studies have shown that the likelihood of being rear-ended by a following vehicle actually increases when advanced braking systems such as ABS are implemented in vehicles (e.g., Evans & Gerrish) [51]. Emergency brake advisory systems activate the rear brake lights earlier in the braking process, allowing more time for the following vehicle to react. Rather than relying on pressure of the brake pedal to activate the rear-brake light, these systems detect an emergency brake via the rapid depressing of the accelerator. This decreases the time required to detect an emergency brake by milliseconds, increasing the potential reaction time of the following driver. Some emergency brake systems illuminate the brake lights with greater intensity to indicate an emergency braking situation to other road users (eSafety Forum; Lind, et al. [236] [239]).

It prevents rear-end crashes. Estimations of the approximate reductions expected with adaptive brake lights in Germany were reported by eSafety Forum [239]. This estimation assumed these systems achieved 70% penetration of the German passenger vehicle fleet. It was expected that 25% of rear-end crashes in moving traffic and 15% in stationary traffic would be affected, leading to a 14% reduction in these crashes. This would equate to a 1.5% reduction in all crashes. Mercedes-Benz [245] found a flashing rear brake light reduce braking reaction time by up to 0.2 seconds in following drivers, equating to a 4.4 metre braking distance reduction at 80 km/h, or 5.5 metres at 100 km/h (Daimler Chrysler) [261].

6.5.1.1.15 Following Distance Warning

Applicable for both commercial and passenger types of vehicles. Following distance warnings serve to assist the driver in maintaining a safe following distance between the motorcycle and the leading vehicle. Following distance warning systems monitor the time or distance headway between the current and lead vehicle, and issue an auditory or visual warning this distance is deemed to be unsafe. The system continuously monitors the gap between the vehicles via radar or laser and acceleration sensors. If this distance is breached, the system comes into effect issuing a visual or auditory warning, or intervention via automatic braking pressure. The current headway, in either time or distance, may be continuously presented on an in-vehicle display. Different levels of alerts of headway size (e.g., green, orange, red) may also be presented to the driver.

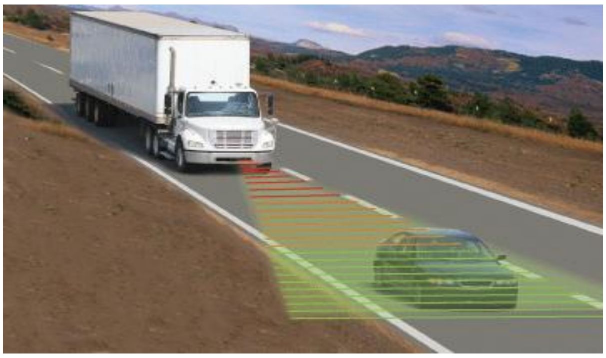


Figure 6.18: Forward distance warning

Suitable to minimize rear-end crashes; object crashes and crashes where fatigue or inattention are factors. Kullgren, et al. [237] estimate following distance warning and forward collision warning systems may be able to reduce the incidence of rear-impact crashes by 57%.

Harrison and Fitzgerald [262] estimated that following distance warning systems would result in the following reductions in rear-end related crash costs in Australia, presented in Table 6.5. This analysis assumed that 50% of the effects of the system would be the prevention of crashes, while the other 50% would be the reduction of crash severity (i.e., fatal becoming serious injury).

System type	Effectiveness	Penetration	Cost reduction
Warning	60%	100%	47%
	60%	10%	6%
Avoidance	60%	100%	44%
	60%	10%	7%

Table 6.5: Reduction in crash costs expected with following distance warning and avoidance systems in Australia.

Also, Young, et al. [263] found young drivers viewed FDW as potentially annoying in heavy traffic.

6.5.1.1.16 Forward Collision Warning and Avoidance

The system is applicable for both commercial and passenger type of vehicles. Forward collision warning systems monitor the roadway ahead and provide alerts to the user when upcoming hazards are detected. Alerts are issued if a stationary obstacle or vehicle moving slower than the user's vehicle is detected at a range close enough to be hazardous. These systems employ radar, laser, lidar and/or computer vision technologies to monitor the roadway. Information about steering wheel position and speed relative to the object ahead is monitored to determine whether or not the object is in the vehicles path, and whether a crash is likely. Warnings about obstacles are presented to the user via auditory or visual alerts or heads-up displays, and some systems may incorporate haptic feedback such as seat vibration or seatbelt tension (Bishop) [231]. Forward collision avoidance systems feature an additional active avoidance component. If a hazard is deemed imminent, automatic braking force is exerted by the system if the driver does not respond rapidly or forcefully enough to avoid a crash.

Rear-end crashes; head-on crashes; object crashes and Crashes where fatigue and/or distraction/inattention are factors are avoided by this system. McKeever [218] reported an estimated reduction in the number of fatal rear-end crashes in the order of 48% in the USA. Forward collision avoidance systems are expected to be applicable to almost 90% of all rear-end crashes, and have been estimated to prevent almost 50% of rear-end crashes in the US (FHWA) [220].

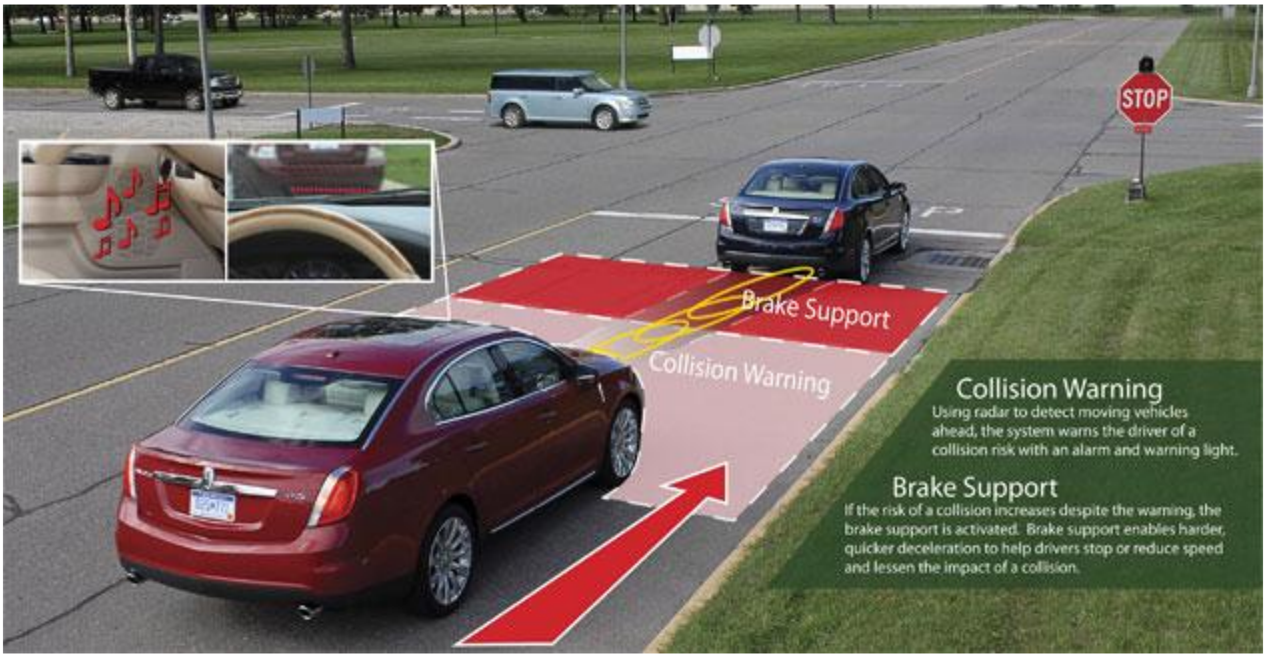


Figure 6.19: Forward Collision Warning

Paine [264] suggested forward collision warning systems could reduce 25% of crashes if installed in heavy vehicles.

Estimations of the approximate reductions expected with obstacle collision warning systems in Germany (assuming 70% penetration of the passenger vehicle fleet) was reported by eSafety Forum [239]. It was expected that 25% of crashes in longitudinal traffic would be affected, leading to a 12.5% reduction in these crashes equating to a 3.1% reduction in all crashes.
The False alarms or ‘nuisance alerts’ must be minimal in these systems to maximize driver acceptance and prevent drivers learning to ignore warnings (Regan, et al., 2001; Taylor & Khan, 2004) [233] [265].

6.5.1.1.17 Heads-Up Display
Heads-up display (HUD) project visual information to a position within the user’s field of view so that the display is visible to the user while they are looking at the road ahead. HUDs serve to ease

driver workload and minimize the need for the driver to take their eyes off the road to gather information from the instrumentation panel or consol. HUDs have been widely employed by the aviation industry and military. In vehicles, the display is projected onto the windshield (figure 6.20), typically at a focal point just in front of the vehicle, giving a floating appearance. This reduces the need to re-focus when glancing between the roadway and display, as there is less discrepancy in the focal length of the driving task and the display (Tufano) [266]. HUDs may also reduce mental workload, while improving reaction times, task efficiency, safety and enjoyment (Merryman) [267].It is applicable for all types of vehicles.

The content of the HUD may vary depending on what aspect of the vehicle it is integrated with. This may be information from the dashboard instrumentation panel, such as speedometer, RPM, fuel level, vehicle warnings and so on. Also, HUDs may be incorporated into other ITS technologies, such as collision warning and vision enhancement systems. The systems consist of a projector, a combiner, which reflects the images from the projector while allowing the road ahead to be seen, and an electronic circuit which controls the display information and brightness (Aono) [268].

Figure 6.20: Head Up Display

HUDs may show relevance to crashes where distraction/inattention are factors.

Watanbe, et al. [269] found that response times to warnings presented via a HUD varied as a function of the location of the display. HUDs located in the upper right and lower left of the field of view showed significantly response times than other display locations. It was also noted that the presence of HUDs did not significantly reduce reaction times to events occurring on the road.

Liu and Wen [270] found drivers responded to warnings presented on a HUD almost one second faster than when presented on a HDD in both high and low driving load conditions.
eSafety Forum [271] suggested that, assuming 70% penetration of the passenger vehicle fleet, 25% of crashes involving this system would be affected leading to a 17.5% reduction in these crashes, equating to a 0.1% reduction in all crashes (2001).

6.5.1.1.18 Helmet-Mounted Displays

This system is applicable for Motorcycle users. In order to enhance the availability of information to motorcyclists, additional visual displays can be presented to the rider via the motorcycle helmet. Helmet mounted displays (HMDs) are essentially heads-up displays integrated into the visor of the helmet. Information that is typically provided on the instrument panel, such as speed, fuel levels, RPM can be displayed with these systems, as well as information form other ITS applications of ISA. These systems eliminate the need for the rider to take their eyes off the road. Mini-projectors within the helmet superimpose visual displays over the riders viewing field so that the user does not have to adjust the focus of their viewing distance to see the display. The visual information can also be enhanced by auditory information.

Figure 6.21: Helmet-Mounted Displays

6.5.1.1.19 Intelligent Lighting Systems

The system is applicable for all type of vehicles. It minimizes the crashes where poor visibility is a contributing factor. Intelligent lighting systems may incorporate one or a number of technologies that serve to enhance the visibility of other road users, the road environment, and/or automate control of the headlights. Adaptive headlights improve the illumination of the vehicles path on curves and to suit varying speeds and road environments, while automated headlights control the activation of the headlight and/or high beam without driver input. Intelligent lighting systems may include the following system variants and functions:

Automated Headlights: Automated headlights automatically turn of the vehicles headlights when low ambient levels of luminance are detected. These systems aim to reduce driver workload and eliminate the need for the user to take eyes of the road when activating the headlights. Ambient light sensors monitor the luminance of the environment, and a control unit turns the headlights on if a minimum threshold of luminance is detected. The system differentiates the total level of ambient light, the frontal sources of light, and can distinguish different conditions such as tunnels compared with night time.

Cornering/Axis Controlled Headlights:

When cornering, traditional headlights illuminate the area directly in front of the vehicle, leaving the intended path of the vehicle dark. Sensors detect the vehicles speed and the rotation of the steering wheel and/or axles, and direct additional lighting to the left or right of the vehicle depending on the direction of the curve.

In motorcycles, the changing optical axis of the headlight that occurs when the motorcycle tilts when cornering creates reduced visibility, where the beam illuminates the shoulder, not the road. Vehicle speed and angular velocity sensors are incorporated with a rotating mechanism behind the headlight. The position of the headlight is adjusted in accordance with the speed and position of the bike, so that it maintains a horizontal axis that is parallel with the road surface. Adaptive headlights ensure that the illumination from the headlight is projected on the motorcycles intended path when banking.

According to Bishop, future cornering headlight systems will be cooperative, featuring satellite maps that inform the system of upcoming curves. This would allow pre-emptive adjustment of the auxiliary beam.

Figure 6.22: Cornering/Axis Controlled Headlights

Speed Adapting Headlights:

Headlight systems may also adjust the pattern of luminance to suit the vehicle speed (Bishop) [231]. The beam is projected downward and outward at low speed to increase the visibility of the road environment and road surface, and projected in a narrower, longer beam for faster speeds to allow greater viewing distances.

Auto-dimming Headlights:
Other intelligent headlight systems may automatically dim the high-beam headlights when oncoming vehicles are detected.

Lind, et al. [236] estimated that both adaptive headlight and vision enhancement systems have the potential to affect 30% of pedestrian fatalities and 15% of bicyclist fatalities in Sweden. It was predicted that by the year 2015 these systems will have resulted in reduce pedestrian fatalities by 15% and bicyclist fatalities by 8%. The 'verified' potential of this adaptive headlights (based on the results of other studies) to reduce all road fatalities was reported to be less than 0.5%, while the 'full' potential (an optimistic estimate based on full deployment) is 8%.

The expected effects of adaptive headlights in Germany were reported by eSafety Forum [239]. It was expected that, assuming 70% penetration of the passenger vehicle fleet, 25% of crashes involving vulnerable road users in low visibility conditions would be affected leading to a 17.5% reduction in these crashes, equating to a 0.1% reduction in all crashes.

Negative behavioral adaptation may occur with these systems, where drivers compensate for then additional visibility by increasing vehicle speeds (eSafety Forum) [239].

6.5.1.1.20 Lane Change Collision Warning and Avoidance

This system is advisable for both of commercial and passenger vehicles. Lane change systems serve to monitor the vehicles lateral blind spot, detecting vehicles that are located in this space and warning the user to their presence. The lateral field is monitored by short range laser, radar, lidar, computer vision or ultrasonic scanning techniques. Visual or auditory warnings are presented to the user when a vehicle is detected in this space. In order to minimize false alarms, the system should differentiate stationary objects that do not present a crash risk from moving vehicles in the lateral field. Some systems may delay the alert; so that overtaking vehicles are allowed time to pass. Other advanced systems may also monitor the road ahead, detecting oncoming vehicles that may present head-on crash hazards while overtaking [231]. Ultrasonic sensors or microwaves sensors, mounted on the lateral and rear areas of the vehicle, are the major technologies deployed in this case (figure 6.23).

Figure 6.23: HMI solution (rear view mirror leds) addressing Lateral rear area monitoring.

It reduces the side-swipe crashes.

Lind, et al. [236] estimated that lane change assistance has the potential to affect 20% of off-path fatalities in Sweden, and predicted that by the year 2015, these systems would reduce run-off road fatalities by 10%.

McKeever [218] estimated the predicted system-wide effects of the full deployment of numerous ITS on all fatal and injury crashes in the US. It was predicted that a 0.2% reduction in fatalities and a 0.7% reduction in injuries could be expected with lane changing systems.

Collision avoidance systems have been estimated to reduce the total number of crashes by 17%, resulting in an economic benefit of $25 billion US [217]. Also, the FHWA [220] estimated that these systems (with lane keeping assistance) could prevent 19,000 rural running off road crashes in the US and 52,000 crashes in urban areas.

Paine [264] suggested lateral collision warning systems could reduce 16% of heavy vehicle crashes and 6% of bus crashes.

The eImpact project suggested that the introduction of the “Lane changing assistant” system would achieve the following crash severity reductions (2005).

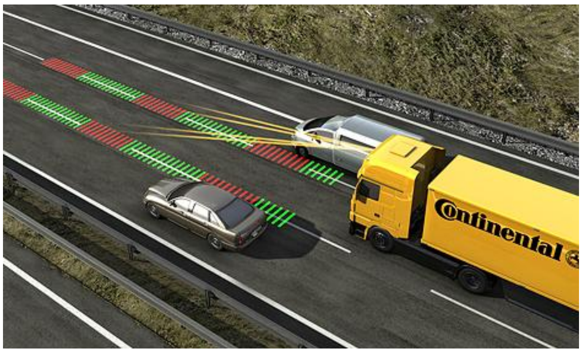
- Head-on collisions: 25% reduction in accident severity
- Left roadway accidents: 15% reduction in accident severity
- Side collision accidents: 10% reduction in accident severity

6.5.1.1.21 Lane Departure Warning and Control

The system is applicable for all commercial and passenger type of vehicles. The system reduces the Head-on, off-path on straight; off-path on curve; sideswipe crashes and crashes where fatigue or inattention/distraction are factors.

If a truck strays out of its lane, a critical situation can easily arise. In fact, official statistics show that one in five accidents involving commercial vehicles is the result of a sideways collision. Lane departure warning systems monitor the position of the vehicle relative to lane markings and features, and provide alerts to the driver should the vehicle deviate from the lane. The lateral position of the vehicle may be monitored with laser, radar or video monitoring of the lane edge markings ahead and to the side of the vehicle. The vehicle's position and course is monitored via steering wheel movement. Feedback is provided to the driver through visual, auditory or haptic signals, such as a 'rumble strip' noise effect on the side appropriate to the lane deviation. This only occurs if the vehicle begins to drift, not when direct steering wheel force or indicators are used in deliberate lateral movement. Controlling systems also involve corrective steering movements that maintain a correct lane position.

Detection of lane edge markings is a complex process, particularly on curved or unmarked roads. This can be achieved with sophisticated computer imaging and processing, or in a cooperative fashion that uses GPS, digital maps, or magnetic markers embedded in the road. The most common types of systems employ monochrome video cameras mounted to the front of the vehicle and image processing technology (Bishop) [231]. Lane markings of various patterns, widths and lengths (for broken lines) are recognized by these systems. The vehicles lateral position relative to these features is continuously monitored. Lane Departure Warning (LDW) detects the lane up to 40m ahead of the vehicle with a camera, optimized for this specific application.



Standard rumble strips give auditory feedback to non-alert drivers, leading to reduced crossing of the line (Rasanen) [272]. On motorways they are used as countermeasure to fatigue induced accidents and on rural roads as centre lane marking to discourage overtaking.

Figure 6.24 Lateral area monitoring and information presented to the driver in a truck

Lane departure warnings in heavy vehicles were expected to reduce the total number of heavy vehicle crashes by 10% (eSafety Forum) [239].

Estimations of the approximate reductions expected with lane departure warning systems in Germany (assuming 70% penetration of the passenger vehicle fleet) were reported by eSafety Forum [30]. It was expected that 25% of injury off-path crashes would be affected, leading to a 17.5% reduction in these crashes, equating to a 2.9% reduction in all crashes.

Lind, et al. [236] estimated that lane departure warnings and lane keeping assistance have the potential to affect 40% of off-path fatalities in Sweden, and predicted that by the year 2015, these systems would reduce run-off road fatalities by 20%.

Regan, et al. [240] estimated that around 5% of single vehicle off-path crashes and sideswipe crashes would be avoided with lane departure warning systems, resulting in an economic benefit of $3.3 million (AU) annually. Depending on the levels of effectiveness and acceptability of the system, it was estimated that lane departure systems could lead to up to 30% of fatal crashes becoming serious injury and up to 30% of serious injury crashes becoming injury crashes. Reductions in other injury and minor injury crashes were predicted to be up to 12%.

Young drivers tend to be reluctant to accept the intervening function of lane departure systems (Young, et al.) [263].

6.5.1.1.22 Lane Keeping Assistance

Lane keeping assistance (LKA) systems actively support the driver in maintaining lane position. These systems monitor the vehicles lane position with image processing technology in the same manner as lane departure warning systems. LKA provides additional torque to the steering wheel, which increases the resistance in the steering wheel. This makes it more difficult for the vehicle to drift, therefore reducing the occurrence of minor variations in lane position. This minimizes the need for the driver to make small corrections in lane position, which as Bishop [231] notes can be, a source of fatigue in long journeys on highways. LKA systems are typically only active at high speeds and on relatively straight roads. If sharp corners are detected (i.e. through frequent steering input from the driver) the system will disengage. Additionally, the system requires continuous driver steering input to ensure the driver is remaining vigilant and attentive.

In combination with an electric intervention in the steering LDW becomes an active Lane Keeping Assistant (LKS). A smooth recommendation in the steering is another warning to the driver but the driver's decision takes priority at all times. Through these system interventions important seconds are gained which can save lives, especially when at the edge of the verge. Because of a legislative initiative this type of system may become obligatory for all new commercial vehicles registered within the EU as of 2013.

This system reduces the crashes where fatigue and distraction/inattention are factors.

The eImpact project suggested that the introduction of the "Lane keeping assistance" system would allow the following accident and severity reduction (2005).

- Head-on collisions: 25% reduction in accident severity, 25% reduction in related accidents

- Left roadway accidents: 15% reduction in accident severity, 25% reduction in related accidents
- Side collision accidents: 10% reduction in accident severity, 60% reduction in related accidents
- The percentage of accidents where this system is relevant is about 19.5%.

6.5.1.1.23 Linked Braking Systems

The system is advisable for Motorcycles. Linked braking systems serve to maximize the stopping potential of the motorcycle. The independent action of the front and rear brakes of motorcycles can result in a failure to achieve maximum deceleration. One of these braking systems, usually the front, tends to be under-utilized by the rider. Linked braking systems automatically apply braking pressure from both wheels, where both the front and rear brakes are applied when only one of these is manually activated by the rider. These systems can also be combined with ABS, allowing greater vehicle control and stability as well as improved braking force. [230]

6.5.1.1.24 Parallel Parking Assist

The system is applicable for both passenger and commercial vehicles.Parallel parking assist is a semi-automated system which aids the user in reversing the vehicle into a parking space. Bishop [231] describes the only currently known system of this type, modeled on the Toyota Prius at the ITS World Congress in Madrid, 2003. A rear-mounted camera and image processing system monitors the position of the vehicle relative to the desired parking space. The user informs the system of the location of the parking space by manually positioning a rectangle over a touch-screen image of the view behind the vehicle. The user remains in control of the acceleration and braking of the vehicle while the system automatically steers the vehicle into the desired position. The user must manually finish the parking maneuver when the vehicle is placed in forward gear. Earlier models of parking assistance systems have employed vocal prompts to guide the user into the parking space, but have not involved automated steering control. It minimizes the parking crashes.

6.5.1.1.25 Pedestrian Detection Systems

According to recent studies (SCANIA 2009) [273], around 30% of all deaths related to accidents with heavy vehicles involved are pedestrians and two wheelers, also denoted as vulnerable road users. The sheer number of vulnerable road users who died in Euro-15 during 2007 was a staggering 15,000, with at least 150,000 more being injured. Measures to reduce these figures for the vulnerable road user are necessary.

The system of pedestrian detection system is applicable for all types of vehicles. Pedestrian detection systems aim to detect the presence of pedestrians that are in close enough proximity that a crash is likely. These systems may employ video, laser, radar or infrared sensors to detect the presence of foreign objects in the path or periphery of the vehicle. Detection of moving pedestrians in a cluttered visual field is a challenge for any such system, as they may vary in height and width (depending on their physical size or orientation to the vehicle) as well as speed. Also, the sensors must be powerful enough to detect the object with enough time for evasive action to be taken, with a minimal risk of false alarms. The sensors used in this technology must be able to differentiate the characteristic shape and movement patterns of pedestrians of all sizes. It must also be able to recognize pedestrians when they are partially or temporarily completely obscured by objects in the road environment. The system must also be able to do this while the vehicle itself is moving. The system reduces the pedestrian crashes.

Figure 6.25: HMI of the onboard VRU detection system.

Thus, significant technological advances are expected before a full scale market deployment of such systems. Prototype systems seem to enhance the detection rate up to 80 m but still up to limited vehicle speed. The best commercial performance of such a system seems to be to detect a pedestrian in a range of 5–25 m, and up to 4 m lateral, in real time, for a vehicle speed of up to 40 km/h (operating at 7–15 Hz).

6.5.1.1.26 Rear-Impact Countermeasures

The system is applicable for both commercial and passenger vehicles. Rear-impact countermeasures have been developed to reduce the incidence of rear-end crashes involving buses, although they also are applicable to passenger vehicles and other commercial vehicles. Buses may be rear-ended when making stops along routes where other vehicles would not normally be stopping. Other driver inattention is often a factor in this (Bishop) [231]. In order counteract this inattention or inappropriate driving behavior; rear-impact countermeasures employ sensors (lasers or radar, etc) to monitor the area directly behind the vehicle. If another vehicle is detected within this space at a distance that is incompatible with the bus’s current speed, visual warnings (such as flashing or moving patterns of lights) are presented to the driver of the other vehicle in order to attract their attention (Burns) [274].It reduces the rear end crashes.

Burns [274] found that drivers behaved less riskily, braked sooner and required less braking when following two buses that had been equipped with a flashing light bar. This system was effective in reducing aggressive closing behavior in other drivers.

6.5.1.1.27 Rear-View Displays

The system is applicable for all types of vehicles. Rear-view displays provide greater visibility of the road environment directly behind the vehicle to the driver. A rear-facing camera projects a view of the road and traffic behind the vehicle to a display system, providing a superior view than what is shown by rear-view mirrors. This technology may be in-vehicle or helmet mounted (for motorcyclists). Some rear-view displays for passenger vehicles may only be active when the vehicle is reversing.

Helmet-based systems incorporate both the camera and the display into the helmet itself. The camera is built into the helmet to avoid compromising its structural integrity. The visual display is projected to the top portion of the visor, above the frontward view of the road. This system does reduce some of the visual field, although it does remove the need to look away from the road.

The rear-end crashes; side-swipe crashes, parking crashes are minimized with the application of this system.

6.5.1.1.28 Reverse Collision Warning System

This system is applicable for both passenger and commercial vehicles. Reverse collision warning systems may employ a range of proximity detection sensors (ultrasound, radar or laser-based) or video cameras (rear-view displays) to detect objects behind vehicle when reversing. These systems typically have a range of around 15 feet, and are able to detect slow moving and stationary obstacles within this range and alert the user to their presence. These systems provide warnings to the driver that are typically auditory.

Reverse collision warning systems are relevant to reversing or parking crashes, where the vehicle is travelling in reverse at low speeds. There are two types of backing crashes (Dingus, et al.) [275]: encroachment crashes, which involve stationary or slow moving objects in the reversing vehicles path, and crossing path crashes, where a vehicle or other obstacle collides with the reversing vehicle.

The parking crashes; emerging crashes (when reversing) are reduced by this system. Lee and colleagues [276] found reverse collision systems that provided early warnings to the user reduced backing collisions by 81%, while systems that provided late warnings resulted in reductions of 50%.

Current systems are limited by a compromise between range and accuracy. The greater the range of the system's sensors, the greater the rate of false alarm warnings. Also, small and irregularly shaped objects may be more difficult for these systems to detect (Regan, et al., 2005) [277]. Regan and colleagues also expressed concern that these systems will lead to negative behavioral adaptation effects.

6.5.1.1.29 Road Departure Warning and Avoidance Systems

The system is applicable for both commercial and passenger vehicles. Road departure warning/avoidance systems share similarities with lane departure systems. However, road departure systems typically incorporate curve speed warnings and object collision warnings. Visual imaging, GPS, and long- and short- range radar sensors monitor the vehicle's position in relation to the lane and road edge markings, upcoming curves and obstacles in the road environment. If the vehicle's speed is deemed to be too fast for an upcoming curve, or if the vehicle begins to drift laterally out of the road way, warnings and/or intervention from the system occur. This may be in the form of auditory, visual or haptic alerts, or corrective steering or braking control. Road departure systems are able to detect features and objects in the road environment and adjust warnings accordingly (Bishop) [231]. For example, drifting from the laneway on a wide shoulder would induce a less urgent response than drifting on a roadway with parked cars along each edge.

The off-path on curve; off-path on straight crashes and crashes where fatigue and inattention are factors are reduced.

The FHWA [220] suggested that if road departure avoidance systems were 65% effective, 296,000 crashes could be avoided annually in the US, while these systems may be relevant to approximately 38% of all road departure crashes.

McKeever [218] estimated the predicted system-wide effects of the full deployment of numerous ITS on all fatal and injury crashes in the US. It was predicted that an 8.4% reduction in fatalities and a 4.0% reduction in injuries could be expected with road departure avoidance systems.

6.5.1.1.30 Road Surface Condition Monitoring

Road surface condition monitors serve to alert the motorcyclist to abnormalities in the road surface ahead. Radar, laser or visual imaging of the road surface directly ahead of the vehicle is monitored for abnormalities such as potholes, debris, gravel, ice or oil spills. This information can also be integrated with ACC, ABS, collision avoidance and speed limiting systems so that vehicle performance is altered to suit the driving road surface conditions (Bishop, 2005) [231]. For example, ACC may adjust headway times to allow for longer braking distances in icy conditions. The system is applicable for all types of vehicles.

A variant of road surface condition monitoring is road surface temperature monitoring. These systems monitor the temperature of the road. Road temperature information is gathered in order to detect the presence of ice on the road surface. This may be used to warn drivers of ‘black ice’ spots or in road maintenance vehicles to determine the appropriate application of salt or other anti-icing liquids is necessary.

These systems may also employ a cooperative approach, where information from roadside beacons or other data collection points are transmitted to the vehicle or presented on variable message signs. This allows more advanced warning of changes in road surface conditions.

The crashes where poor road surface is a contributing factor are minimized.

Lind, et al. [236] estimated outside temperature warnings have the potential to affect 40% of fatalities attributed to poor road surface in Sweden and predicted that by the year 2015, these systems would reduce these fatalities by 20%.

6.5.1.1.31 Seatbelt Reminder and Interlock Systems

The system is applicable for both commercial and passenger vehicles. Seatbelt systems detect the presence of vehicle’s occupants and ensure they are restrained. This may take the form of either visual or auditory alerts that persist or increase in intensity until the seatbelt is used (reminder systems), or disabling of the ignition (interlock systems) until all occupants present are restrained. These systems involve sensors in the seatbelt assembly that detect whether the seatbelt is in use. To detect the presence of other occupants aside from the driver (as the driver will always be present), the system may also involve weight and pattern recognition sensors built into the passenger seats.

Crash relevant to occupants are unrestrained are reduced.

It has been estimated that if seatbelt reminder systems in all vehicle were able to increase seatbelt usage by 6%, 730 driver fatalities could be prevented annually in the US (IIHS, 2006b).

Kullgren, et al. [237] estimate that if 100% of vehicle occupants were restrained in Europe, around 7600 fatalities could be avoided each year.

A HARM analysis conducted by Regan, et al. [277] showed that seat-belt reminder systems (not interlocking systems) would result in savings of $335 million AU in crash costs to the Australian community. Following an on-road trial of a seat-belt reminder system, it was predicted that these systems will lead to significant reductions in amount of unrestrained travel, although whether this effect is the same for passengers as drivers was inconclusive in this study.

Lind, et al. [236] estimated that seat belt reminders have the potential to affect 50% of unrestrained occupant fatalities in Sweden, and predicted that by the year 2015, these systems would reduce unrestrained fatalities by 25%. Lind, et al. estimated that occupant protection systems (that is, seatbelt reminders and airbag) have the 'verified' potential (based on other studies) to reduce all road fatalities by less than 4%, while the 'full' potential (an optimistic estimate based on full deployment) is 10%.

Seatbelt systems are associated with considerable acceptability issues. Interlock systems have shown to be unpopular; therefore many systems are only reminders (Regan, et al., 2005) [277]. Indeed, Young, et al. (2003b) [263] found young drivers viewed an interlock system negatively while a reminder system was positively regarded by this group.

Kullgren, et al. [237] noted that reminder systems are only effective for those that forget to use their seatbelts, rather than those that deliberately choose not to.

6.5.1.1.32 Speed Alerting and Limiting Systems

The System is applicable for all types of vehicles. Speed limiting systems take an active role in speeding prevention. Speed alerting and limiting systems typically use the same principles to determine the actual speed of the vehicle compared to the appropriate or desired speed (figure 6.26). When an excessive speed is reached, the system employs mechanisms within the vehicle prevent further acceleration. This can occurs via mechanical control of the fuel and energy systems of the vehicle. The maximum speed may be absolute, or manually or variably determined. Absolute measures are typically used in commercial vehicles, where the top speed of the vehicle is fixed at a certain point which cannot be over-ridden by the driver. Manually set systems can be changed or modified by the user, while variable systems adapt to the speed limit of a given area (as in ISA).

Two types of speed limiting systems are retarders and governors. Speed retarders continuously dissipate energy, typically using a magnetic field in the vehicles transmission that creates a braking force in the drive system (Regan, et al.) [233]. Speed governors restrict the engine's fuel input. Speed governors are mandatory in heavy vehicles in Australia and the European Union (OECD, 2003) [234].

Figure 6.26: On board speed limit display

The System minimizes the rick of crashes of over Speeding. With the application of the Speed alerting and limiting System, 2% reduction of all the injuries may be possible by the expectation of OECD 2003. [234].

BMW's upcoming 7-series will have the ability to reads speed limit signposts and variable speed limit signs, informing the driver via the head-up display and the instrument cluster (figure 6.27). Tom Noble, General Manager Marketing, BMW Group Australia says "The new BMW Speed Limit Display will significantly reduce the risk of drivers exceeding the speed limit by mistake, especially on roads with multiple speed zones,"

Figure 6.27: Head –up display of speed limit

6.5.1.1.33 Stop-and-Go

The system is applicable for both commercial and passenger vehicles. Stop-and-go operates under similar mechanisms to Adaptive Cruise Control, with a greater automotive function. In addition to automatically braking when the leading vehicle slows (as in ACC), stop-and-go systems automatically accelerate to follow the lead vehicle when it moves forward. With high-speed ACC the user must manually accelerate the vehicle to begin moving, and ACC does not operate below a certain threshold, typically 40 km/h. Different versions of these systems may operate differently. Some systems require the driver to manually begin acceleration if the vehicle's speed drops below 5 km/h (so called stop-and-wait systems).

The term 'Stop-and-go' has also been used to refer to cooperative systems which are linked to traffic light signals, so that the vehicle automatically decelerates when red/amber signals are detected, and accelerates or continues through the intersection when green signals are detected.

The system reduces the rear-end crashes in low-speed, high density traffic.

Hoetink [278] suggested that ACC systems that feature Stop-and-go functions may have safety enhancing effects, as well as benefits in reducing traffic congestion. However, no reported evidence has been found as yet.

6.5.1.1.34 Traction control systems

The system is applicable for both of commercial and passenger vehicles. Traction control systems (TCS) maintain maximum contact between the tyres and road when accelerating. These systems provide additional control while accelerating, in a similar way to ABS when braking. Essentially, traction control is the reverse of ABS. Traction control prevents tyre skidding by applying brakes or reducing the fuel or power supply. Rotation sensors in all wheels detect the spin of all wheels relative to each other. If one or more wheels begin to skid when accelerating on slippery surfaces, the system applies braking force to the relevant wheels. Engine torque is also transferred to the wheels with good grip. If the other wheels also loose traction, the system reduces the torque of the engine until the skid is overcome (www.renault.com). Traction control is able to prevent wheel skid and therefore maintain trajectory control, during acceleration from a stationary position and while in motion, and on curved sections of road. TCS, along with ABS, make up the major components of ESC.

The off-path on curve crashes, off-path on straight crashes, crashes where poor road surface or weather are contributing factors are reduced.

6.5.1.1.35 Tutoring Systems

This system is advisable for all the commercial and passenger vehicles. These systems provide feedback to drivers regarding their driving performance. Information from vehicle acceleration and deceleration, lane position, speed limiting systems and stability sensors may be monitored. Drivers are provided with feedback and recommendations for speed, following distance and lane position. When a potentially hazardous situation occurs, or if vehicle speed, position or stability are deemed to be inappropriate, the driver is ‘tutored’. This may be in the form of visual, auditory or haptic feedback. Haptic feedback in the form of accelerator pressure (for speed system) may be more effective and less cognitively demanding than visual messages (Rumar, et al.) [219].

Tutoring systems may also be infrastructure-based. The systems employ roadside beacons that continuously monitor the passing traffic. If a vehicle is deemed to be travelling too fast or too close to the leading vehicle, a message specific to that road user is presented.

The rear-end crashes, off-path on curve crashes, off-path on straight crashes and crashes where speed, inattention/distraction and fatigue are contributing factors are reduced

Lind, et al. [236] estimated that the ‘verified’ potential (based on other studies) of in-vehicle tutoring systems (in combination with enforcement strategies) to reduce all road fatalities is 3%, while the ‘full’ potential (an optimistic estimate based on full deployment) is 7%.

6.5.1.1.36 Vision Enhancement

The System is applicable for both commercial and passenger vehicles. The 30 per cent of road accidents that happen at night involve half of the people killed on the roads. Darkness is a major risk factor: while drivers travel just 28 per cent of their miles at night, 55 per cent of all motor fatalities occur after sunset. Ninety per cent of a driver's reaction depends on vision, which is severely limited at night. Depth perception and colour recognition are also compromised after sunset. Other dangers besides reduced visibility include fatigue, drowsiness, blurring of peripheral vision and impairment in judgment of distances and movements.

Two types of vision enhancement systems exist. Passive systems detect the naturally radiated energy from objects in the environment with infrared cameras. Active systems employ illumination or scanning techniques to visualize the roadway. The system architecture and component design for an advanced vision enhancement system for night driving based on:

- An automotive-specific Complementary Metal Oxide Semiconductor (CMOS) camera.
- A near infrared sensor light source integrated into a newly designed vehicle headlamp.
- An innovative, user-centred human machine interface.

Two different modules were designed offering a direct-view display inside the dashboard and a head-up display installed on top of the dashboard in view of the driver's eye. The main components of both are a display, a light source and the interfaces. The head-up display includes a mirror that magnifies and projects the image coming from the display. General Motors invented the technology of displaying the edge of the roadway using vehicle's infrared cameras and the laser could 'paint' the edge of the road onto the windshield so the driver knows where the edge of the road is (figure 6.28C).

Figure 6.27: Vision enhancement at night driving

A system described by Lawrence, et al. [279] involves a set of infrared headlights. An infrared sensitive camera mounted on the front of the vehicle detects the reflected infrared radiation. This scene is projected from a display module to a heads-up display over the entire windscreen. High contrast images of other vehicles, vulnerable road users and obstacles are projected at the same focal length as the regular field of view. The result appears similar to a photographic negative. This display can also incorporate information from the instrumentation panel as in HUDs. the case of motorcycles, this may be a display on the consol or a helmet-mounted display.

The system reduces the crashes where poor visibility is a contributing factor. The OECD (2003) [234] has suggested reduced visibility is a factor in 42% of all traffic collision.

Estimations of the approximate reductions expected with vision enhancement systems in Germany (assuming 70% penetration of the passenger vehicle fleet) were reported by eSafety Forum [239]. It was expected that 25% of vulnerable road user crashes occurring in low visibility would be affected, leading to a 17.5% reduction in these crashes, equating to a 0.1% reduction in all crashes

Cadillac's (full size luxury car manufactured by General Motors) "Night Vision" system increases the viewing distance of the user from 90 metre with standard headlights, to up to 450 metres (Lawrence, et al) [279].

Lind, et al. [236] estimated that vision enhancement systems that include adaptive headlights have the potential to affect 30% of pedestrian fatalities and 15% of bicyclist fatalities in Sweden, and predicted that by the year 2015, these systems would reduce pedestrian fatalities by 15% and bicyclist fatalities by 8%. The 'verified' potential of this system (based on other studies) to reduce all road fatalities is less than 0.5%, while the 'full' potential (an optimistic estimate based on full deployment) is 8%.

Archer [280] suggests that the benefits of vision enhancement systems may be negated by a tendency for users to drive at higher speeds.

6.5.1.2 Passive Systems

6.5.1.2.1 Active Head Restraints

The system is applicable for both commercial and passenger vehicles. The proper alignment of both the seat and headrest can play a vital role in minimizing injury in traffic crashes. However, evidence suggests that a large proportion of drivers and passengers fail to satisfactorily adjust their headrest for their height, most commonly leaving it in the lowest position (Olssen, et al.) [246]. With standard, incorrectly aligned, headrests the head rolls backward over the headrest causing sudden and forceful hyper-extension of the neck (Fielding, et al., 2005). For this reason, some manufacturers have introduced fixed head restraints, while others have invested in ITS technology.

Active head restraints should address three key issues associated with traditional head rests: the head rest must be high enough to prevent the head rolling backwards; the gap between the back of the head and the head rest must be minimal; and the headrest must have controlled flexibility to prevent forward propulsion of the head. Active head restraints may do this in two ways: either reactively or proactively. Proactive systems detect the height of the occupant and adjust the headrest accordingly before any crash occurs. Reactive systems, respond to the additional force in the driver or passenger seat cause by a collision by adjusting the head restraint into a more upright and forward position immediately after a collision is detected. This may occur through either a mechanical system located in the back of the seat, or with inflatable headrests. As an alternative, some manufactures have included electronically adjustable headrests. These lack the direct safety benefits of active head restraints, but make it more convenient to set a correct headrest position (Fielding, et al.) [281].

Figure 6.28: Active head restraint

Active head restraints are primarily aimed at reducing whiplash related injuries caused by rear-end crashes.

Nissan's active head restraint system has been reported to reduce the bending force of the neck in a rear-end collision by 45% (Nissan) [281].

Farmer, Wells, and Lund (2003) [362] reported a 44% reduction in the incidence of neck injuries with the instillation of a number of (reactive) varieties of active head restraints in 409 vehicles. Viano and Olsen [283] found a 51% reduction in neck extension during crashes with the use of a reactive Self-Aligning Head Restraint (SAHR), and a reduction of injury risk from 11% to 3% with the use of SAHR.

Bigi, et al. [284] found inflatable head restraints to reduce head acceleration by 30% to 50%.

6.5.1.2.2 Airbag Jackets

This is advisable for Motorcycles. Jacket-based airbags involve the same principles as vehicle-mounted airbags, where upon detection of a crash situation the airbag is automatically deployed to minimize injury to the rider. However, the mechanisms of airbag jackets are quite different. Jacket airbags come into effect once the motorcyclist has been thrown from the vehicle, rather than preventing this from occurring. The jacket is connected to the vehicle through a cable, and when this connection is severed (when the force of the rider being thrown from the motorcycle uncouples a pin or key in the jacket) the airbag inflates. The rider will still hit the ground with the same force, but they will be protected with a cushion or air surrounding their upper body. Airbag jackets are inflated by a carbon dioxide cylinder built into the jacket, which is less flammable than the gases used to inflate vehicle-mounted airbags.

Figure 6.29: Airbag Jacket

This reduces the fatality of motorcycle crashes where the rider is thrown from the vehicle or crashes with other vehicles.

There are a number of commercially available airbag jackets in the United States, however, there is no existing independent evaluation of their effectiveness. One manufacturer, Hit-Air conducted a shock absorbing test on their airbag jacket, showing that this system was more effective than both a regular riding jacket and a jacket with additional padding (www.hit-air.com).

6.5.1.2.3 Airbags

This is applicable for all types of commercial and passenger vehicles. Airbags serve to reduce injury severity by absorbing the kinetic energy of the occupant when they are propelled forward in a crash. Airbag systems involve crash sensors, typically a unit that continuously monitors the acceleration and deceleration of the vehicle. Rapid deceleration that exceeds a threshold of intensity (i.e. a collision) triggers the deployment of the airbag. A pyrotechnic pump rapidly releases gas into the airbag, which inflates within hundredths of a second.

In motorcycles, the system comprises the airbag mounted on the front of the vehicle below the handlebars, and acceleration sensors and impact sensors located on either side the front wheel suspension. Frontal impact is detected by these sensors, and the airbag is deployed. The airbag acts to cushion the forward propulsion of the rider and prevent them from being thrown from the vehicle. The sensors of the system are calibrated to deploy the airbag in collision impacts only, not in other situations such as riding over potholes or curbs. To increase its stability, straps hold the airbag in place.

Airbag reduces the consequences of all types of crashes. Airbags have been associated with reductions in fatal frontal impact crashes by 25% for drivers and 15% for front passengers when combined with seatbelt usage. For both drivers and passengers, thoracic injuries have decreased by 65% and head injuries have decreased by 75% (www.renault.com).[363]

Lind, et al. [236] estimated that occupant protection systems (that is, airbags and seatbelt reminders) have the ‘verified’ potential (based on other studies) to reduce all road fatalities by 4%, while the full potential (an optimistic estimate based on full deployment) is 10%.

Paine [242] estimated a benefit cost ratio of 0.81 for driver airbags, 0.19 for front passenger airbags and 0.20 for side curtains airbags in Australia.

The NHTSA [285] found airbags to be effective in reducing driver fatalities in frontal-impact crashes by 19% (31% for purely front-impact crashes), and 11% in all crash types. It was estimated that airbags reduced fatalities risk by 9% for restrained drivers and 13% for unrestrained drivers.

Torpey, et al. [286] calculated a 12:1 benefit-cost ratio for the Australian community associated with the use of driver airbags.

A number of additional in-vehicle airbag and supplementary systems exist. These supplementary systems adjust the deployment of the airbag to suit the number and type of occupants present. Also, variants of traditional airbag systems exist that aim to reduce deployment times and prevent occupant injury resulting from airbag deployment (Olsson, et al.) [246]. Airbag systems may integrate a number of these technologies in order to provide maximum protection for occupants who may be of different size, weight or position.

Adaptive Steering Column

These systems direct the motion of the steering column away from the occupant during airbag deployment. When the airbag is deployed, the steering column pin is also released by a pyrotechnic mechanism, causing downward motion of the steering column. This increases the space between the driver, the steering column and airbag.

Buckle Sensors
Seatbelt buckle sensors detect whether the occupant is restrained, and adjust the impact severity thresholds of the airbag for that seat. These also involve occupant sensors. The airbag threshold is modified so that it deploys at lower impact intensity and higher inflation rate for unrestrained occupants.

Dual-stage Airbag
These airbags deploy during two stages. The activation of these stages depends on the severity of the crash. Stage two, or full deployment, occurs during severe crashes.

Inflatable Carpet
Inflatable carpet systems are airbags located in the floor of the vehicle, under where the feet rest. These lift the feet away from the floor upon inflation, reducing impact force to the lower limbs.

Inflatable Seatbelt
Inflatable seatbelts involve a tube along the shoulder strap of the seatbelt which inflates upon impact. This reduces load on the seatbelt and protects the upper body of the occupant during a crash. This serves to absorb and spread force, as well as tensioning the seatbelt.

Knee Airbag
Knee airbags protect both the knees and hips during a collision, prevents the occupant submarining. This also ensures the occupant in the optimal upright position for airbag protection.

Radial Deployment Airbag
Radially deploying airbags inflate the airbag in a radial motion, increasing the time between airbag deployment and contact with the occupant. The bag first inflates radially before inflating toward the occupant. This may be especially beneficial for occupants positioned close to the airbag.

Roofbag
Heudorfer, et al. [287] described an airbag concept to protect occupants during a rollover crash. A multi-chamber airbag located in the top of the seat inflates slowly (around 250 ms), pushing the occupants head forward. This forces the occupant to flex their neck, increasing the load the head and neck are able to withstand without injury, provided additional cushioning between the head and roof, and increases the space between the head and roof.

Seat Position Sensor
Detection of the position of the seat allows the modification of the deployment of the airbag. If the seat is positioned further forward, the airbag may be deployed at stage one instead of stage two (for dual stage airbags).

Side Airbags
Airbags located in the side of the vehicle (e.g., inflatable tubular structure, inflatable curtain, torso side airbags) protect the occupants head during side-impact and rollover crashes.

Figure 6.30: Side Airbag

Weight and Pattern Recognition Sensor

Weight and pattern recognition sensors determine the presence of a passenger, and to discriminate adults from children. The physical characteristics of the occupant are evaluated with weight and pressure sensors in the base and backrest of the seat. If a child is detected, the airbag may be disabled or modified to deploy at a lower inflation rate.

Child Seat Detector

Child seat sensor systems deactivate the passenger seat airbag when a child seat is in place. A child detection system for a child seat includes a pressure sensor is adapted for detecting when weight is positioned on the presser sensor. The pressure sensor is selectively positioned within a seat cushion of a restraining seat. A primary processor is electrically coupled to the pressure sensor. The primary processor is adapted for is electrically coupled to a vehicle computer system of a vehicle in which is positioned the restraining seat. A sound emitter for emitting an audible sound is operationally coupled to the primary processor. When a child seat is detected, the sensor transmits this information to the airbag control unit to disable airbag deployment, preventing injury to infants and children.

6.5.1.2.4 Anti-Submarining Seat

This is applicable for both commercial and passenger vehicles. Anti-submarining seats prevent the occupant slipping under the lap belt, which can result in injury to the internal organs of the abdomen. This may occur when there is slack in the seatbelt or when the seat cushion allows downward and forward occupant displacement. The anti-submarining seat contains an inflatable or up-ward moving structure in the base of the seat which supports the occupant during a crash. This prevents the occupant slipping downward during a crash without compromising the comfort of the seat during normal driving.

In case of frontal collision and sudden braking it prevents the injury under the lap section of the driver.

Figure 6.31: Anti-Submarining Seat

6.5.1.2.5 Automatic Rollbars

It is applicable for convertible vehicles. Automatic rollbars for convertibles provide protection for rear-seat occupants during a rollover crash. Convertibles lack protective structures around the rear-seat, rendering passengers particularly susceptible to upper body injury during a rollover. Automatic rollbars are located within the head restraint of the rear seats, and move upward during a rollover event. They are triggered when the tilt of the vehicle exceeds a certain threshold. Deployment of the rollbars is not affected if the roof is in use. The system is electromechanical, not pyrotechnical, allowing more gradual deployment of the rollbar so as to minimize risk to the occupants. This also allows the rollbars to be retractable
(www.renault.com).

It reduces rollover crashes involving convertibles.

6.5.1.2.6 Crash Data Recorders

This system is applicable for both commercial and passenger vehicles. Crash data recorders in passenger vehicles perform the same function as black boxes in the aviation industry. They record information regarding the activities and physical condition of the vehicle prior to and during a crash, which can be later accessed and analyzed. Crash data recorders consist of a variety of vehicle system sensors and detectors to measures factors such as acceleration, location, pre crash activity, time of crash, rollover and yaw data, braking activity and airbag deployment. Data is provided only for the seconds leading up to a crash. These are not logs of driving behavior over extended periods, but recordings of the crash event only. According to the IIHS [288], crash data recorders are essentially extensions of airbag sensors, which measure vehicle deceleration and velocity. Other data, such as time, date, speed prior to impact, seatbelt use and the activation of other active and passive systems can also be included.

Crash data recorders will have no direct effects on safety. However, they provide crash investigators a better understanding of the factors contributing to crashes, which may lead to better road and vehicle design.

Kulmala [289] reported that event recorders have actually been shown to reduce number of crashes and crash severity when installed in commercial vehicles as a means of driver performance monitoring.

6.5.1.2.7 Emergency Lighting Systems

This system is applicable for both commercial and passenger vehicles. Emergency lighting systems illuminate the vehicle post-crash. When a crash event has occurred, detected through airbag crash sensors, tilt sensors, ACN sensors or similar, the system automatically activates the vehicles lighting systems. This may be the interior lights, headlights, hazards lights or other emergency lights.

The conspicuity enhancing effects of this system may serve to reduce the severity of crashes by decreasing critical response time, particularly in rural and night time crashes where the vehicle may be difficult to locate. This may be especially relevant to single-vehicle motorcycle crashes.

6.5.1.2.8 External Airbags

This system is applicable for passenger vehicles. External airbags systems are fitted to the exterior of a motor vehicle in order to increase the safety of vulnerable road users in the event of a vehicle-pedestrian collision. A collision with a pedestrian triggers the inflation of airbags located in the bumper and bonnet. These serve to absorb some of the kinetic energy of the pedestrian as their legs, torso and head make contact with the front of the vehicle. Some external airbags are designed to inflate upward over the windshield to protect the occupant from directly hitting the glass.

These systems may also be pre-crash, where an eminent collision with a pedestrian triggers the inflation of the airbags. These systems involve forward facing collision detection systems. As well as determining whether a collision with a pedestrian opposed to a vehicle has occurred, the sensors of the system must be able to distinguish children from adults. Children require greater protection from the bumper and lower bonnet, while adults are more likely to strike the upper bonnet (Holding, Chinn, & Happain-Smith) [290]. The pedestrian detection component of the system may involve thermal imaging, radar, laser or infrared imaging.
Pedestrian crashes.

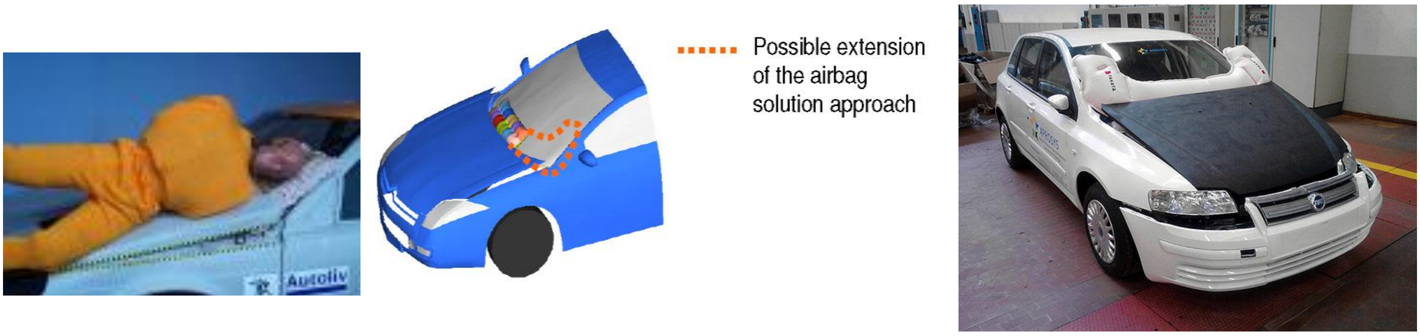


Figure 6.32: External Airbags to protect pedestrians

Holding, et al. [290] studied the effects of external airbags on a sedan vehicle on collisions with adult and pedestrian crash test dummies. They found significant reductions in the acceleration forces of chest, pelvis, and knees in collisions at 40 km/h and concluded that head injuries could be reduced by 20% with these systems

6.5.13.2.9 Impact-Sensing Cut-Off Systems

This system is applicable for both commercial and passenger vehicles. Impact-sensing systems disable fuel and electrical systems to prevent the vehicle igniting after a crash has occurred. The system may involve crash sensors and fuel leakage detectors (i.e. vapour sensors) which detect a crash or malfunction of a vehicle system (Olssen, et al.) [246]. For example, Delphi's Pyrotechnical Safety Switch disconnects the main power cable from the vehicles battery in the early stages of a crash (Delphi, 2005)[364]. This prevents a short circuit from occurring. The system does not cut off power from the vehicles passive safety systems, interior lighting or door locks.

6.5.1.2.10 Impact-Sensing Door Unlock

This system is applicable for both commercial and passenger vehicles. Impact-sensing door unlock systems detect the occurrence of a crash and automatically unlock the vehicle's doors. A crash severe enough to trigger the vehicles airbags will trigger this system. This enables rapid escape from the vehicle and easy access for emergency services to occupants trapped inside the vehicle.

6.5.1.2.11 Pop-Up Bonnet Systems

This system is applicable for passenger vehicles Pop-up bonnet systems increase the 'crush' space between the pedestrians head and torso in the event of a pedestrian-vehicle crash. In frontal impacts, the pedestrian is particularly vulnerable to head injury resulting from the densely packed components under the bonnet of the vehicle (Fredriksson, Haland & Yang) [291]. When contact between the front bumper and a pedestrian occurs, the system pushes the bonnet upward from the rear creating a larger gap between the bonnet and engine beneath. This cushions some of the pedestrian's kinetic energy, minimizing injury. Alternatively, some systems may differentiate contact between a pedestrian and another vehicle. If the impact is with another vehicle, the system makes the bonnet more rigid, affording greater occupant protection.

These systems may involve sensors within the front bumper, which detect a collision with a pedestrian as contact is made with the front of the vehicle. Alternatively (and ideally), the system may involve sensors that detect the vulnerable road user in the path of the vehicle before a collision has occurred. This allows more rapid activation of the system, ensuring the pop-up mechanisms have deployed and the bonnet has been stabilized before the pedestrian makes contact with the vehicles front structures. This is a CAPS version of the system.

Figure 6.33: Pop-Up Bonnet Systems

The system reduces the Pedestrian crashes. A recently developed external airbag system has been reported to reduce the risk of fatality from a frontal pedestrian-vehicle crash at 40 km/h from near-certain to less than 15% (Autoliv) [292].

Lawrence, et al. [279] estimated the benefit-cost ratios of pop-up bonnet systems in various types of vehicles. Best estimates for benefit cost ratios were:

- No pop-up bonnet: 7.4
- Pop-up bonnets on all sports cars: 6.6
- Pop-up bonnets on all sports and executive cars: 6.1
- Pop-up bonnets on all sports, executive and large family cars: 4.6
- Pop-up bonnets on all cars: 3.3

Lind, et al. [236] estimated that vulnerable road user protection systems such as pop-up bonnets and extendable bumpers, have the 'verified' potential (based on other studies) to reduce all road fatalities by less than 0.5%, while the 'full' potential (an optimistic estimate based on full deployment) is 0.6%.

6.5.1.2.12 Seatbelt Pre-Tensioners

This system is applicable for both commercial and passenger vehicles. Seatbelt pre-tensioners decrease the amount of slack in the seatbelt during a crash. Upon detection of an impact, excess seatbelt slack is taken up by the system, reducing the forward propulsion of the occupant and the likelihood of them submarining in the seat. In order for this to be effective, the seatbelt must pre-tension before the occupant is propelled forward by the force of the crash. This of course relies on accurate crash sensors. The pre-tensioners can retract as much as 15cm of seatbelt in 5ms (Zellmer, Luhrs & Bruggemann,) [293].

It reduced all crashes involving restrained occupants.

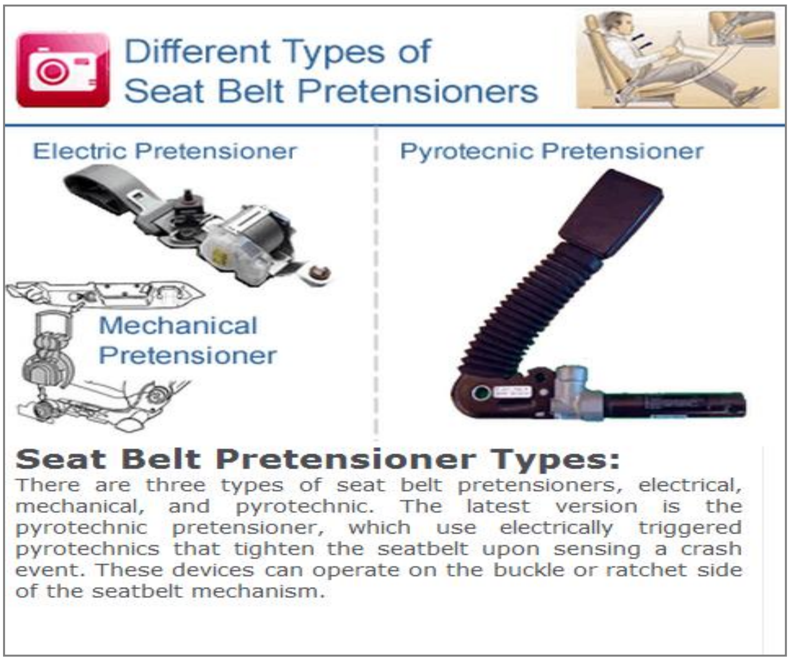


Figure 6.34: Seat Belt Pretensioner

Paine [242] estimated a benefit cost ratio of 1.12 for front seat seatbelt pretensioners in Australia.

Intelligent restraint systems have been estimated to reduce the probability of a severe head or chest injury by 14%, and up to 17% for an occupant of small stature (Clute) [294].

Olssen, et al. [246] noted that pre-tensioners are not compatible for all vehicle types, such as convertibles.

6.5.1.2.13 Seatbelt Load Limiters

This system is applicable for both commercial and passenger vehicles. Seatbelt load limiters operate in conjunction with pre-tensioners. Load limiters gradually reel out additional seatbelt slack after the seatbelt has been pre-tensioned. This reduces the load from the seatbelt on the occupant during the rapid deceleration that occurs in a crash.

Adaptive load limiters are more sophisticated variants of this technology. These systems can determine the occupants size and position and the force of the impact, and adjust the load limiting of each belt accordingly. This may incorporate a gearbox system that releases slack into the seatbelt in various stages (Olssen, et al.)[246].The first gear has the strongest grip, releasing minimal additional belt, while the second gear allows more constant release of the seatbelt. High severity crashes cause the system to stay in the first gear for longer before transferring into lower gears.

It reduced all crashes involving restrained occupants. Intelligent restraints have been estimated to reduce the probability of a severe head or chest injury by 14%, and up to 17% for an occupant of small stature (Clute) [294].

6.5.1.3 Combined Active and Passive Systems

6.5.1.3.1 Extendable Bumper

This system is applicable for both commercial and passenger vehicles. The extendable bumper system serves to increase the crush space of the front of the vehicle during a frontal collision. Pre-crash sensors detect and eminent crash and the bumper is extended laterally by around 6 inches and is locked in place. This 'softens' the front end of the vehicle, allowing it to absorb greater force from the other object or vehicle during a frontal collision. This enhances the safety of not only the occupants of the vehicle with the extendable bumper, but also the occupants of the other vehicle involved in the collision (www.gm.com).

The multiple-vehicle crashes at intersections; head-on crashes; rear-end crashes; pedestrian crashes are reduces. Lind, et al.[236] estimated that vulnerable road user protection systems such as extendable bumpers and pop-up bonnets, have the 'verified' potential (based on other studies) to reduce all road fatalities by less than 0.5%, while the 'full' potential (an optimistic estimate based on full deployment) was estimated to be 0.6%.

6.5.1.3.2 Motorized Seatbelts

This system is applicable for both commercial and passenger vehicles. Motorized seatbelts automatically retract to take up excess slack in the seatbelt when a crash is deemed to be likely or unavoidable. These may be linked to active emergency control systems, such as brake assist, ESC, pre-crash or collision warning systems. In these systems the activation of the active or pre-crash safety systems also activates the seatbelt retractor. For example, Nissan's pre-crash seatbelt system is linked to the Intelligent Brake Assist system. These active and pre-crash safety systems can also be linked to other intelligent restraint systems, such as pre-tensioners and load limiters. Alternatively, eminent crashes may be detected via forward-facing radar. A system described by Nishikaji [295] also tightens the seatbelt during cornering to reduce occupant discomfort during such maneuvers. This system incorporates lateral sensors to determine turning movements as well as longitudinal sensors to determine braking action.

It reduced all crashes involving restrained occupants Pre-crash seatbelt systems have been estimated to reduce serious injuries by up to 20% (Regan, et al.)[296].

Nissan expects a 25% reduction in fatalities and serious injuries to be associated with a motorized seatbelt system linked to brake assist (Takagi & Pal) [297]. A simulation study found that the peak G force on the thorax decreased by 7% with this system compared to a normal belted occupant.

6.5.1.3.3 Pre-Crash Systems

This system is applicable for both commercial and passenger vehicles. Pre-crash systems come into effect when an inevitable crash is been detected. Forward-facing sensors, such as those in collision avoidance systems, determine the eminent crash and prepare the vehicle to minimize the effects of the crash. For example, passive safety systems such as braking assist, airbags and seatbelt pre-tensioners may be pre-charged to minimize delays in their deployment. The system may use radar sensors (or similar) to monitor the road environment ahead or directly behind the vehicle. The speed and trajectory of the user's vehicle is continuously monitored in relation to the speed and position of other objects. If a crash is calculated to be inevitable or unavoidable, the system may employ active safety systems (e.g., brake assist) as well as passive safety features. Also, the course of the vehicle may be altered. If the system determines that a single vehicle crash will be less serious than a high speed head-on collision, for example, the system will veer the vehicle onto the roadside (Rumar, et al.)[219].

Current systems, such as that offered by Mercedes-Benz, do not involve detection of hazards in the road environment. Rather, they detect activation of other active safety measures, such as brake assist or ESC, and take additional safety measures such as closing the sunroof and activating seatbelt pretensioners (Olssen, et al.) [246]. More advanced pre-crash systems may also become cooperative, incorporating GPS and inter-vehicle communication functions to better predict (and therefore protect against) a potential crash.

The type of crash effected depends of the sensors of the system (e.g., forward facing, rear-facing or lateral sensors).

Sugimoto and Sauer [298] modelled the effects of a pre-crash 'collision mitigation brake system' (CMBS) on 50 accident scenarios. This system provides auditory, visual and haptic warnings, tensions the seatbelts and automatically applies light braking pressure if a crash is deemed likely. It was estimated with CMBS, 38% of the crashes investigated in this study would have been avoided, with a 44% reduction in the probability of a fatal outcome. Sugimoto and Sauer noted that it is difficult to assess the outcomes of pre-crash systems in real-world crash data, as the conditions leading up to crash are rarely known.

Lind, et al. [236] estimated that pre-crash systems, including those that intervene with the path of the vehicle, have the 'verified' potential (based on other studies) to reduce all road fatalities by less than 0.5%, while the 'full' potential (an optimistic estimate based on full deployment) was estimated to be 1%.

A study from Daimler Chrysler and Mercedes, suggested a reduction of 30% to 50% for head injuries, and another 20% to 40% reduction in neck injuries (2002). [299]

6.5.2 Infrastructure-Based Systems

6.5.2.1 Active Systems

6.5.2.1.1 Animal Detection Systems

Animal detection systems serve to detect the presence of large animals on the road ahead and provide alerts to approaching drivers. To maximize their effectiveness, animal warning signs should serve to both increase driver awareness and decrease vehicle speed (Huijser,) [300]. These systems are generally designed for and implemented in regions where collisions with large animals, such as elk and deer, are common.

Four variants of animal detection systems exist (Huijser,) [300]. In all cases, the detection of an animal on or in the roadway triggers a visual alert that is presented via roadside signs. This is typically a flashing light and picture of an animal (e.g., a deer) (figure 6.14), and may incorporate speed warnings. The systems differ in how they detect the presence of animals:

Area cover systems: Monitor a given area with video, radar or infrared to detect movement and/or body heat of an animal crossing or near the roadway.

Break-the-beam systems: Rely on an infrared beam between two sensors parallel to the road. An animal passing through this beam will interrupt this signal and trigger a roadside warning. A limitation to this system is that the direction of movement and the number of the animals cannot be determined, leading to false alarms when animals leave the roadside.

Geophone systems: These consist of units buried in the ground that detect the vibration caused by large animals walking over the crossing area.

Radio collar systems: Animals with radio collars trigger alarms when they come within a certain proximity roadside sensors. This relies on a high proportion of a herd of animals being collared, and that 'lead' animals within the herd are collared. Animals without radio collars are only detected when they are accompanied by a collared animal.

Area cover and break-the-beam systems are the most commonly used types of animal detection system.

Huijser [301] outlined an additional form of animal collision prevention system. Animal warning systems alert the animal to the presence of motor vehicles, as opposed to detection systems which have the reverse action. Vehicle sensors in the area leading up to the areas where animals frequently cross detect approaching vehicles and trigger signals that either alert the animals or encourage them to move from the area. This may occur through auditory (i.e. whistles) and/or visual alerts on the roadside.

The system reduces the animal crashes.

A US study had observed small reductions in vehicle speeds (4 m/ph). This literature review reported that animal detection systems have been associated with in 82% reduction in collisions with large animals (Huijser) [301]. A cost-benefit analysis was also conducted, showing if an animal detection system prevented at least 5 collisions with deer (or 3 with elk or 2 with moose), the economic benefits of the system outweigh the costs.

6.5.2.1.2 Automated Enforcement Systems

Automated enforcement systems encompass a number of technologies that serve to enforce road traffic laws. Automated enforcement systems have a number of advantages, including improved traffic safety and crash reduction, deterrence of law violations, greater efficiency in the use of police time, continuous enforcement and objective evidence (FHWA; Retting, Ferguson & Hakkert)[302][303]. They also allow the punishment of offenders who violate red lights and railway crossings, when it may not be safe for police to pursue the offenders. These systems may be integrated with the infrastructure, or hand-held devices used by law enforcement individuals.

The multiple-vehicle crashes at intersections and crashes where speed, intoxication (both alcohol and illicit drugs) are contributing factors are reduced by this system.

McKeever [218] estimated 20% of crashes within the US could be avoided with automated enforcement of speeding and red light running. Conservative estimates show a reduction in injury crashes of 8.3% and fatality crashes by 4.4% with automated enforcement systems (OECD, 2003)[234].

A Korean application of automated speed enforcement, utilizing automatic license plate detection, speed cameras and inductive loop detectors resulted in a 60% reduction in fatalities and 28% reduction in all crashes in the area immediately around the enforcement system (Kang & Hong) [368].

The overall effectiveness of automated enforcement systems in reducing injury crashes has been estimated to be 17% (Rumar, et al.) [219]. Red light cameras alone are estimated to reduce injury crashes by 12%. While it was suggested that automated speed enforcement systems have the potential to reduce injuries and fatalities on motorways by around 10-15% and reduce injuries by over 10% on rural roads.

Automated enforcement strategies which identify the road user are often regarded as an invasion of privacy within the USA (Savage; OECD, 2003) [304][234]. The system encompasses the following methods:

Breath Testing
Roadside alcohol breath testing is used to determine the BAC of drivers. Drivers are required to blow into a device which analyses the alcohol content of their breath. If a BAC higher than the legal limit is detected, the individual is required to provide a blood sample to verify their BAC.

Alcohol breath testing has been an internationally successful enforcement strategy. In a review of literature regarding the effectiveness of breath testing checkpoints in the US, Europe and Australia, all studies in all locations showed that roadside breath testing strategies were associated with a reduction in the number of crashes of up to 36%. (Centre for Disease Control and Prevention) [305].

Electronic License Plates
Electronic license plates are one of a number of automatic vehicle identification (AVI) technologies. Electronic license plates can employ simple two-way transmitter systems or satellite communication. Information about the vehicles registration, type, current speed, vehicle specifications and so on are stored in an on-board unit that communicates this information to infrastructure-based receivers. This can either occur at continuous intervals while travelling, or when beacons are detected (Hubaux, Čapkun & Luo) [306].

Electronic license plates are relevant to enforcement in the location of stolen or offending vehicles and automatically detect speeding vehicles. Electronic license plates also have particular relevance to the commercial vehicle industry in fleet management (e.g., automatic vehicle location), electronic clearance and weigh-in-motion strategies (Walton). [307]

Headway Monitoring
The headway between two vehicles can be determined using hand-held or fixed laser devices. The system measures the speed of the leading vehicle, then the speed of the following vehicle. This information, as well as the distance from the laser, is used to determine the following distance between the two vehicles.

Laser Speed Detectors
Photo radar systems employ a combination of radar technology to determine the speed of vehicles and supplementary photographs to identify offending vehicles. Alternatively, speed enforcement may hand held radar devices.

Numerous studies of the effectiveness of laser speed detectors in the US have reported reductions in the number of total crashes by as much as 51% (ITE, 1999) [308]. Speed cameras in the UK have been associated with a 35% reduction in fatal and serious injury crashes at camera sites (Gaines, et al.)[309], while in London, reports have shown 10% speed reductions and crash reductions ranging 20-80% (Jernigan, 1998)[310]. Various studies in Europe and Australia have given estimates in crash reductions as high as 56%. PIARC (OECD, 2003) [234] reported a benefit-cost ratio of 4.1 for speed enforcement technologies, and that speed cameras have been shown to prevent up to 50% of crashes in Australia and Europe.

Rail Crossing Enforcement

Railway crossing enforcement systems are similar to red light camera systems. They involve a photographic camera which faces the direction of traffic over a barrier or signalized railway crossing. An inductive loop detector senses when a vehicle violates the railway crossing signals or drivers around the crossing barriers, and photographs of the vehicle are taken. These systems must be integrated with the timing of the railway system.

Reductions in the number of rail crossing violations as high as 92% have been reported in the US (Meadow) [311]. This was also associated with a 70% reduction in vehicle-train collisions.

Red Light Camera

Red light camera systems consist of a photographic camera facing the direction of traffic in the intersection which is synchronized to the light sequence. When activated by a vehicle travelling over an inductive loop within the intersection during a red light sequence, the camera typically takes two photographs to identify the vehicle, confirm the traffic signal was red, and that the vehicle continued to travel through the intersection.

Red light cameras are one of the most widely investigated ITS in terms of safety benefits. Numerous evaluations of their effects have reported reductions 20-87% in violations at intersections with red light cameras in the US (e.g., Retting, Ferguson & Hakkert; ITE, 1999; Maccubbin, Staples & Salwin; Hansen; Fleck & Smith)[303][308]. However, other studies have also reported significant reductions in crashes. Across various studies in Australia, the USA and Singapore, red light cameras have been estimated to reduce injury crashes by between 7-46% (OECD, 2003) [234]. After various instillations throughout the USA, red light cameras were found to reduce violations by up to 42%, and reductions in crashes of up to 70% (Savage, 2004). Reductions in violations and crashes were also observed for intersections that were did not have red light cameras.

However, red-light cameras have been associated with a 28.2% increase in the number of rear-end crashes in Australia (Passetti) [312]. Also, red light cameras were concluded to be effective at reducing traffic signal violations, but not crashes, in a literature review by Betchel, Geyer, and Ragland (2001) [313]. Maccubbin, et al. [314] reported that the effects of red light cameras in the US are so far inconclusive.

Saliva Testing

Saliva testing of drivers for illicit drugs is a relatively new enforcement strategy. Saliva tests for methamphetamines and THC (the active component of marijuana) currently exist. Drivers are required to place an absorbent material in their mouth, which is analyzed by a hand-held device. If an illegal substance is detected, further samples are taken to verify the initial sample

Tagging and Tracking Systems
In order to avoid potentially dangerous high-speed pursuits, projectile tracking devices have been developed. A small dart containing a GPS receiver, radio transmitter, power supply is fired from a hand-held or vehicle-mounted launcher (www.starchase.org). The offending vehicle is allowed to drive off, and it is remotely tracked so that authorities can organize road blocks to apprehend the offender.

6.5.2.1.3 Bicycle Signal Systems

Bicycle safety countermeasures serve to specifically enhance the safety of bicycles at signalized intersections. The systems detect the presence of the bicycle and alter traffic signals to facilitate the safe movement of bicyclist through intersections. These strategies may involve one or both of the following technologies:

Bicycle detection systems: Control of traffic at signalized intersections to better suit the needs of bicyclists. Bicycles may be detected passively, through infrared, video camera or inductive loop detectors, or via manual push buttons. The presence of a bicycle at an intersection may alter the traffic signal timing or activate bicycle-specific signals.

Bicycle signals: These are traffic signals for specifically bicycles and no other road users. This provides cycles of green, amber and red signals specific to bicycles that are coordinated with signals for other vehicles and pedestrians, allowing the passage of bicycles through the intersection with no conflicting vehicles or pedestrians.

The system reduces the Bicycle crashes. Bicycle signals are high-cost systems to implement (www.bayareatrafficsignals.com).[315]

6.5.2.1.4 Pedestrian Signal Systems

A number of systems exist that are designed to enhance pedestrian protection at intersections. These aim to increase the duration of the green ‘walk’ signal, increase the frequency of green ‘walk’ signals, or adapt the signal patterns to suit vulnerable road user’s needs. However, Ekman and Hyden [316] suggest that the extension of ‘walk’ times has no real safety benefit. Rather, preventing pedestrians walking across a red ‘don’t walk’ signal is more important. This relies on the accurate detection of pedestrians and coordination of traffic signals.

The following conclusions about pedestrian crossing ITS were made:

- Automated Pedestrian Detection: Effective at reducing pedestrian-vehicle conflicts.
- Flashing Crosswalk Lights: Associated with an overall crash reduction.
- Countdown Signal: Increase in proportion of pedestrians who complete crossings before ‘don’t walk’ signal.
- Scanning Eyes: Effective at reducing pedestrian-vehicle conflicts.

The system encompasses the following methods:

Accessible Pedestrian Signals
These systems supplement signalized intersections by providing additional traffic information for visually or hearing impaired pedestrians. This may be in the form of audible tones, ‘talking signs’,

vibrating surfaces (www.bayareatrafficsignals.com). This can be used to communicate the location of the intersection or the status of the crossing signal to the pedestrian.

Transport and infrastructure information can be provided to specific vulnerable road users with these systems. The Czech Republics Command Rig System provides information to visually impaired pedestrians via transmitters that can be integrated into the 'white stick' commonly used by visually impaired individuals (ERTICO, 2002) [317]. Audible traffic signals have also been shown to improve traffic signal compliance in sighted pedestrians as well as visually impaired individuals (Ragland, et al.) [318].

Automatic Pedestrian Detection

Pedestrian detection systems involve sensors which detect the presence and speed of pedestrians at crosswalks. The system senses approaching pedestrians and triggers the green 'walk' signal in place of traditional push-button systems. The duration of the 'walk' signal may be adjusted to accommodate slow-moving pedestrians. This may be achieved with the use of infrared, radar and/or microwave pedestrian detectors, or pressure sensitive mats.

Automated pedestrian detection appears to be effective at reducing pedestrian-vehicle conflicts when combined with traditional manual push buttons systems, but are associated with an increase in conflicts when they are used to replace pushbuttons (Ragland, et al.)[318].

A trial of automatic pedestrian detection system in four sites in the US was associated with an 81% decrease in pedestrians crossing during the 'don't walk' signal (Hughes, et al.) [319]. A 89% reduction in pedestrian-vehicle 'conflicts' (where either the pedestrian or vehicle must stop or slow down to avoid a collision) was observed in the first half of the crossings but in the second half of the crossing this reduction was 42%.

Pedestrian detection systems have been shown to significantly decrease the number of pedestrians who violate 'don't walk' signals in the US (Maccubbin, et al.)[314].

Countdown Signal

Countdown signals supplement traditional signalised pedestrian crossings. When the green 'walk' signal becomes a flashing red signal, a timer is also presented indicating how many seconds until the signal changes to 'don't walk'. This discourages people entering the roadway when the countdown is nearly complete and speeds up crossing clearance times.

Flashing Crosswalk Lights

Flashing lamps located in the pavement leading up to the cross walk provide advanced warning to approaching drivers that a pedestrian is on the crossing. The lights are activated by the manual crossing push-button.

High-intensity Activated Crosswalk

These are a type of signalized crossing, where the pedestrian presses a button on the roadside which activates a traffic signal. The signal is initially a flashing yellow lamp, followed by a solid yellow and finally solid red lamp. This indicated to the driver to prepare to stop and then that they must stop. When the signal becomes a flashing red lamp, the vehicle may proceed. This minimizes the delay associated with normal traffic signals, but increases the likelihood of the vehicle stopping (www.bayareatrafficsignals.com)[315].

Pedestrian Warning Sign

These are illuminated signs on the roadway that are triggered when a pedestrian crosses at a particular intersection or crossing. The movement of the pedestrian across the road is detected with infrared sensors, indicative loops, etc., and the sign is activated to warn approaching road users (Ekman & Hyden) [316].

Scanning Eyes

Scanning eyes systems use an animated LED sign of eyes scanning laterally to remind pedestrians to scan the roadway (www.bayareatrafficsignals.com).[315]

Scanning eyes systems have been shown to reduce pedestrians failing to see vehicles by 22-29% and reducing pedestrian-vehicle conflicts be 59-94% in various studies in the US (Ragland, et al.) [318].

Smart lighting

Smart lighting systems detect pedestrians in a crossing area and increase the lighting intensity. This serves to increase the visibility of the pedestrian and increase alertness in the road users. Also, there are economic benefits from the reduced luminance when the crosswalk is not in use, and pedestrians may feel safer at night (Ragland, et al.) [318].

Wheelchair Detection

Pedestrians in wheel chairs may be detected in a number of ways. This may be with automatic mechanisms including video detection or in-pavement wheelchair loops, or additional manual pushbuttons. The signal timing may also be adapted to accommodate pedestrians in wheelchairs.

6.4.2.1.5 Speed Feedback Indicators

Speed feedback indicators are self-contained roadside units that serve to remind road users of the speed limit. The system monitors the speed of passing vehicles via laser or radar detectors. The actual speed of the vehicle is displayed on a variable message sign next to the actual speed limit. For example, a typical speed feedback indicator may read: “Your speed 65. Speed limit 60”.

These systems may also be used to monitor traffic headways. The speed and distance of the following vehicle relative to the lead vehicle is determined with laser sensors, and present either feedback or recommendations regarding the following distance. This may be either speed or distance information, or both.

It reduces the crashes where speed is a contributing factor. As of 2003, speed feedback indicators had been shown to be effective in reducing speeding around schools in the US; however no information regarding crash reductions was available at that point (Ragland, et al.)[318].

Elvik (1997, cited in OCED, 2003) [234] estimated that speed feedback systems may result in 65% reductions in pedestrian crashes, 41% of injury crashes, 16% of rear-end crashes, while Elvik, et al. also reported that a headway feedback system was found to reduce crashes by 6%.

According to the FHWA [302], speed feedback indicators are associated with high implementation costs.

6.4.2.1.6 Traffic Control Systems

These systems aim to 'harmonize' the flow of traffic, thereby reducing congestion. Traffic control systems may be introduced on urban networks and freeways. Traffic control systems involve the continuous monitoring and management of the transport network. Various systems and strategies are involved in the gathering of this information and control the flow of traffic, such as CCTV, inductive loop detectors, and probe vehicles. This may be localized to specific area or intersection, or applied across an entire network.

Rear-end crashes; multiple vehicle crashes at intersections; side-swipe crashes.

Turner, et al. [320] reported 15-16% crash reductions with an integrated traffic control systems in the US, which resulted in a $4.3 million economic benefit.

Estimations of the approximate reductions expected with dynamic traffic management in Germany were reported by eSafety Forum [239]. It was expected that 20% of motorway crashes would be affected for roadways equipped with these systems, leading to a 0.7% reduction in these crashes equating to a 0.17% reduction in all crashes

Lind, et al. [236] estimated that flow control systems, i.e., ramp metering, lane control, route diversion, have the 'verified' potential (based on other studies) to reduce all road fatalities by less than 0.5%, while the 'full' potential (an optimistic estimate based on full deployment) is less than 0.5%.

The system encompasses the following methods:

Automated Tolling; Electronic Toll Collection

Automated tolling allows an immediate transaction between a toll collection point and a tolling agency. The tolling agency provides road users with on-board technologies that allow recognition of the vehicle as it passes through the tolling point. Automated tolling may involve a number of technologies, including smart cards, dedicated short-range communication and licence plate recognition. Automated tolling is expected to reduce safety by reducing congestion and stopping around toll booths (eSafety Forum) [239].

With the exception of license plate recognition, automated tolling strategies have been regarded as successful within the USA (FHWA) [302]. Traffic capacity has been increased by 200-300% with these systems (FHWA) [220], and while improvements in mobility, capacity and emissions have been observed (Maccubbin, et al.; Loukakos) [314].

Congestion Tolling

Congestion tolling is a traffic management strategy that automatically tolls motorists for using certain roadways during certain times. It is a means of discouraging road users from making journeys on congested roadways during peak travel times. Another strategy involves both tolled and non-tolled lanes on the same roadway, where users are able to choose to not pay (i.e., drive in the congested lane/s), not pay and carpool, or pay to drive in the non-congested toll lane. Congestion tolling may be carried out in the same way as automated tolling, however, its purpose is unique.

Smith [321] suggested that the effects of congestion tolling are hard to distinguish, as while fewer crashes may occur in less congested traffic, those crashes that do occur tend to be more severe.

Dynamic Lane Control
Dynamic lane control involves altering the direction of traffic flow of one or more lanes on a multiple lane roadway. The direction of traffic flow is typically controlled by over-head signals. The direction of the lane is determined by traffic demand.

Lane control, in conjunction with other traffic management strategies, was associated with a 23% reduction in crashes in the Amsterdam (Maccubbin, et al.)[314].

Probe Vehicle; Floating Car
Probe vehicles are instrumented vehicles that monitor the characteristics of traffic flow and the road environment while travelling within the road network. The vehicles monitor factors such as congestion, speed, weather, road surface friction and air quality. Information from the speedometer, temperature sensors, windscreen wipers, navigation systems and so on continuously gather information from the road environment. This information is transmitted via GPS to road management centres to provide real-time updates of driving and weather conditions. This information can be supplied to road information networks and maintenance services.

Estimations of the approximate reductions expected with extended environmental information gathering techniques in Germany were reported by eSafety Forum [239]. It was expected that 25% of injury crashes in slippery conditions would be affected, leading to a 12.5% reduction in these crashes equating to a 0.7% reduction in all crashes.

The FHWA [302] stated that "the jury is still out" as to whether these systems are effective, with limited deployment throughout the USA. A pilot study in the UK found a fleet of probe vehicles to be an effective measure of road network performance (Ilgaz, Gates & James, et al.)[322].

Ramp Control/Ramp Metering
Ramp control systems regulate the flow of traffic at freeway on-ramps. Depending on the level of congestion, ramp metering limits the number of vehicles simultaneously entering the freeway using signal controls. This is achieved with either a very brief green signal or a sign denoting the number of vehicle permitted to proceed at each signal interval. Ramp control systems involve continuous monitoring of the traffic flow of both the freeway and on-ramps. Vehicles are only permitted to enter the freeway if there is no traffic blocking the merging area of the on-ramp.

Pearson, Black and Wanat [323] reported that ramp metering has been shown by various evaluative studies in the US to increase vehicle speeds on freeways by up to 60% by eliminating congestion, with crash reductions of up to 50%. A single study in Michigan reported a 71% reduction in injury crashes associated with ramp metering as part of a wider traffic management strategy. A Minnesota ramp metering system resulted in 1041 crashes being avoided, resulting in an economic benefit of over $18 million US.

PIARC (2000, cited in OECD, 2003) [234] reported a benefit-cost ratio of 3.6 for ramp monitoring systems.

Various evaluations of the effects of ramp metering in the US have shown significant crash reduction rates, ranging between 15-50% (Apogee/Hagler Bailly) [324]. Other integrated traffic management and incident management systems have been associated with a 35% reduction in all crashes, a 15% reduction in injury crashes, and a 30% reduction in secondary crashes.

However, it has been suggested that ramp metering may only have significant safety effects on high congestion roads (eSafety Forum) [239].

Route Diversion

Route diversion strategies serve to encourage road users to find alternative, less congested routes. These may be mandatory, i.e., when the road is blocked due to a crash, or recommendations to road users. This information is presented via VMS or other ATIS, typically informing road users of the level of congestion and expected delays.

According to Kulmala [325], this strategy is only effective when the alternative route reduces the exposure to crashes. Wendelboe [326] found that drivers typically only diverted to a less congested route when the discrepancy in the estimated travel times between routes was high. Even when large differences were displayed, drivers only tended to divert 12-14% of the time.

Route diversion during congestion was associated with a 3.8% increase in vehicle diversion and an average time saving of around 10 minutes for road users. This time saving increased to up to 38 minutes during incidents (Abe, Shimizu & Daito)[327].

Signal Control

Signal control systems are part of a wider integrated traffic management scheme. Signal control may effect the signal phases, signal length, coordination with other nearby traffic signals. Signal control may be limited to a single intersection, multiple signals on the same road, or an entire road network. Signal patterns may be coordinated in a number of ways (Pearson)[328]:

Pre-timed: This involves the use of fixed, pre-set signal patterns. This pattern is based on historical traffic flow data.

Progressive: Coordination of multiple signals that may be synchronized to show simultaneous or alternating signals, or coordinated to allow for varying distances between signals. Flexible patterns are changed to suit different traffic flows at various times of day.

Actuated: Signals are triggered by vehicle demand. May be fully actuated or semi-actuated (actuated on the minor road only). The presence of vehicles is detected with inductive loop detectors or similar sensor technologies.

Traffic Responsive: Signal patterns are modified to suit traffic conditions. These may be in response to detectors in the road network, predictive analysis of current traffic conditions, and pattern matching of previous traffic conditions.

Adaptive Control: Use traffic sensors to detect traffic flow and demand, and creates a unique traffic control pattern to suit current conditions.

Maccubbin, et al. [314] reported positive improvements in mobility, capacity and environmental benefits in the US with adaptive signal control. Signal synchronization was associated with positive impacts on safety, with a 6.7% reduction in crashes in one location, attributed to fewer stops and increased speed.

Pearson [328] reported a 12% reduction in rear-end crashes with a traffic signal control system outside a major sporting arena, while another study showed a 89% reduction in all crashes and a 100% decrease in serious injury crashes at dangerous intersections.

Traffic Monitoring
Traffic monitoring employs the use of infrastructure based sensors (i.e., loop detectors, CCTV) to monitor traffic speed, capacity and demand, as well as environmental information. These systems can be combined with floating car data and are used to inform traffic management centres, determine signal and ramp metering control patterns, and guide infrastructure planning.

Vehicle detection systems have been widely deployed in the USA with mixed degrees of success, depending on the type of technology used (FHWA) [302].

6.5.2.1.7 Variable Message Signs

Variable message signs can be used to convey a variety of information to road users, such as traffic congestion, road geometry warnings, estimated travel times, crashes ahead, upcoming construction work, weather conditions, and to vary the speed limit appropriate to these conditions. Other information, such as advertisements of local events, may also be displayed. VMS are used to present information to all road users. The sign may be a fixed or portable structure in the road environment that is linked to a traffic management network.

Variable message signs are often components of other infrastructure-based or cooperative ITS, such as variable speed limits, speed feedback indicators, incident management, route diversion systems and weather information systems. VMS may also be used with advanced traffic information systems, where road users are advised to listen to a specific radio channel for more information.

Bohren and Williams (1997)[329] describe the use of VMS to display feedback to drivers about the state of their vehicle. The system involved infrared remote sensor that analyzed the exhaust pipe emissions of vehicles. Road users are presented with a real-time analysis of their vehicles carbon monoxide level and provided feedback as to whether this was ‘poor’, ‘fair’, or ‘good’.

The crashes where speed, weather, poor visibility; poor road surface are factors are reduced.

Other studies (OECD, 2003) [234] estimated the crash reductions resulting from VMS to be 28% for injury related crashes in the UK, 35% for all crash types in Switzerland, and 10-30% for property damage and injury crashes in Germany (for an unusual condition VMS system only).

VMS that display speed regulation information have been estimated to reduce pedestrian crashes by 65%, injury crashes by 41% and rear-end injury crashes by 16% (Elvik, et al., 1997, cited in OECD, 2003) [234].

6.5.2.1.8 Variable Speed Limits

Variable speed limits alter the posted speed limit for a given area to suit changed traffic or weather conditions. The appropriate speed limit is presented on variable message signs on the roadside, typically using an illuminated LED sign to make the altered speed limit more noticeable. The method for determining the changed speed limit varies between systems. It may be manually set, where traffic management centres determine the speed limit based on an evaluation of the current traffic or road conditions, or the system may be automatically programmed to alter the speed limit under specific conditions, e.g., school start and finish times.

The crashes where speed is a contributing factor are minimized.

In England, reductions of 25-30% in rear-end collisions on approaches to freeways, and have increase freeway capacity by up 5-10% have been observed (Maccubbin, et al.) [314].

Lind, et al. [236] estimated that variable speed limits have the potential to affect 5% of speed related fatalities in Sweden, and predicted that by the year 2015, these systems would reduce speed related fatalities by 4%.

Elvik, Mysen and Vaa (1997, cited in eSafety Forum, 2005) [239] reported 20% reductions in crashes with variable speed limits applied near schools.

6.5.2.1.9 Weather Information and Maintenance Systems

Weather information systems may involve a number of sensors that transmit information to a traffic management centre. These may include temperature, humidity, wind speed and rain gauges, floating car data, and video monitoring (CCTV) of visibility conditions. The road environment is continuously monitored for the early detection of rain, snow, ice and poor visibility (fog, dust/sand storms). Weather systems can be infrastructure-based, where information is communicated to the user via signs on the roadside, or cooperative, where weather detection beacons transmit information to onboard units in the road user’s vehicle. Most commonly, these systems are only linked to VMS. Additionally, when weather management systems are linked to variable speed limit signs, the changes in speed limit can also be automatically sent to road authorities and police so that the lower speed limit is correctly enforced (Goodwin)[330].

Some specific applications of weather management systems are described below. These strategies may be applied in isolation or as part of a coordinated traffic or weather management strategy.

Access Control

These systems restrict the use of freeways during extreme adverse weather conditions, such as heavy snowfalls or natural disasters (tornados, etc.), until the roadway is cleared. Access to freeway onramps is prevented via gate arms, and traffic is diverted to other roadways. The decision employ access control may depend on snow depth, visibility, weather severity, road condition, traffic demand, seasonal/daily travel patterns.

Anti-icing Systems

Anti-icing systems involve the application of anti-icing chemicals to roadways either pre-emptively or as soon as ice is detected on the roadway. Pre-emptive systems gather weather forecasts information from various sources (i.e., weather bureau, internet), while reactive systems involve temperature sensors on the roadway which indicate the presence of ice. Anti-icing agents are then applied to the road surface either via special vehicles or infrastructure-based sprayers.

Flood Warning Systems

These involve water level sensors, rain gauges, flood basin detectors, video monitoring and tide monitors (for coastal areas) to provide advanced warning of rising water levels to emergency management centres and activation of flood warning signs (Goodwin) [330].These systems eliminate the need for manual inspections of waterways and drain systems, and allows emergency information to be made available to the public sooner.

Low Visibility Warning Systems

These systems employ video cameras at regular intervals along the roadside. When visibility drops below a certain threshold, variable messages signs and/or variable speed limit signs are activated. Different levels of warnings may be used, depending on the visibility level and other weather conditions. Instructions for headlight use and to keep trucks in a single lane, for example, may also be presented to motorists (Goodwin) [330]. The posted warnings and/or speed limit may be determined by the average speed of traffic, the level of visibility or wind speed. These sensors may also be linked to roadside lamps that provide additional delineation of the roadway.

Precipitation/Wind Warnings

These systems employ rain gauge, wind speed, and sometimes visibility detectors to detect potentially dangerous road conditions. When wind speed exceeds a certain threshold, or rain reduces traction or visibility, warnings are presented to road users via radio, VMS, or other ATIS systems. These may also be linked to variable speed limits or traffic management strategies (i.e. signal control, route diversion, lane control). Certain vehicles may be prohibited from using the roadway during extreme conditions.

Wet Condition Warning Systems

These systems may be useful in sites where crashes frequently occur when the pavement is wet, but not necessarily when it is raining. In-pavement sensors detect water on the road surface, and activate a VMS presenting an advised or mandatory speed limit. These systems have been effective in reducing maximum speeds, speed variability and crashes (Goodwin) [330].

Weather-related Signal Timing

Adaptive signal control linked to weather management systems allows the rapid clearance of traffic from specific areas during poor weather. For example, in Florida, rain gauges and vehicle sensors have been linked to signal timing on the major roads leaving a popular beach (Goodwin, 2003). To accommodate the large numbers of traffic leaving the area when rainfall and large queues of vehicles are detected, the signal patterns are modified to minimize congestion and clear roads leaving the beaches more quickly.

Alternatively, signal timing may be used to reduce vehicle speeds during severe weather, where signal phases are increased in duration to slow the progression of traffic. With this strategy, vehicles are stopped at regular intervals, preventing them from reaching high speeds.

The crashes where weather, poor visibility and poor road surface are factors are reduced.

The implementation of an automatic anti-icing system on a bridge in the US was associated with a 68% reduction in crashes compared to other winters of comparable weather conditions (Goodwin) [330], while a pre-emptive anti-icing system in the US has been associated with an 83% reduction in crashes in winter, as well as improvements in maintenance efficiency. Goodwin also reported that multiple applications of low visibility warning devices in the US have been associated with reductions in fog-related crashes, speed variability and maximum speed.

Stowe [331] estimated a benefit-cost ratio of 2.36, an 80% reduction in snow and ice related crashes with the introduction of an automated anti-icing system in the US.

A weather monitoring VMS system was estimated to reduce crashes by 30-40% in various European countries (PIARC, 2000, cited in OECD, 2003) [234]. Fatalities and injuries were conservatively estimated to reduce by 1.1% and 2.0% respectively.

6.5.2.2 Passive Systems

6.5.2.2.1 Incident Management Systems

Incident management systems involve the continuous monitoring of road and traffic conditions in order to facilitate the rapid detection and clearance of crashes. The four main activities of incident management are detection, response, management and recovery (COMSIS, 1996) [332]. The technologies employed by incident management systems may differ, however all typically involve various roadside sensors, a processing centre, road user information displays, traffic management and incident clearance strategies (ERTICO; Kulmala; Archer)[317][325][280].

For example, an incident management system may continuously monitor traffic flow with CCTV and floating car data (http://en.wikipedia.org/wiki/Floating_car_data). When an incident is detected, emergency services and clearance teams are deployed to the site, while other road users are informed of possible delays and hazards ahead via VMS and radio or cellular information services. To reduce delays and congestion, route diversion, adaptive signal timing and dynamic lane control systems may also be employed.

The goal of incident management is faster emergency service response times to crashes, reduction of delays, avoidance of secondary crashes, and reduced exhaust emissions from congested traffic.

Maccubbin, et al. [314] found incident management systems to have shown positive impacts on mobility, productivity, environmental outputs and safety across various implementations in the US, including a 2.8% reduction in crashes.

Incident management systems are typically associated with reductions in incidents, particularly reductions in secondary crashes (eSafety Forum) [239]. It was also noted that many studies which report high crash reductions (i.e., up to 45%) may be statistically biased.

An US combined traffic and incident management system has been highly effective since is inception in 1993 (Taylor) [333]. Upon detection of a crash, traffic is diverted. This has lead to 40% reduction in incidents and an 8% reduction in incident severity.

6.5.3 Co-operative systems

6.5.3.1 Active Systems

6.5.3.1.1 Advanced Traveler Information Systems

Advanced traveler information systems (ATIS) are a class of ITS that provide detailed and up to the minute travel information to road users. ATIS is a broad term for a number of pre-trip and en-route information systems that may be infrastructure-based or in-vehicle. While there are some variations in the type and manner of information provided by different ATIS, there is general overlap in their functional properties. An ATIS system typically provides users information about routes, landmarks, congestion, delays, weather, construction zones and expected travel times. In-vehicle signage systems present information that is presented on infrastructure-based signs (speed limits, route information, etc.) on an in-vehicle display. This information is gathered from various data collection points (video cameras, loop detectors, probe vehicles, etc.) and is collated by a traffic management centre. This information is then provided to users through personal communication devices, infrastructure-based data terminals and in-vehicle devices.

Examples of ATIS are:

- *K*iosks: Fixed data terminals in public locations.
- *PDA*'s: It is personal digital assistance system. Travel information can be broadcast to personal handheld devices.
- *Digital watches*: Limited travel information, e.g., expected delays, can be broadcast to digital watches linked to an ATIS network.
- *Internet:* A wide variety of travel information can be accessed through the internet.
- *In-vehicle devices:* Navigation systems provide addition travel information as well as location via on-board displays. These are referred to as IVIS.
- *Phone:* Free or pay-per-use phone services.
- *Mobile phone:* Users receive a broadcast of travel information services through a hands-free in-vehicle mobile phone unit.
- *Radio:* Dedicated radio channels can be used to continuously provide travel information for a whole region or specific road network/highway (e.g., Highway Advisory Radio systems).
- *Television:* Dedicated television channels.
- *VMS:* Roadside displays.

Estimations of the approximate reductions expected with real-time information systems (assuming 70% penetration of the German passenger vehicle fleet) were reported by eSafety Forum [239]. It was expected that 25% of rear-end injury crashes would be affected, leading to a 12.5% reduction in these crashes, equating to a 0.2% reduction in all crashes.

Lind [334] estimated the long-term potential effects of various emerging ITS technologies in reducing crashes, using expert assessment of various areas of potential safety impact. It was estimated that at 10% implementation of trip planning ATIS, there would be no reduction in crashes, although with 100% implementation, this was expected to be 3%. Public transport information system were not expected to have any reduction effects, even at 100% implementation, while parking systems (that aid motorists in finding available parking spots) were expected to show 1% and 13% reductions in crashes with 5% and 100% implementation rates, respectively.

An in-vehicle ATIS that utilized a mobile phone network was associated with a 2% reduction in crashes (FHWA) [335].

6.5.3.1.2 Advanced Warning Device

Advanced warning devices (AWD) serve to provide advanced warning to road users of the presence of emergency vehicles. The device detects the presence of an on-call emergence vehicle within a given radius, and provides auditory or visual alerts to the user. This can be seen as a simplified version of inter-vehicle communication systems. They serve to alert other drivers of the presence of the approaching emergency vehicle, but do not provide the speed and position information that intervehicle communication does, nor do they transmit information about other vehicles to the emergency vehicle. The system detects the siren and flashing lights of the emergency vehicle before they become visible and audible to the user. This serves to enhance the conspicuity of emergency vehicles, and allow more time for other road users to move out of the way.

A variant of this technology is motorcycle detection systems. Such systems address motorcycle conspicuity crashes, where the driver fails to perceive the motorcycle. Rather than relying on the auditory and visual warnings from the emergency vehicle, the presence of the motorcycle emits a radio or infrared signal from a transmitter mounted on the vehicle. This signal is detected via receivers on the front and rear of the other vehicles and the driver is informed of the motorcycles presence through auditory and visual displays.

Multiple-vehicle crashes at intersections; rear-end crashes and crashes where conspicuity is a factor. This system will also show benefits in the reduction of emergency service response times.

In a simulator evaluation of the effects of AWD found that the advanced warning device was associated with greater reductions in speed than the approaching emergency vehicle without the AWD (Lenne, et al.) [336]. With the AWD, speeds were reduced much earlier than without the device. As soon as the warning was activated speed was reduced, while without the device, speeds remained constant until the emergency vehicle was in the immediate vicinity. Also, participants tended to change lanes earlier with the AWD to clear the path for the emergency vehicle.

6.5.3.1.3 Electronic Clearance/Screening

Electronic clearance systems and strategies facilitate more accurate and more efficient inspection of commercial vehicles and reduce congestion around safety inspection points. Automated screening procedures reduce, but do not eliminate, the need to stop commercial vehicles at safety inspection points and border crossings. Fixed and portable inspection points are still used, however, vehicles with electronic screening equipment are allowed to pass through without stopping provided they meet safety standards, while vehicles that do not have electronic screening capabilities or those that fail to meet safety standards are stopped. Vehicles that are correctly weighted, legally compliant and have good safety records are allowed to pass.

The criteria for stopping vehicles are determined by state authorities. The vehicle is usually equipped with a transponder that passes information regarding registration, cargo, destination, and so on, to the safety inspectors, while weigh-in-motion scales measure the vehicles weight. This information is analyzed and transmitted back to the vehicle along with the necessary permits and certificate of inspection. Electronic license plates may also be involved in these screening systems. The information collected from electronic clearance can be used for both enforcement and to better plan and manage transport networks to suit commercial vehicle traffic flows.

There are four general categories of electronic screening/clearance. A safety inspection point will most commonly employ all or a number of these systems.

Credential Checking

Automated credential checking can be regarded as electronic permit approval and fee charging. Heavy vehicle credentials typically include registration, location of operations, insurance, weight/size limitations, driver licenses, and state/region fuel taxes (Cutchin, 2005) [337]. Electronic credential systems are regulated by a state authority.

Border Clearance

This is essentially credential checking at national border crossings. Border crossing declarations are electronically submitted prior to crossing, and border inspection facilities are therefore able to conduct automated safety screening and credential checking, speeding up the processes of border inspections (Cutchin)[337].

Safety Screening/Automated Vehicle Safety Inspections

Automated safety screening procedures involve the use of in-vehicle telematics that transmit vehicle and cargo information to safety inspection points. This may be information regarding hours of service, cargo type and quantity, previous safety inspections, and the status of various vehicle systems. Other technologies may also be used to screen vehicles at inspection points. For example, Christiaen and Shaffer [338] described an infrared brake screening technology. An infrared image of the vehicles tyres is taken as they brake in their approach to the safety inspection point. If the vehicles wheels appear white, they are warm and the brakes are functioning normally. Dark (cold) wheels indicate inoperative brakes. This is then verified by manual inspection.

Weigh-in-motion

Weigh-in-motion provides a more efficient and objective means of ensuring commercial vehicles are within their weight limits. Weigh-in-motion allows vehicle weight to be determined without it stopping. The system measures the vehicle weight, axle weight and spacing, speed and vehicle height. Weigh-in-motion stations may be permanent, semi-permanent (when the sensor are fixed but the data collection system is portable) and portable. The system involves sensors in or across the road surface linked to a data collection point. The sensors may be bending bar plates, bar sensors, mat sensors or utilize existing bridge structures (ERTICO) [317].

Orban, et al. [340] suggested commercial vehicle screening technologies will enhance safety in direct and indirect ways. Direct safety benefits will stem from the reduction of out of service vehicles on the roads, resulting from the increased enforcement of operating condition standards. Indirect benefits will be seen through more commercial vehicle operators improving their compliance with operating standards as a result of more strict enforcement standards

Electronic screening has been estimated to have cost-benefit ratios ranging between 3.3-6.5 for small commercial vehicle operators to 1.8-3.8 for large operators (Pritchard) [340], and 4.8-12.1 ratios for state governments, depending on the level of implementation, where full implementation was associated with higher cost and therefore a lower ratio (Gillen & Haynes) [341]. It was also estimated that up to $8.6 million US could be saved in crash costs as a result of credentials checking.

Evanco (1997, cited in Lund, et al., 2003) [236] suggested that widespread introduction of automated safety inspections could result in a reduction in commercial vehicle fatalities by up to 15%.

6.5.3.1.4 Fleet Management Systems

The system is also known as Commercial Vehicle Operations (CVO) system. Fleet management systems encompass a number of technologies specifically designed and implemented in commercial vehicles, including buses. These systems are designed to enhance the efficiency of commercial vehicle operations by tracking fleets, better route planning and monitoring of drivers, vehicles and cargo. The majority of these systems are cooperative, in that they involve communication between the vehicle and fleet management centre, or communication between multiple vehicles.

Their potentials is to reduce driver workload and travel times is expected to enhance user safety by reducing overall crash exposure. These systems are relevant to any crashes involving commercial vehicles.

Fleet management systems in combination with electronic clearance has been estimated to reduce fatalities by 14-32% (FHWA) [220], with an annual estimated benefit-cost ratio of 4:1 for medium fleets and 20:1 for larger fleets.

The system encompasses the following methods:

Automatic Vehicle Location; Computer Aided Dispatch
Automatic vehicle location (AVL) allows dispatchers to continuously monitor the location and activities of all vehicles in a fleet. This may involve a number of different technologies, such as GPS, roadside beacons (signposting) and dead-reckoning techniques. GPS based systems track the vehicle via satellite, allowing constant monitoring of the vehicles location. Roadside beacons are more typically used for public transport, where infrastructure-based sensors detect the proximity of a bus. The time, location and bus identification number is transmitted to the dispatcher, usually via fixed cable networks (Jones) [342]. Both these systems may be supplemented by dead-reckoning to provide additional location information when GPS is unavailable or between roadside beacons. Dead-reckoning estimates the position of the vehicle by measuring the direction and distance travelled from a known location. From this, it can be estimated when a vehicle has turned and how far they have travelled. AVL can be integrated with vehicle status monitoring systems, public transport information and signal pre-emption systems.

AVL systems may have passive safety benefits in reducing emergency response times by accurately locating vehicles in the event of a crash.

Cargo Monitoring Systems
Cargo monitoring systems detect unsafe cargo movements and position, and alert the driver and fleet management to this hazard. These systems could reduce goods transport vehicle fatalities by up to 15% (Kulmala) [289].

Digital Tachographs
Digital tachographs record vehicle and journey characteristics such as speed, distance, location, vehicle faults, time travelled and so on (ERTICO) [317]. These systems employ speedometer/odometer, an on-board recording unit, an intelligent senor connected to the transmission, smart card slots, and a printer. Digital tachographs must be tamper-resistant

Electronic Towbar; Electronic Coupling
Electronic towbar systems allow the automation of a convey of commercial vehicles, so that only the lead vehicle requires manual control. The lead vehicle transmits information regarding all

aspects of driving, e.g., acceleration, axle position, indicator use, to all subsequent vehicles via radio communications and infrared pattern detection (Bishop) [231]. This eliminates the disadvantages of a physical towbar, and reduces the number of drivers required per fleet (European Communities, 2000) [221].

Electronic towbars have been estimated to reduce the number of injury and fatal crashes by 143-286 annually in Germany. European Communities (2000) [221] also estimate a global economic benefit of €28.9 million.

Hazardous Materials Systems/HAZMAT
These systems automatically inform emergency services the nature and quantity of hazardous materials that the vehicle is carrying. These are passive systems.

These systems have been estimated to save up to $85 million US in crash costs annually (FHWA) [220].

Smart Cards
Smart cards are often incorporated into driver logging devices or tachographs. Smart cards allow driver identification and store vehicle and driver behavior from in-vehicle recording devices. Smart cards for public transport passengers are similar to personal debit or credit cards (Jones) [342].

6.5.3.1.5 Intelligent Speed Adaptation (ISA)

ISA describes any system which either warns the driver or automatically limits the speed of the vehicle when it exceeds the legal speed limit of a given area. These systems establish the location of the vehicle and compare the current speed with what is the posted speed for that location. If the vehicle exceeds this speed, the system takes effect, either be in the form of a visual or auditory warning (informative system), or intervention (actively supporting systems). Actively supporting systems may provide haptic feedback to the driver through increased pressure or vibration in the accelerator pedal, but this can be overridden by the user.

In addition to these alerting systems, speed limiting systems also exist. These employ speed governors or retarders, which physically prevent the speed of the vehicle exceeding a predetermined limit, whether that is the speed limit or a manually set limit. These systems must be linked to some or all of the vehicles ignition, fuel, throttle or electrical systems. This limit can be set in one of two ways, for both alerting and limiting systems. The current speed limit may be communicated to the vehicle via roadside beacons or through GPS technology. GPS systems store a digital map on an on-board computer, and continuously determine the position of the vehicle in relation to this map with a GPS receiver.

Several types of ISA can be distinguished. This may be in terms of what level of intervention they take, or what type of speed limit is enforced by the system. In terms of intervention, ISA may be:

· Advisory: The system only alerts the user to the speed limit.
· Voluntary/driver select: The user can enable or disable the system.
· Mandatory/limiting: The speed limit cannot be overridden.

In terms of speed limit, ISA may be:
<u>Fixed:</u> The posted speed limit is enforced by the system.

Variable: The driver is additionally informed about (lower) speed limits at special locations, like road construction sites, pedestrian crossings, sharp curves, etc. Therefore, the speed limits are dependent on the location.
Dynamic: The dynamic ISA system uses speed limits that take account of the actual road and traffic conditions (weather, traffic density). Therefore, besides being determined by location, the dynamic speed limits are also dependent on time.

According to the above, there are three main categories of ISA (speed alert) systems, in terms of technology deployed (figure 6.35).

Figure 6.35: ISA systems alternative HMIs'

ISA reduces the Speed related crashes.

Regan, Young and Haworth [343] estimated the following annual cost savings for speed-related crashes in all vehicle types and heavy vehicles (but not buses). These calculations, presented in Table 6.6, were based on an assumed 80% effectiveness and 50% acceptability:

Crash severity	All vehicles ($m AU)	Heavy vehicles($m AU)
Fatal	105.1	16.6
Serious injury	232.8	26.5
Injury	52.5	3.2
Property damage only	19.9	3.2
Total	304.4	49.4

Table 6.6: Expected reductions in crash costs associated with ISA for various crash severities.

Carsten and Fowkes [344] and Carsten and Tate [345] estimated the potential for the variants of ISA to enhance user safety in the UK. The best estimates of crash reductions are presented in Table 6.7:

System type	Speed limit type	Injury reduction	Fatality reduction	Fatal and serious injury reduction
Advisory	Fixed	10%	18%	14%
	Variable	10%	19%	14%
	Dynamic	13%	24%	18%
Voluntary	Fixed	10%	19%	15%
	Variable	11%	20%	16%
	Dynamic	18%	32%	26%
Mandatory	Fixed	20%	37%	29%
	Variable	22%	39%	31%
	Dynamic	36%	59%	48%

Table 6.7: Reductions in fatal and injury crashes expected with ISA system variants

6.5.3.1.6 Intersection Collision Avoidance

Intersection collision avoidance systems rely on roadside sensors to detect the presence of vehicles approaching the intersection. The number of vehicles, and their speed and location relative to the intersection is communicated to the road users either via on-board displays within the vehicles (cooperative systems) or via roadside displays (infrastructure only systems).

Various intersection collision avoidance system concepts exist (Ferlis) [346]:

Traffic signal violation warnings and stop sign violation warnings: Act to remind the violator of the traffic signal and warn other road users of the hazard. Roadside sensors detect that an approaching vehicle is unlikely to stop, and visual warnings are activated. These remind the (potentially) violating vehicle that there is a red signal/stop sign ahead, and alert other road users in adjacent roads that the intersection may not be clear. This may occur either through a VMS, warning lights or haptic feedback (an ‘intelligent rumble strip’, Ferlis) [346].

Left turn assistance **:**(note: this is a US system; this would be right turn assistance in Australia, UK etc.): Vehicles performing turns across traffic are informed of the gap between oncoming vehicles. Roadside sensors monitor the distance between vehicles passing through the intersection, and advise the turning vehicle through VMS or a modified turning arrow when there is a safe gap.

Stop sign movement assistance systems**:** Inform road users when it is safe to move on from a stop sign, that is, when there is a sufficient brake in traffic from adjacent directions. This is similar to left turn assistance, where the distance between vehicles is monitored by roadside beacons and the gap advisory information is presented on a VMS or other signal. Another type of intersection collision avoidance involves the automatic detection of traffic signals (Bishop; eSafety Forum) [231] [239]. Visual imaging techniques detect a stop signal or red light ahead and advise the user if they are not slowing sufficiently, or automatically alert the driver to other traffic signs.

This system reduces the multiple-vehicle crashes at intersections. Studies cited in OECD (2003) [234] reported a 50% reduction in intersection crashes with the introduction of intersection collision avoidance systems in the USA, and a reduction in crashes involving vehicles from opposite directions by 46% in Japan.

Studies cited in OECD (2003) [234] reported a 50% reduction in intersection crashes with the introduction of intersection collision avoidance systems in the USA, and a reduction in crashes involving vehicles from opposite directions by 46% in Japan.

The Invent project suggested that approximately 60% of city accidents and 29% of all accidents with severe injuries could benefit from this system.

6.5.3.1.7 Inter-Vehicle Communication Systems

Inter-vehicle communication systems provide real-time information to road users about the proximity of other vehicles. These systems give road users advanced knowledge of approaching vehicles outside their field of vision (i.e. on curves), or in complex driving situations. Information about other vehicles is detected and displayed on a heads-up display, navigation console or via auditory guidance.

Variants of inter-vehicle communication systems exist:

Vehicle-vehicle communication: These systems allow vehicles to directly communicate their speed, position, course, and vehicle type to other vehicles. The system is two-way, in that vehicles both transmit and receive vehicle information so that all road users have an enhanced knowledge of the dynamic road environment.

Vehicle-infrastructure-vehicle communication: Roadside beacons on the approach to an intersection or hazardous curve detect the presence, speed and size of oncoming vehicles. This information is then transmitted to other vehicles that are also approaching the area.

Multiple-vehicle crashes at intersections, head-on crashes; rear-end crashes.

The system reduces the crashes where conspicuity is a contributing factor.

Estimations of the approximate reductions expected with inter-vehicle ‘hazard’ warnings in Germany (assuming 70% penetration of the passenger vehicle fleet) were reported by eSafety Forum [239]. These systems communicate information regarding road environment hazards to other vehicles. It was expected that 25% of injury crashes in slippery conditions would be affected, leading to a 12.5% reduction in these crashes, equating to a 0.7% reduction in all crashes.

6.5.3.1.8 Navigation Systems

It is also known as Route Guidance System. Navigation systems provide dynamic and personalized travel information to the user, as well as the ability to plan and share travel routes. These systems may be either in-vehicle or employ a mobile device such as a PDA. On-board systems tend to be better integrated into the HMI, however, they are limited by the inflexibility of the data stored within the unit. Mobile device systems allow access to a wider range of information but do not have the same usability benefits as on-board systems (Mitterreiter, Schlagmann & Stocker) [347]. Hybrid systems, which are integrated into the vehicle in a similar way to on-board systems and allow regular updating of information, may serve to improve the safety of these units considerably.

Navigation systems are typically designed to find the shortest or fastest route to the given destination. However, they also may incorporate safety information. This involves the programming of crash statistics into digital maps (Rumar, et al.) [219].

While these systems may not show direct safety benefits, their potential to reduce driver workload and travel times is expected to enhance user safety by reducing overall crash exposure.

Lind, et al. [236] estimated that route guidance systems that show a preference for safer alternative routes have the ‘verified’ potential (based on other studies) to reduce all road fatalities by less than 0.5%, while the ‘full’ potential (an optimistic estimate based on full deployment) is also less than 0.5%. This was expected to be a result of increased distraction due to the in-vehicle unit.

McKeever [218] estimated the predicted system-wide effects of the full deployment of numerous ITS on all fatal and injury crashes in the US. It was predicted that a 0.2% reduction in fatalities and a 0.3% reduction in injuries could be expected with in-vehicle navigation systems. McKeever further reported an estimated 1% reduction in crashes in urban areas with navigation systems in the USA.

6.5.3.1.9 Pay-As-You-Drive Insurance

Pay-as-you-drive insurance systems record the distance, time, location and frequency of travel using in-vehicle telematics and GPS tracking. This information is then assessed by insurance companies to calculate a monthly/annual payment. These systems allow a user-pays approach to insurance, and can be used to discourage particular driving patterns. For example, drivers may be charged higher rates for driving in high alcohol times, or for driving for excessively long journeys where fatigue may become a factor.

The system involves an in-vehicle unit that records and calculates driving behavior, much like an electronic logging device in commercial vehicles. A GPS system monitors vehicle location, and the information is sent via a mobile network to the insurance company. Other versions of pay-as you drive insurance records only mileage (from odometer readings), and does not track the time, location or pattern of driving behavior.

Crashes where speed, fatigue, intoxication are contributing factors. Indirect benefits may also be seen from reduced crash exposure.

6.5.3.1.10 Railway Crossing Systems

Railway crossing systems serve to enhance the safety of road users at signalised railway crossings. They are cooperative systems, in that the infrastructure-based signals require coordination with the rail network or approaching trains. Numerous systems may be applied to railway crossings in order to better coordinate signals, enhance warnings to road users, or enforce crossing laws.

Methods for detecting the presence of trains include tag readers (with tags located in each carriage of the train), acoustic detectors, lidar and radar. Railway crossing signals may also be integrated with nearby traffic signals to better facilitate the flow of traffic and prevent congestion around railway crossings (Lee, et al.) [348]. Other techniques to improve the efficiency and safety of railway crossings include consistent warning times for crossing signals, leaving crossing gates open when trains are stopped at stations near the crossing, minimizing transient gate openings (when the gates open for a brief period, i.e., less than 15 seconds, before closing again), and railway crossing cameras

This system reduces the crashes between trains and pedestrians and vehicles.

Hellman [349] found that a four-quadrant crossing gate combined with an indicative loop vehicle detection system resulted in a significant reduction in vehicle entering the crossing after the crossing signal lights were activated, and a 100% reduction in vehicles entering the crossing after the gates were deployed.

The system encompasses the following methods:

Advanced Warning for Railroad Delays

Sensors along railway lines on the approach to crossings detect the speed, length and proximity of approaching trains. This information is used to calculate the expected time delay caused by the train at the crossing, and this information is passed onto road users via variable message signs. The aim of such systems is to encourage road users to take detours to prevent congestion around railway crossings

An estimation of the effectiveness of advanced warning systems predicted an 8.7% reduction in crashes with even only 20% of drivers responding to VMS delay warnings (Carter, Luttrell & Hicks) [350]. If this compliance increased to 45%, time savings of 19% were also expected.

Automated Horn Warning

The provide additional warnings to road users that a train is approaching but eliminate the noise pollution typically associated with train horns. Rather than a horn located on the train itself, which has to be sounded from a considerable distance to give road users sufficient warning, the horn is part of the crossing infrastructure. The same mechanisms that activate the crossing signals also activate the horn. This localizes the sound to the area of the crossing only. Activation of the horn is indicated by a display in the train cabin. If this fails to activate, the driver is alerted and can manually sound the train horn.

Gent, Logan and Evans [351] found an automated horn warning system to significantly reduce the negative noise effects of traditional train horns without compromising crossing safety.

In-vehicle Warning System; Vehicle Proximity Alert

The system provides an in-vehicle visual and/or auditory alert to road users that an active railway signal crossing is ahead. Activation of the crossing signals also causes a radio signal to be transmitted from the crossing. Vehicles equipped with transmitters in the vicinity detect this signal, and the in vehicle alert is activated. Information such as the distance of the vehicle to the crossing may also be provided, as well as whether there is a train present. This system has been implemented in school buses in the US, where the system automatically adapts the auditory warning so that it can be heard over the ambient noise in the bus (SRF Consulting Group) [352]. Other applications include emergency vehicles, commercial vehicles and vehicles carrying hazardous materials (Carroll, Passera & Tingos) [353]. In order to minimize false alarms, the system is only activated when the vehicle is travelling toward, not away from, the crossing.

Obstacle Detection Systems

Radar, laser, lidar or inductive loop sensors obstacle detection systems may be used to detect the presence of road users or objects in the crossing area. Traditional systems are only able to detect objects as large as cars, leaving pedestrians, bicyclists and motorcyclists vulnerable. However, more advanced systems have been developed. The presence of a vehicle or pedestrian in the crossing is detected by the system, and this information is provided to the driver of the oncoming train.

Lee, et al. [348] estimated the economic benefits of full and incremental deployment of various railway crossing technologies. Savings of around $81,000 and $320,000 US in collision costs could be expected with full deployment of a VMS warning system and stationary vehicle detection systems, respectively. With incremental deployment of the stalled vehicle detection system, savings of $26,000 US were expected.

Railway Crossing Cameras

Automated enforcement strategy to prevent road users disobeying crossing signals. See Automated Enforcement Systems.

McKeever [218] estimated the predicted system-wide effects of the full deployment of numerous ITS on all fatal and injury crashes in the US. It was predicted that a 0.8% reduction in fatalities and a 0.2% reduction in injuries could be expected with rail crossing enforcement technologies.

6.5.3.1.11 Road Geometry Warnings

Vehicle warning systems provide feedback to road users on potentially hazardous sections of road, such as corners, steep descents and curved ramps. These systems may involve in-vehicle units or infrastructure-based warnings and signals. Essentially, speed warnings based on upcoming changes in the road geometry are communicated to the driver, either through an on-board display or via message signs on the roadside. This advice may be in the form of a recommended speed, a warning that the vehicles current speed is too fast, or information regarding the angle and camber of the road ahead.

Infrastructure-based: Roadside speed sensors detect the speed of vehicles approaching a curve. If the speed of the vehicle is deemed too fast, VMS display warnings or advisory speeds. Variants of this system resemble speed feedback indicators, where the vehicles actual speed is presented next to the suggested speed.

In-vehicle: Upcoming curves are detected through on-board navigation units (GPS, etc.) or a roadside beacon transmits the warning to an in-vehicle unit. The current speed of the vehicle relative to the geometry of the curve is assessed, and the driver is warned if vehicle speed should be reduced (Bishop) [231]. Variants of this system may only advise that a curve is ahead, without the speed warning function. A system described by Sayer and Devonshire [354] incorporated a two-stage alert. The first stage involved haptic feedback (seat vibration), while the second stage elicited an auditory warning. Another variant, NAVTEQ's Electronic Horizon, monitors the speed and position leading traffic in relation to a digital map and indicates to the driver when it is safe or unsafe to overtake the leading vehicle (Telematics Journal) [355].

The off-path on curve crashes; off-path on straight crashes and crashes where speed is a contributing factor are reduced.

Estimations of the approximate reductions expected with speed alerts for 'black spots' in Germany (assuming 70% penetration of the passenger vehicle fleet) were reported by eSafety Forum [239]. It was expected that 50% of crashes on black spots would be affected, leading to a 1.75% reduction in these crashes equating to a 1.75% reduction in all crashes.

Infrastructure-based systems which provide warnings to road users about downhill and curve speed, and rollover warnings have been deployed to a limited degree in the USA, and have been regarded as a success (FHWA) [302].

A similar system using weigh-in-motion and VMS preceding a steep decline was associated with a 13% reduction in speed-related heavy vehicle crashes, and 24% fewer trucks used the runaway ramps in this area (Inside ITS, 1997) [356].

6.5.3.1.12 Rollover Warning Systems

Rollover warning systems provide feedback to heavy vehicle drivers on potentially dangerous curved sections of road, such as highway ramps. Similar to curve speed warnings, the system assesses the approaching vehicles speed and advises the driver through a VMS or other such visual warning if their speed is too great. However, rollover warning systems also involve additional sensors that determine whether the heavy vehicle is likely to rollover. The critical threshold for a given vehicle to rollover is determined by sensing the vehicles speed, height and weight (with weigh-in-motion sensors), compared with the curvature and camber of the road.

The rollover crashes, off-path on curve crashes involving heavy vehicles are minimized with this system.

Strickland and McGee [357] reported significant average speed reductions (8.3 mp/h) with the use of a rollover warning system for heavy vehicles. No rollover collisions occurred in the 3-year evaluation period following instillation of the system, compared to 10 rollover crashes in the preceding 5 years.

A study of the Cambridge University Engineering Department, suggests a reduction of 29% of rollover related accidents for semi-trailers and 20-30% for trailers. (Sampson & Cebon

6.5.3.1.12 Vehicle Pre-Emption Systems

Vehicle pre-emption systems involve cooperation between the infrastructure and certain vehicles. Emergency vehicles, buses or trains are given priority signals at intersections. Signal pre-emption systems facilitate the movement of emergency service and public transport vehicles through signalized intersections. Traffic signals may not automatically change to green for buses, but they may experience shortened red signals. Rather than skipping signals, the system speeds up signals that conflict with the priority vehicles needs. Also, the system may only be used when the bus is already delayed.

These systems may function in one of two ways:

<u>Vehicle-signal communication</u>: They may involve in-vehicle transmitters and roadside receivers which detect approaching vehicles and maintain or change to a green signal until the vehicle has passed through the intersection. This may involve an infrared signal or radio transmitter to communicate vehicle location with infrastructure. Sensors within traffic signals detect an approaching emergency vehicle or bus, either via visual imaging, sound or light detectors (which recognize the siren and/or flashing lights of the vehicle), infrared or radio communication. The traffic signal pattern can be interrupted so that the priority vehicle has a green signal until they pass through the intersection.

<u>Management centre-signal communication</u>: Other forms of vehicle pre-emption utilize automatic vehicle location and remote control of traffic signals. Of course, the accuracy of the AVL is very important in these systems (Jones) [342]. Traffic signals are managed through coordination between fleet management centres and traffic control centres. Information from automatic vehicle location systems is used to alter the traffic signal, without the use of vehicle sensors located at each intersection.

Multiple- vehicle crashes at intersections. These systems are also expected to show benefits in reduced emergency service response times.

Maccubbin, et al. [314] regards signal priority for public transport vehicles to have had positive impacts on mobility, productivity and efficiency. Emergency vehicle pre-emption was deemed to have had significant positive impacts, reducing response times by up to 23%.

PIARC (2000, cited in OECD, 2003) [234] reported a benefit-cost ratio of 4.8 for emergency vehicle preemption.
Perrett and Stevens (1996, cited in Lind, et al.) [236] estimated that emergency vehicle priority systems will result in 2% of crashes will reduce in severity (i.e., fatal crashes will become serious injury, serious injury will become minor injury).

6.5.3.2 Passive Systems

6.5.3.2.1 Automatic Crash Notification

The system is also known Mayday Systems, Emergency Notification Systems.

Automatic crash notification (ACN) systems aim to reduce critical incident response times to crashes by automatically informing emergency services when and where a crash has occurred. Automatic crash notification uses input from the vehicles ignition, acceleration, tilt and shock sensors to determine if the vehicle has crashed. Often ACN is linked to the vehicles airbag system, so that any crash severe enough to result in the airbag being deployed will also activate the ACN.

Emergency services are automatically contacted through a mobile telephone network and the location of the vehicle is provided by a GPS systems. More advanced systems are able to inform the emergency services of the severity and nature of the crash, and may have speakers so that the driver can communicate with the emergency services operator. The system can usually be overridden by simply pressing a button.
ACN should perform several important functions. The system should be able to inform the user that emergency services have been contacted and when they are due to arrive through auditory and/or visual displays, the system should provide information to the user from the emergency services operators, and the system should update this information in real-time.

The system reduces all crash types. These systems are expected to show benefits in reduced emergency service response times.

According to Abele, et al. [232], at maximum potential effectives, ACN systems have the potential to reduce the severity (i.e., reduce fatal crashes to serious injury, serious injury to minor injury) of 15% of all crashes, and reduce incident related congestion by 20%. Even if ACN only has minor effectiveness, it is still expected to reduce fatal crash severity by 5% and serious injury severity by 10%, while reducing congestion by 10%.

Various European studies have estimated that 5-15% of all fatalities could be reduced to serious injury and 10-15% of serious injuries could be reduced to minor injuries with ACN. No effect on minor injuries is expected (eSafety Forum) [239].

Estimations of the approximate reductions expected with ACN in Germany (assuming 70% penetration of the passenger vehicle fleet) were reported by eSafety Forum [239]. It was expected that 12% of fatalities in rural areas and 7% of fatalities in rural areas would be prevented, with an overall reduction in fatalities of 11%.

Lind, et al. [236] estimated that ACN has the potential to affect 40% of remote fatalities in Sweden, and predicted that by the year 2015, these systems would these fatalities by 30%. It was also estimated that ACN has the 'verified' potential (based on other studies) to reduce all road fatalities by 0.8%, while the 'full' potential (an optimistic estimate based on full deployment) is 1%.

Regan, et al. [240] estimated that ACN systems could result in reduction of approximately 5% of fatal crashes (which became serious injury crashes), with an estimated annual saving of $21 million (AU). This analysis assumed that ACN would have no effect on serious or minor injury crashes.

The eImpact project suggested that the introduction of the "e-Call" system will allow a reduction of 5 % to 15 % of road fatalities to severe injuries and 10% to 15 % of severe injuries to slight injuries (2005).

6.6 ITS AROUND THE WORLD

The basic reasons for introducing ITS are similar everywhere in the world. These include [360]:

Efficiency
•Enhancing mobility for both people and freight
•Reducing traffic congestion
•Managing the transportation infrastructure more effectively and economically

Safety
•Reducing the number and severity of crashes, to lower the number of traffic-related deaths and injuries.

Environment
•Reducing the environmental impact of cars, trucks, and buses, by reducing fuel consumption and emissions

The world regions which led the introduction of ITS – Europe, the U.S., and Japan – use approaches that have many features in common, including:

•An interest in pursuing advanced technology and applying it to social and economic problems
•A desire to expand the capabilities of the transportation system in a well-integrated manner
•A strong desire to expand existing markets and open new ones
•A belief that the best results are produced through the cooperative efforts of industry, government, and academia.

However, each world region also has its own individual approach to introducing ITS -- its own "ITS Culture."

Europe

Europe has a long tradition of applying technology, including computers and communications, to broad social issues including safety and mobility. As Europe continues to move toward a common continental economy, ITS is playing an important role in lowering barriers for the movement of people and freight throughout Europe. ITS is regarded both as a transportation tool and as part of Europe's Information Society.

Europe has been able to introduce transport control technology to advance social goals. This includes using technology to limit the speed at which trucks can travel and "intelligent speed adaptation" which advises vehicles of safe speed limits and has the capability to limit driving speed. Europe is taking a very aggressive approach to traffic safety, with the objective to halve the number of traffic fatalities by 2010 and aim for "zero traffic fatalities" by 2020. This is part of a public-private sector initiative called "eSafety" that is being led by the EU's Information Society Directorate. eSafety's objective is to improve road safety by using Intelligent Vehicle Safety Systems, and it has established a timetable for the Europe-wide adoption of in-vehicle systems like antilock brakes, electronic stability control, automatic crash notification, etc.

Europe has been very successful in establishing partnerships to conduct tests and demonstrations among European national and city governments, vehicle manufacturers and suppliers, and universities. Europe has also succeeded in establishing a robust industry for ITS infrastructure systems and end-user products, with customers worldwide.

Europe is attempting to reform the way it charges for the use of the road infrastructure, although this process is still regarded as very controversial politically. An EC directive called Eurovignette (www.eurovignettes.eu) prescribed moving toward a road charging system, starting with heavy trucks, based on vehicle weight, distance traveled, and other criteria. This has been experimentally introduced in Germany and Switzerland, and there are plans to introduce it in the UK in 2006. Although huge interest has been expressed for these schemes, there are continuing arguments about their consistency and fairness.

Figure 6.36: eSafety for Road Safety in Europe

Europe takes a very active and aggressive role in regional and international ITS standards activities to advance it are ITS technology in the world market. The European Committee for Standardization (Comité Européen de Normalisation – CEN) has a technical committee (TC278 – Road Traffic and Transport Telematics) focused on ITS standards issues. TC278 works in close cooperation with the ITS Technical Committee (TC204) of ISO. Many ITS standards items are developed in parallel by ISO/TC204 and CEN/TC278.

Like other parts of the world, Europe has had little success in introducing telematics (wireless delivery of information and services to vehicles). Several attempts to develop telematics services by vehicle manufacturers and wireless carriers have been unsuccessful. General Motors' OnStar service is attempting to enter the European market, but is far from being profitable. A few companies in the UK (Trafficmaster and ITIS, http://www.itisholdings.com/) and France (MediaMobile) are delivering rudimentary real-time traffic information. Similar to Global positioning system (GPS), GALILEO is a global navigation satellite system (GNSS) currently being built by the European Union (EU) and European Space Agency (ESA). Service will be tested as of 2014 and will be provided as Galileo reaches full operational capability with a constellation of 30 satellites. The Satellite information data could also be beneficial for using 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.

USA

The U.S. government recognizes ITS as an important, even crucial part of the future transportation infrastructure. Most U.S. government efforts in this field have aimed at introducing ITS to traffic managers and working toward interoperable traffic management and traveler information systems.

ITS has been an important part of major highway transportation laws. These laws set government directions and provide funding for transportation programs. They include the Intermodal Surface Transportation Efficiency Act (ISTEA, 1991) and the Transportation Equity Act for the 21st Century (TEA-21, 1998). The latest version of this highway reauthorization legislation (tentatively called the Safe, Accountable, Flexible and Efficient Transportation Equity Act, or SAFE-TEA) is still being developed, but is expected to be adopted in the fall 2004.

Safety is also an important issue in the U.S., although it is pursued less aggressively than in Europe. The U.S. Dept. of Transportation sponsored an Intelligent Vehicle Initiative to test and demonstrate in-vehicle technology to enhance driving safety. This program has now concluded, but important portions are continuing, namely the development of intersection collision avoidance systems and integrated vehicle safety systems.

The deployment of safety products in the U.S. has been hindered by concerns about product liability lawsuits and, in general, the domestic ITS industry is less robust in the U.S. than in Europe or Japan, especially for ITS in-vehicle and consumer products.

The most important new program in the U.S. is called “Vehicle-Infrastructure Integration.” The objective of this program is to create an integrated, intercommunicating surface transportation system. The system will use wireless communications, primarily DSRC (Dedicated Short Range Communication) to link the infrastructure and its managers with vehicles and their drivers. It will gather and share information about the transportation system to help improve the performance of the infrastructure, vehicles, and drivers. This effort currently includes U.S. DOT, state transportation departments, and auto manufacturers.

Another program that is becoming wide-spread in the U.S. is called “511”. The digits 511 have been reserved as a nationwide telephone number for obtaining traveler information. Several states are already providing 511 services, consisting of current traffic information, weather and road conditions, and public transport information. U.S. DOT is encouraging and helping to fund the national 511 deployment. So far 43 of the 50 states plus the District of Columbia have collectively received over $4 million in 511 planning support.

Since the terrorist attacks of Sept. 11, 2001, transportation security has also been a major issue in the U.S., though most of this focus has centered on air travel. The Bureau of Customs and Border Protection of the new U.S. Dept. of Homeland Security uses ITS to monitor freight crossing into the U.S.

Electronic toll collection (ETC) is becoming widespread in the U.S. as a means to reduce delays at toll barriers and lower the cost of collecting tolls. There are, however, many incompatible ETC systems in the U.S., but there has been some success in making systems interoperable in certain regions (e.g., EZPass in the New York City metro area). One insight from this effor t is that arranging compatible technology is not nearly as hard as making compatible organizational and administrative arrangements.

In the U.S., there is great political resistance to changing existing roads from “free” to toll, even though the U.S. is potentially approaching a crisis in funding road construction and maintenance. Funding now depends primarily on a fairly small gasoline tax (less than five cents per liter). The total amount collected is likely to decrease in the coming years as vehicles become more fuel-efficient and begin to use alternative fuels like ethanol and hydrogen. ITS offers the prospect of far more flexible ways of charging for infrastructure use (e.g., based on time of day, level of congestion, required level of service, demand, etc.), but this will require a shift in the thinking of how to fund the development and maintenance of t transportation infrastructure.

Japan

The promotion of ITS in Japan today is led by four Ministries and Agencies. The National position on ITS promotion was laid down in 1995 in the "Basic Guidelines on the Promotion of an Advanced Information and Telecommunications Society." Japan recognizes ITS as an opportunity to advance its industrial and trade interests as well as a means to improve domestic transportation. Japan pursues international ITS standardization with a view to encouraging international competition and safeguarding Japan's competitive position.

Japan has been very successful in translating its strengths in electronics technology into successful ITS. The most prominent ITS programs in Japan are the widespread adoption of car navigation systems and the nationwide deployment of the Vehicle Information and Communication System (VICS), which provides real-time traffic information to vehicles. Japan's complex and congested road system has made these technologies particularly attractive to the driving public. In addition, Japanese consumers have traditionally been early adopters of new technology-based products and services.

Japan's emphasis on ETC deployment has mainly been to reduce congestion at toll barriers, with less emphasis on improving the efficiency and reliability of collection. Deployment of ETC was relatively late in Japan due to its insistence on having a nationally interoperable system. However, this was undoubtedly a good long-term approach. Japan is encouraging the spread of ETC by discounting electronically collected tolls and by subsidizing the purchase of ETC transponders (making their cost less than US $50). Between May 2003 and May 2004, the number of ETC transponders in service in Japan tripled from 1 million to 3 million, and, as of May 2004, nearly 20% of tolls were being paid electronically.

Dedicated Short-Range Communications (DSRC), which is used for ETC, is also being deployed for use with VICS. The intention is to use this communications infrastructure as a basis for multiple other ITS applications.

ITS Culture in Developing Countries

Many developing countries are well on their way to having their own ITS cultures. An examination of the three major developing regions (East Asia, Eastern Europe, and Latin America) reveals both common and individual characteristics.

All three regions have introduced basic systems to manage road traffic. These include traffic signal systems, traffic surveillance systems using CCTV, and traveler information systems based on variable message signs (VMS). As expected, systems that provide a high rate of return on investment have the greatest likelihood of being introduced. These include electronic toll collection and fare payment systems, commercial vehicle tracking systems, and bus management systems.

Regional characteristics include:

In East Asia: Traffic information services have become common using multiple broadcasting and communications media.

In Eastern Europe: Road management systems have been introduced to identify road surface conditions, reflecting an emphasis on improving infrastructure maintenance. In addition, the trading of "empty cargo space" has become common, to improve the efficiency of freight logistics.

In Latin America: Border-crossing systems have been introduced as a result of the regional emphasis on promoting cross-border trade to increase the economic strength of the region

6.7 PRINCIPALES FOR ASSESSING ADVANCED TECHNOLOGY

A number of principles can be followed in the assessment of advanced technology proposal which are given as below [361]:

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

In addition, there are advantages if

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

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

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) [365]. Three broad-based categories of evaluation approaches are currently being used [366]:

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.

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) [367] 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 summarized 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.

6.8 CONCLUSION:

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 cooperative 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. The relevance of those systems in terms of crash avoidance/reduction, as well as in derived injuries is also describes. Some of the systems have been found to be especially effective (ESC, e-Call, ACC), while the effectiveness of some other systems is not proved to be so relevant. Nevertheless, most of them act simultaneously or have a similar function (e.g. Lane Changing Assistant or Lane Departure

Warning), or even they interact between the car/user and the road (e.g. Traffic Sign Recognition), what makes them more efficient.

The importance of passive safety systems in the future has been found to be related to active systems, which are called “combined active and passive systems”. In that field, the most relevant systems are the ones that act just before a crash occurs. Some of those Pre-Crash systems use some forward-facing sensors, such as in the case of collision avoidance systems, to determine the eminent crash and prepare the vehicle to minimize the effects of the crash. For example, passive safety systems like the seatbelt pre-tensioners have the objective of diminishing the consequences of a crash in case it occurs. Some other systems consist on the detection of elements on the road that can interfere in the trajectory of the vehicle (e.g. the Automatic Pedestrian Detection or the Animal Detection System), which derives also in an important reduction of crashes and injuries.

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.

CHAPTER 7
CONCLUSION AND RECOMMENDATIONS

Road safety policy is an excellent strategy to minimize road fatalities. The strategy provides for the systems approach outlined which requires fundamental, wide scale, long-term re-working of various aspects of the design and operation of the national traffic system, to achieve better interface between human, and vehicle and road environment. Most of the casualty reduction progress to date, however, has been achieved through securing compliance with key safety rules through a combination of police enforcement and publicity and realizing benefits in the vehicle fleet from vehicle improvements arising, in the main, from overseas regulation and consumer information. Reaching the targets, against rising traffic, will mean that these two strategies will need additional initiatives (and both hold much further potential). In the other three key policies of the systems approach - managing exposure to risk (e.g. restrictions on licensing, access to powerful vehicles, area-wide safety impact assessment on land-use and transport planning provisions and encouraging choice of safer transport modes), shaping the road environment for injury prevention; and post impact care - implementation and monitoring needs to be put in place as soon as possible in several areas to achieve the systems approach rationale.

The creation of a long-term vision for road safety beyond 2010 which draws together those visions in existing transport strategies could be useful, given that these visions for transport and injury prevention might be perceived to be in conflict. The qualitative and quantitative gaps provide opportunities for renewed political leadership in road safety in rolling out a series of evidence-based policy packages with new and current measures covering the priority areas of the strategy, especially in relation to engineering safer roads, improving vehicle safety, managing vehicle speed, improving pedestrian and cyclist safety, improving young and novice rider and driver safety and combating drinking and driving. Developing and implementing evidence-based packages in no way excludes innovative measures (properly monitored so as to learn from them) to try to address problems such as fatigue, where research has provided only limited pointers so far to effective countermeasures, and new phenomena such as the mobile phone, where early action seems plausibly to be required ahead of longer term research. But of course, such interventions should not divert resources from the mainstream packages.

As mentioned in chapter 5, Education and training of road users, enforcement of road rule, safer road infrastructure, safer vehicle, modern technology and protect vulnerable road user emphasized by European Union. The improvement of education, training and enforcement are very essential for the road user because they are the first link in the road safety chain. Traffic enforcement, safer vehicle, promote modern technology and protect vulnerable road user should be monitored properly because by implementing above this, it is possible to improve road safety substantially. Seat belt use has a great importance to improve passive safety for the users. Seat belt use should be mandatory for the car users in every country and it should be monitored by proper authority to reduce the consequences the road fatalities.

In U.S.A, they emphasized five policy objectives to reduce road fatalities such as: Exceeding speed limit, Use of safety belt, Drink driving, Night time driving and young drivers. Not only in U.S.A but also all over the world, statistics shows that the highest number of male and female young drivers whose age limit within 15 to 20 years are killed by road accident. Several countermeasures have been adopted to address the particular crash characteristics seen among young drivers. Most of these are policy based. High rates of alcohol related fatal crashes led to changes in states' minimum legal drinking age laws, and by 1988 all states had raised their drinking age to 21. During the changeover, states with a minimum legal drinking age of 21 were found to have substantially fewer single vehicle, nighttime (proxy for alcohol related) fatal crashes among drivers under age 21. In 1998, all states had also adopted lower legal blood alcohol concentration limits for drivers under age 21 ("zero tolerance" laws). During that changeover, states with a zero tolerance law were found to have further decreased their rates of single vehicle, nighttime fatal crashes. Drink driving is another problem for road safety which occurs by young driver mostly. Young adults ages 20 to 24 have the highest rates of alcohol impaired driving and alcohol involved fatal crashes of any age group. Alcohol should not be sold between 2.am to 7.0am which could be a better solution for improving road safety. On the other hand if it is not possible then public transport should be available in whole night which could play an important role for road safety. It is only possible for big city which is open for 24 hr, for small city it is not the solution. Nighttime driving risk is influenced by a number of factors that are not unique to nighttime including alcohol, fatigue, and the proportion of young drivers. The defining characteristic of night driving, lack of natural light is the only major factor that is unique to nighttime. Recent studies of crash data have been reasonably successful in isolating the component of increased risk at night that is attributable to darkness itself rather than the other factors that vary between day and night. So to ensure sufficient light in road infrastructure could be reducing road fatalities.

In Asian region, developing country like India has considered it relevant to frame a draft National Policy on Road Safety covering both preventive and post-accident aspects of Road Safety encompassing initiatives of public policy as well as implementation aspects, as also the responsibilities of various stakeholders. The Indian government could undertake additional steps to promote road safety practices at national, state and local levels. Safety conscious planning and design of roads and road networks could be encouraged whilst undertaking new as well as up gradation and rehabilitation road schemes through application of road safety audits. Continuing application of Intelligent Transport System (ITS) to achieve safe and efficient transport system will be encouraged. Safer vehicle is very important in order to reduce road fatalities. The government could take steps to strengthen the system to ensure that safety aspects are built in at the stage of design, manufacture, usage, operation and maintenance of vehicles in line with prevailing international standards in order to minimize adverse safety and environmental effects of vehicle operation on road users and infrastructure. In order to manage driving license problem especially for young drivers the government could strengthen the system of driver licensing and training to improve the competence and capability of drivers. Improvement the manpower both quantitatively and qualitatively, tests and the driving ability of all license applicants should be evaluated. This would be done by a system of accreditation of the quality of testing and evaluation of drivers. In this manner it could be possible to get safer driver. In order to manage traffic enforcement the government could take appropriate measures to assist various state and other governments to improve the quality of their enforcement agencies. By applying all this policies road safety could be improve substantially and we can save lot of human life.

OVERARCHING ISSUES REGARDING INTRODUCING NOVEL TECHNOLOGIES ON ROAD SAFETY:

Motorized 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 realized and possible disbenefits are minimized. This may result in a need for changes in current practices, *e.g.* in traffic laws and the education of road users

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.

In the next paragraphs the government objectives, human factors, social acceptance and education, standardization, regulation, legal issues, data collection and use and implementation issues are addressed to promote the introduction of new safety technologies and limit the potential for the development of unsafe technologies.

Aligning national transportation visions for deployment of new technology:

There is a need to balance international standardization 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 standardization 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 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 adaptable system architecture are essential parts of the vision.

Human factors considered for the deployment of new technology:

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 reduce. 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).

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:

- 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 ADAS (advanced driver assistance systems) provides 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.

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 behavior detrimental to safety should be minimized.

Education and social acceptance issues of new technologies:

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. ITS systems affecting safety and mobility will require drivers to acquire new knowledge in order to realize 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

The need to improve road transport efficiency and safety is well accepted. 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 behavior. The public needs to appreciate that a new technology fulfils a useful purpose and that they can realize a personal benefit before the technology can be expected to gain wide acceptance.

Standardization issues:

Formal standards for system design, data sharing and system functionality are important in minimizing 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. Standards should be developed on regional – and if possible global – basis to avoid difficulties of harmonizing national standards.

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. 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.

Liability Issues:

One of the large deployment challenges of technologies 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, minimize the effects of inappropriate technology, and educate the driver to take full advantage of the existence of affordable electronics. 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. Standardization 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. 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.

ENABLING LEGISLATION AND GOVERNMENT INITIATIVES FOR DEPLOYMENT OF NEW TECHNOLOGIES:

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. 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 standardized processes to achieve the full safety benefits inherent in the technologies. Achieving these results would mean that development takes place in a highly focused way that targets the most important technologies first. These processes will also encourage co-operation and communication across nontraditional 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, and 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 harmonization as needed or global harmonization when called for.

INDUSTRY ROLE FOR THE DEPLOYMENT OF TECHNOLOGY:

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. They should do the following activities:

- Maintaining a high-level commitment to safety
- Developing meaningful partnerships with appropriate government agencies
- 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.

IMPLEMENTATION CONSIDERATIONS OF NEW TECHNOLOGY:

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, is 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.

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 commercialization 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.

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 cooperative systems. Consultative mechanisms will need to be established between organizations, *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. Standardization organizations 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.

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 standardized, 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

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 minimize 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.

FUTURE RECOMMENDATIONS:

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 minimize 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 foster 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.

A framework within which governments can begin to examine the possibilities and directions for ITS technologies to be developed and deployed for safety is needed. It 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.

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