

Evaluation of Intelligent Transport System in Road Safety

Gholamreza Khorasani, Ashkan Tatari, Ali Yadollahi and Milad Rahimi

Abstract—The seriousness of road traffic accidents in terms of personal injuries, fatalities, and property damage, has been recognized by the World Health Organization as a social and public health problem. Intelligent Transport Systems (ITS), based on advanced telecommunication and information technology, offer a great potential for improving the road safety situation for all types of road-users. At first this article presents the identification of ITS and its benefits and after that it will present the importance of ITS in road safety parameters and investigate that how ITS can influence all of the key macroscopic variables of the road safety problem, i.e. exposure, risk, and the severity of accident. At last this article presents one case study of South Africa ITS implementation and will compare the effects of ITS after implementation with before that.

Keywords— ITS, Intelligent Transport System, Road Safety, Road Accident, Road Fatality .

I. INTRODUCTION

INTELLIGENT Transport Systems (ITS) are advanced applications which, without embodying intelligence as such, aim to provide innovative services relating to different modes of transport and traffic management and enable various users to be better informed and make safer, more coordinated, and 'smarter' use of transport networks.

Although ITS may refer to all modes of transport, EU Directive 2010/40/EU of 7 July 2010 on the framework for the deployment of Intelligent Transport Systems in the field of road transport and for interfaces with other modes of transport defines ITS as systems in which information and communication technologies are applied in the field of road transport, including infrastructure, vehicles and users, and in traffic management and mobility management, as well as for interfaces with other modes of transport[7].

ITS is a collective name for a number of technology-based approaches that are designed to improve the quality, safety

and efficiency of transport networks. One way of categorizing these approaches is into the following application areas:

- Traffic management and control
- Tolling
- Road pricing
- Road safety and law enforcement
- Public transport travel information and ticketing
- Driver information and guidance
- Freight and fleet management
- Vehicle safety.

All these applications are being developed with assistance from research and pilot implementation programs in Europe, USA and Japan. In the UK, in supporting the 10-year plan, the Department for Transport has sponsored a number of initiatives. These include:

- Urban Traffic Management and Control (UTMC)
- Transport Direct
- Travel Information Highway
- Clear Zones
- Smart Cards
- Road User Charging
- Active Traffic Management (ATM)
- ITS Assist.

The UTMC program is developing an open system design specification for traffic management applications in urban areas. The new specification will enable greater flexibility for procurement and development of new applications. Transport Direct is a national travel information service to enable people to plan journeys and to compare routes and prices. It covers UK travel by air, rail, coach, bus and car. The Travel Information Highway will allow local authorities and travel information suppliers to connect to a network and

Ashkan Tatari is with the University Putra Malaysia, Dept. Civil Engineering (corresponding author to provide phone:+60-173052647; e-mail: Ashkantatari@gmail.com).

Gholamreza Khorasani is with the University Putra Malaysia, Dept. Civil Engineering (corresponding author to provide phone:+60-104377724; e-mail: Reza.khorasani@gmail.com).

Ali Yadollahi is with the University Putra Malaysia, Dept. Civil Engineering (corresponding author to provide phone:+60-147156131; e-mail: Ali.Yadollahi@gmail.com).

Milad Rahimi is with the University Putra Malaysia, Dept. Civil Engineering (corresponding author to provide phone:+60-122222584; e-mail: Milad.Rahimi12@gmail.com).

automatically transfer information to other organizations. The Clear Zones project aims to reduce pollution and traffic in towns and enhance manufacturing and export opportunities by developing innovative technologies and transport solutions. The Department is supporting the development of multi-function smart cards through the Pathfinder Project, ITSO and the Transport Card Forum. As well as progressing a charging system for heavy goods vehicles in the UK for introduction in 2007, the Department is also studying the possible introduction of road user charging for all motorized vehicles beyond 2010. A demonstration project covering the M42 is investigating the introduction of a number of motorway ATM measures including ramp metering (first trialed on the M3 and M27) and peak time hard shoulder traffic operation. The Department has listed a number of the benefits of ITS in a series of Traffic Advisory Leaflets. The Department's ITS Assist project provides advice, guidance and information to local authorities on the development and deployment of ITS solutions.

II. BENEFITS OF ITS

Through its use of information technology, ITS offers advantages that is not available in convent transportation systems. Basically, ITS provides two kind of benefits. One kind is the resolution of traffic problems, including traffic congestion, air pollution, and traffic accidents. The other kind is improved services for users and increased efficiency of the transportation system and its operators. The introduction of ITS can bring about the following benefits. [4]

•Resolution of traffic problems

2.1 Mobility

For a strong and flexible economy, people need the ability to travel between their homes and their workplaces conveniently, reliably, and affordably. People also need to get to school, to shops, and to recreational facilities. Shifting demographics, urbanization, and changes in the patterns of where people live, work, shop, and relax make providing mobility more complex. Mobility is especially important for people with special needs, including the elderly, the poor, the disabled, and people who live in more remote areas. Better mobility improves their quality of life and their ability to contribute to the economy, rather than just to depend on it. In the global economy, freight moves across oceans and through countries and across borders in trucks and on trains, often changing carriers en route to its final destination. It is important to move freight promptly and efficiently. It is also important to keep track of the location and content of containers and vehicles as they travel and to safeguard sensitive or hazardous cargo. ITS includes many approaches to enhance the mobility of people and freight in all transportation modes. Traveler Information helps travelers avoid congestion and can help improve traffic conditions. Traffic Management, e.g. the more effective timing of traffic signals, can help increase traffic efficiency. Demand Management, e.g. road and access pricing can help relieve heavily congested urban areas. Commercial Vehicle Management helps to increase security and efficiency not only

for carriers but also for related public agencies. There are many more examples as well. [4]

2.2 Traffic Congestion

Traffic congestion is a serious problem in all parts of the world. The problem is growing fastest in developing countries where urbanization and the use of motorized vehicles is increasing most rapidly. Congestion causes delays and uncertainty, wastes fuel, results in greater air pollution, and produces a larger number of crashes. ITS can help to mitigate congestion by helping people plan travel better, by suggesting alternate routes and travel times, by keeping travelers well informed, by leveling traffic loads on roadways, and by helping to respond to and clear incidents more rapidly. [4]

2.3 Environmental Impact

Maintaining air quality was once viewed as a luxury of developed countries, which could more easily bear the cost of technology to keep emissions under control. However, the impact of poor air quality, especially on health and productivity, is now recognized as a large cost to all national economies, including developing and transitional economies. ITS helps reduce the environmental impact of road travel by optimizing trips, reducing congestion and crashes, improving vehicle and driver performance, and helping to manage the transportation system well. [4]

2.4 Reducing Fatalities and Crash Severity

Traffic accidents around the world continue to claim hundreds of thousands of lives each year and cause millions of injuries. The personal tragedy of each death is magnified by the economic and social costs of these losses. The World Health Organization estimates that nearly 1.2 million people worldwide died each year as a result of road traffic accidents. Low-income and middle income countries have significantly higher traffic fatality rates than high-income countries. 90% of road accident deaths are in low-income and middle income countries. ITS is helping to shift the safety focus from minimizing the consequences of crashes (through the use of seat belts, head rests, impact absorbing front ends, etc.) to the use of technology to make crashes less severe and to prevent them altogether. The EU has set a goal of "zero traffic fatalities" by 2020 and ITS America has adopted a "Zero Vision" for future surface transportation: zero fatalities, zero delays. [4]

2.5 Managing the Transportation Infrastructure

Modern transportation systems are more complex and their parts are more interdependent. The effective management of modern transportation systems requires better, faster, more comprehensive information about the current and future state of the system, and better management and control tools. One specific intent of ITS is to help provide information and tools of this kind. For example, sensors built into the infrastructure and sensors in automobiles can help continuously monitor pavement conditions. By doing so, developing pavement problems can be diagnosed and repaired early before they become worse, cause problems, and require more expensive repairs. Better infrastructure management systems can also

help contain costs by more effectively allocating and scheduling maintenance resources. These systems can also provide a more accurate and comprehensive picture of the financial aspects of road asset management. [4]

- Improve services for users and increase efficiency of the transportation system and its operators

2.6 Reducing Travel Uncertainty

One of the interesting insights realized by transportation planners in recent years is that a major benefit of their programs has been to provide greater reliability and predictability in transport, and not just to get more people to their destinations faster. An unfortunate aspect of most current transportation systems is that travel times, both for people and for freight, can vary widely from day to day. This can be due to weather, demand, traffic incidents, or a large number of other external factors. This uncertainty means that travelers and shippers must allow extra time for worst case possibilities or risk being late at least some of the time. This is disagreeable and expensive. ITS can help reduce travel uncertainty by smoothing traffic (and therefore reducing travel time variance). ITS can also provide improved real-time and predictive information that allows travelers to plan trips better and allows shippers and carriers to plan shipments better. Public transport agencies can stay on schedule better and provide their riders with current and advance information about travel times and connections. In-vehicle navigation systems can incorporate real-time traffic information to dynamically adjust driving routes to optimize trips based on current information. [4]

2.7 Increasing Security

A particular transportation-related concern has grown significantly in the last few years. This concern surrounds the security of the transportation system (vehicles and infrastructure) and the security of cargo and people in transit. Containerized freight has been recognized as a particular concern, since containers may be loaded and sealed in far off locations. Improperly managed containers could contain dangerous materials (explosives, biohazards) intended to cause terrorist destruction in another country. Even legitimate hazardous materials could be hijacked or otherwise misused. Similarly, travelers are potentially at risk, particularly at travel terminals (bus and train stations) and on high-occupancy vehicles (buses and trains). ITS provides technology to address these concerns through the use of GPS (or other positioning technology), wired and wireless communications, and improved sensors and information systems. ITS can monitor the contents and locations of containers, monitor the cargo and routes taken by trucks, track the location and status of public transport vehicles, and generally support, simplify, and increase the visibility of transport logistics. This is an area in which increased security can facilitate increased efficiency and productivity by standardizing and integrating the processes for managing the transportation of people and cargo. [4]

2.8 Increasing Efficiency for Operators

There are many other ways in which ITS can improve the operational efficiency of the transportation system. One of the most successful and widespread applications of ITS has been ETC. With ETC, drivers establish an account with a toll agency and receive an electronic transponder that identifies their vehicle and their account. When the transponder-equipped vehicle passes a toll collection point, the toll is automatically deducted from the driver's account. The advantage to the toll agency is lower labor costs, more reliable collections, a more efficient toll operation that will attract more users, and the financial benefit of float (i.e., earnings from toll fees collected in advance, when drivers establish or replenish their accounts). In the long term, ETC opens the possibility of more flexible tolls that can be varied based on time of day, level of congestion or demand, and many other factors. More generally, ITS provides transportation system operators with better and more current information about the status of the transportation system and better tools to plan, operate, and maintain the system. [4]

2.9 Increasing efficiency for users

ITS also helps travelers to be more efficient. For example, the ETC systems mentioned above have advantages for drivers as well as system operators. The immediate advantage to the driver is that there is no need to stop at a toll barrier – the toll can be paid while the car keeps moving. The indirect advantage is an overall decrease in delays at toll barriers for all vehicles, even those that are not using ETC. Similar mechanisms can help other travelers. For example, there is a growing use of smart cards to pay a variety of fees. In many parts of the world, the same smart card can be used as a public transport fare card, for parking, and for other purposes. The smart card is a convenient way for governments to provide travel subsidies to poor or elderly citizens. This can be done by electronically storing money on the smart card or by having the fare collection system adjust the amount collected depending on whose smart card is paying the fare. A very popular ITS application in developed countries is in-vehicle navigation. An in-vehicle navigation system calculates and delivers driving directions to a destination stated by the driver. In-vehicle navigation systems include a map database, location sensors, a computer, and a user interface (e.g., a touch screen). The user interface lets the driver specify a destination and lets the system deliver directions. Navigation systems can generate efficient routes and help drivers keep from getting lost. In the future, navigation systems will receive real-time traffic information and adapt routes dynamically based on current conditions. As the cost of navigation systems continues to come down, it is expected that these systems will start to appear in developing countries as well. In general, ITS can provide travelers with better and more current information about the state of the transportation system, both for drivers and for users of public transport. This information will help travelers plan their trips better, make better connections, and, as observed above, reduce the uncertainty of travel. [4]

III. WHAT IS TRAFFIC SAFETY?

Traffic safety is usually regarded in terms of traffic “unsafely”, i.e. as the number of fatalities or injuries resulting from traffic accidents. Many researchers [c] have defined traffic safety as the expected number of fatally or otherwise injured persons of an entity in a unit of time. Here the entity can mean a road section, a junction, a driver or a group of drivers or a vehicle. It is imperative to note the word “expected” as the actual number of fatalities will fluctuate around the expected number in a way best described with a purely random distribution, often from the Poisson distribution family. As [8] showed, traffic safety has three primary dimensions of exposure, risk and consequence. Here exposure is measuring the magnitude of being exposed to accidents, usually expressed in person, ton or vehicle kilometers or hours travelled, or number of vehicles or vehicle kilometers passing through amenity. These three dimensions have a multiplicative relationship with regard to safety as shown in Fig. 1 [8]:

$$E(\text{Injured}) = \text{Exposure} \times \left(\frac{\text{Risk}}{E(\text{Accidents})} \right) \times \left(\frac{\text{Consequence}}{E(\text{Injured})} \right)$$

$$E(\text{Fatalities}) = \text{Exposure} \times \left(\frac{E(\text{Injured})}{\text{Exposure}} \right) \times \left(\frac{E(\text{Fatalities})}{E(\text{Injured})} \right)$$

Fig.1 Relationship between three dimensions and safety

This is illustrated in Fig. 2, where the volume of the rectangular box is the expected number of injured or fatalities: Regarding safety in the three dimensions above is a result from the systems theory currently prevailing in road safety research and practice.

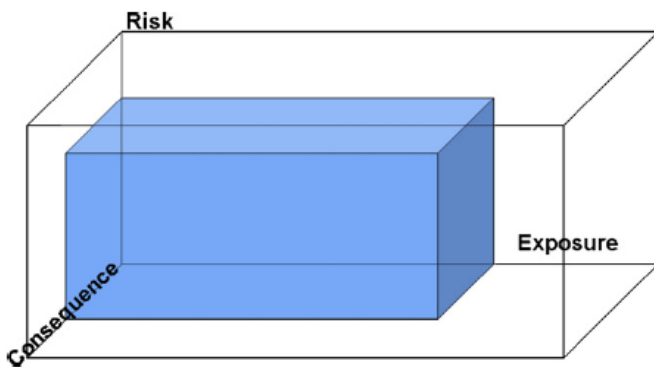


Fig. 2. The three dimensions of traffic safety—exposure, risk and consequence.

As well illustrated and explained by [c] and complemented by [5], there have been five major theories trying to explain road safety and road accidents: (1) theory of accidents as purely random events, (2) statistical accident theory and accident proneness theory, (3) causal accident theory as expressed in the in-depth case study approach to accidents, (4) systems theory and epidemiological accident theory and (5) behavioral accident theory. The three last ones are currently

being widely applied in road safety activities, and it is useful to highlight their starting points. Causal accident theory was developed to identify actual causes of accidents by thoroughly investigating the events and circumstances that have resulted in accidents. The underlying assumption was that if the causes of the accidents were determined, countermeasures could be designed to prevent the accidents. One of the main findings repeatedly found everywhere was that 85–90% of accidents are caused by human factors [2]. However, the excessive focus on human aspects led to the question of why a human makes errors. More generally, the advanced applications of this theory concluded that accidents are typically multi-causal events and almost no accident involves a single factor that should be the focus of accident prevention. This resulted in an approach that Systems theories were designed in the 1950s as a counterbalance to accident proneness and accident causation theories. According to the main premise of systems theory, accidents are the results of maladjustments in the interaction between the components of complex systems. It is not possible to pick out any part of the road transport system as more crucial than others for its successful operation. Furthermore, there is no interest in causes or persons at fault. It is accepted that humans err, but it is essential why they make errors, what are the errors like, etc. In general, the technical components of the system are not adequately designed and matched to human capabilities [c]. Application of systems theory resulted in modifying the technical components of the road transportation system. Better roads and vehicles were designed in terms of human capabilities and limitations (e.g. channelization of intersections, roundabouts, modern guide signing, daytime running lights, and many ergonomic aspects of vehicles). Many of these applications currently seem self-evident. Furthermore, safety research focused on the investigation of normal driver behavior, requirements of safe behavior, and searching for the best solutions from the viewpoint of road users [5]. The behavioral theories as proposed by [c] for the next road safety paradigm attempt to describe how human risk assessment and human risk acceptance affect the accident involvement of road users. [5] regards these theories as an elaboration of the systems theory rather than a new and different concept. [5] views the transport systems involving road users, traffic environment, vehicles and control of the system as well as the interactions between the various elements. These interactions are forms of human behavior containing sub-systems such as Perception – Information processing – Decision – Response Selection – Response Execution. Today systems and behavioral theories are dominating road safety research, methodologies and deployment activities. Accident causation methods and tools based on the causal theory are also used. Typical application areas for these include in-depth investigation of accidents for identifying the contributing factors to accidents or pointing out the guilty or faulty parties in the accidents. Concentrated on ordinary driver behavior and what contributes to these unintended errors. The concept “system” saw the light of the day [5].

IV. EFFECTS OF SAFETY MEASURES

Safety measures, or any measures undertaken in the transport systems, influence safety by affecting one or several of the factors contributing to any of the three dimensions of safety—exposure, crash risk or consequence. In the case of a safety measure, these factors tend to be the primary target of the measure. In addition to these “target factors”, the measure can also affect other factors related to the three dimensions of safety. If those other factors have an adverse effect on safety, their impact may totally or partly outweigh the positive effect due to the positive impact on the target factors. Usually the effects on other factors occur due to behavioral changes evoked by the measure and are described with the term “behavioral adaptation”, i.e. road users adapt their behavior to various measures to a greater or lesser extent, but not necessarily to fully compensate for the measures. Probably due to the frequency of engineering based measures, the effect on target accident contributory factors is called “engineering effect” [c]. This is illustrated in Fig. 3.

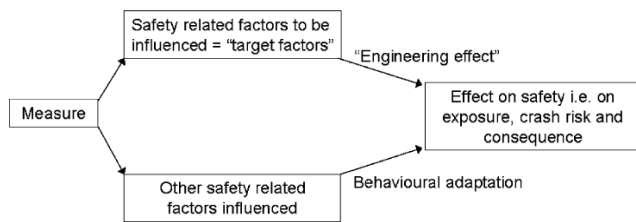


Fig. 3. Schematic presentation of safety effects due to behavioral adaptation, based on [c].

The behavioral adaptation can be explained more generally in terms of the utility theories. These theories claim that individuals and thereby also road users behave rationally on the individual level and try to satisfy their own needs and preferences, aiming to maximize their utility. Road users derive utility naturally from not being injured in crashes, but also from reaching their destination on time, feeling comfortable, listening to their favorite music, being able to utilize travel time to working, etc. The behavioral adaptation can also be regarded to be primarily connected to the perceived risk of the drivers and the changes in the perceived risk brought about by the systems. Behavioral adaptation is thereby talked in terms of risk compensation.

Behavioral adaptation can exist in many forms and at all levels of driver (or more generally road user) decision making suggested by [8] i.e. strategic, tactical and operational. At the strategic level, behavioral adaptation can exist as changes in journey making, timing, mode choice and route choice, while at the tactical level, it can manifest itself in changes in lane choice as well as target speed levels and following headways. At the operational level, behavioral adaptation may affect, e.g. gap acceptance, situation awareness, alertness, speed choice, and maneuvering. Most of the discussion has so far concentrated, however, only on the tactical and operational level behavioral adaptation. Spyropoulou et al. (2008) review different ITS systems with regard to their direct and indirect (modification of driving behavior as a consequence of system

use). They point out user frustration and acceptance as crucial issues for system use and thereby effectiveness in addition to listing examples of behavioral adaptation. identified six parameters that characterize driver behavior and, at the same time, the state of the art concerning behavioral adaptation to driver support systems. These parameters were: attitudes/personality, experience/competence, task demand, driver state, situation awareness/alertness, and intentions/goals. proposed five hypotheses designed to explain road user behavioral adaptation to any road safety measures. These can be listed in the following way utilizing [1]:

1. How easily a measure is detected If the road user detects a change in any element of the system, he or she may perceive this as a change in the level of risk. If sight distance along the road is increased, for example, most road users would probably perceive this as a gain in safety margin. On the other hand, if cars are equipped with collapsible steering columns, drivers would not detect it and might not even know it. Measures that introduce changes that are easily detected by road users are more likely to lead to behavioral adaptation than measures that they do not easily detect.

2. Antecedent behavioral adaptation to target factors If road users have already adapted their behavior to the target factor, i.e. the safety related factor that the measure is meant to influence, the measure is more liable to behavioral adaptation than if such an adaptation has not taken place. Periodic inspections of private cars is probably more liable to behavioral adaptation than road lighting, because road users try to compensate for technical defects in cars by driving more carefully but they do not adapt their behavior as much to reduced visibility at night by slowing down or being more alert.

3. Size of the engineering effect on target factors the greater the engineering effect, the greater the probability that there will be behavioral adaptation. For example, it is more likely that improving a car's headlights will lead to behavioral adaptation when driving in the dark than when driving in daylight.

4. Whether or not a measure primarily reduces injury severity Measures which reduce the risk of being involved in an accident are more liable to risk compensation than measures which reduce the severity of injuries in a crash. For example, ESC should be more liable to behavioral adaptation than air bags.

5. Whether or not additional utility can be gained The road user will adapt his or her behavior only if this results in higher utility. For example it is difficult to think of a behavioral adaptation to gates blocking the road partly or totally at railroad level crossings. For a vast majority of drivers, driving in a zigzag pattern between lowered gates is too dangerous to outweigh the benefits due to saved travel time.

V. INTERMEDIATE INDICATORS OF SAFETY IMPACTS

5.1 Direct safety impact by intelligent speed adaptation

The number one safety related ITS concept these days is intelligent speed adaptation (ISA). There have been national as well as EU projects in the last decade (MASTER, PROSPER) concentrating on its different forms, expected impacts, its acceptance by the driving community, etc. Speed choice of the drivers in different traffic situations has a tremendous effect on traffic safety, both by influencing the probability of avoiding an accident to occur in a critical traffic situation, and by having influence on the impact of collision and on the outcome of an accident. The intermediate factors behind the safety impact in this case may be allowing more time for assessing situations for both the equipped and the non-equipped partner. The ISA system does not imply changes in the driving task, but it may lower drivers' workload by taking over some of the task of controlling speed. It is important to make it clear that the locus of responsibility for speed adaptation remains with the driver even if the system does not allow exceeding the speed limit. A possible safety impact that needs to be studied is if speed control systems have behavioral adaptation effects, i.e. what speeds drivers adopt in non-equipped areas and in situations which need a lower speed than the actual speed limit (turning, giving way, etc.). It also may happen that equipped drivers engage in other negative forms of adaptation, e.g. close following or more aggressive interaction with other vehicles.

5.2 Direct safety impact by driver monitoring

The second area where direct safety impact is expected from intelligent transport systems is the area of driver monitoring. The idea behind these systems is that dangerous driving is the cause of most traffic accidents and therefore monitoring whether drivers adhere to the traffic rules will have a tremendous positive safety impact. These systems are clearly not attracting drivers to buy them but they may be made compulsory for some user groups (tachygraphy for bus and truck drivers, etc.) or insurance companies may develop an incentive system for those who use them. These systems do not intervene with the driving task in any other way than by monitoring if the driver violates traffic rules. It is a function that is at present allocated to the police and fulfilled by occasional monitoring, using a lot of human resources. Information technology makes it possible that the function be automated and carried out in a much more regular way. Another advantage of an intelligent driver monitoring system is that it can provide immediate feedback to the violating driver. The main expected impact of such a permanent monitoring is to reduce driving errors and violations and improve traffic safety by that.

5.3 Secondary safety impacts

There is a very wide range of intelligent transport systems that do not aim primarily to improve safety but that still have positive or negative safety impacts (sometimes the same system has both positive and negative one) in many different

ways. Safety impacts may be generated by the following functions:

5.4 Providing drivers with information

Many new systems that give drivers' information or advice have been developed in order to increase drivers' situation awareness by informing them on factors that are hidden for the naked eye but have influence on the driving task. Factors like that are adverse road surface-, visibility- or traffic conditions in a short distance ahead, state of the vehicle, etc. If drivers get information on these conditions, their situation awareness increases.

5.5 Assisting drivers

One of the basic needs behind implementation of new technology in road transport is to reduce human errors that lead to accidents, and assist drivers in driving functions where machines can function more accurately than human beings. Many systems, especially driver assistance systems (dynamic vehicle control and collision avoidance systems, speed control system, etc.) have the potential to prevent human errors, such as errors in distance keeping, lane keeping, selection of appropriate speed, etc. However, driving is a dynamic process in which drivers may use the assistance they get to attain further advantages by e.g. driving faster, taking more risk, and this may produce new sources of error. Moreover, the system intervention itself may be a new source of errors when e.g. different information sources interfere with each other and with the driving task, or systems that are designed to reduce driver workload decrease vigilance in a degree that is already dangerous. It is necessary that human errors created by new systems are carefully analyzed in an early phase of system development, and their sources eliminated before introducing the system into the market. There may be special groups of drivers, first of all elderly drivers who, on the one hand are a primary target group for driver assistance systems (route guidance systems and other information systems, dynamic vehicle control and collision avoidance systems, speed control systems, etc.), on the other hand have special difficulties with learning new ways of driving, and may be prone of special system-created errors. Driver assistance systems have to be tested especially with elderly users, to ensure that their design takes into consideration their special needs and their special shortcomings, too. A system that advise/guide or give assistance in vehicle control (navigation and route guidance systems, speed control systems, dynamic vehicle control and collision avoidance systems, etc.) may decrease driver workload substantially, although mainly in situations which are monotonous even by traditional driving. There is a danger that using these systems drivers will turn their attention to other activities, or their arousal level will be too low, and they will not be able to react efficiently in an unexpected dangerous situation. The situation may be even more difficult if there is some doubt about the locus of control, i.e. for how long is the system taking responsibility for the actions, and when should the driver take over and act. Many systems that assist drivers by substituting some part of the driving task with machines, that are more accurate at measuring e.g. distances, speeds, aim

at increasing road capacity by allowing shorter distances between vehicles. If drivers of none equipped vehicles imitate the behavior of equipped vehicles, in this case keep similarly short headway, it may cause serious traffic safety problems in the changeover period.

5.6 Taking over some control functions

When tasks that traditionally are performed by humans are automated or at least part of the control is taken over by technology from the human operator, it is always a hot topic, who has the overall responsibility for the error-free functioning of the system. Driving a motor vehicle on a road that is not designated only for motor vehicles, but is a place where different kind of road users move around, is an activity that needs a human operator. It is a firm statement of the car industry and road transport technology providers that the locus of responsibility is going to remain at the drivers, even if sophisticated driver assistance systems offer support to them. If this is the case, it must be made clear for those who buy and apply those systems. Even if the overall responsibility for accident-free driving is on the driver, responsibility has to be shared between the driver and the system provider in case of systems that take over part of the control over the vehicle. The most critical period of semiautomatic driving is the hand-over phase, both from safety and from responsibility point of view.

5.7 General behavioral effects of the change

It is a well-known phenomenon that if a change is introduced to the road-vehicle-user system, road users adapt their behavior to the new situation and this adaptation is not always in line with the intention of the initiators of the change. Introduction of new transport technology aims at improving traffic safety and efficiency, but drivers who use the technology have their own aims, and use the possibilities provided by new technology for fulfilling them. One possible behavior adaptation effect on new road transport technology may be the delegation of responsibility on systems that take over some control task (distance keeping, lateral control, speed keeping, etc.), and dividing attention between driving and some other tasks or activities, or simply relaxing and not concentrating fully on the driving task. It may be especially attractive to use new technology, e.g. computer and internet connection available for the driver, to carry out some office work while driving, if some driver assistance system takes over part of the driving task. Another dangerous form of behavior adaptation may be the imitation of the often rather short following distance or relatively high speed of the vehicles that are equipped with systems, such as cruise control or vision enhancement, by drivers of non-equipped vehicles. Also, drivers of vehicles equipped with some driver assistance system may overestimate the assistance they get, and take risks that they would not take without the system. Many ITS systems have a direct or indirect impact on safety. In order to ensure that systems are deployed so as to ensure the maximizing of the benefit to safety, it is vital to carry out proper safety evaluation of these systems. It is equally important to ensure for any telematics system, even one not

aimed at enhancing safety, that any disbenefits to safety are eliminated or minimized.

VI. SAFETY ASPECTS OF ITS

The safety implications of Intelligent Transport Systems are commonly classified into three areas:

1. System Safety — covering safety problems from hardware design and from software design with particular focus on reliability, the propensity for malfunction and the potential to go into a dangerous and/or unanticipated system mode[3].
2. Human Machine Interaction (HMI), that is interaction between the user and the system. Key issues are the design of buttons and controls; menus; screen size, brightness and location; means of dialogue between the user and the system; channel for information (auditory or visual), and feedback to the user (auditory or visual). Inappropriate design 51 can lead to overload (too much effort required) or under load (the user no longer involved in the main task of for example driving) or to distraction from the driving task at inappropriate times[3].
3. Traffic Safety — this is the overall effect of system use on the safety of the traffic system as a whole. It covers the outcome of System Safety and HMI (that is the potential for problems in either area to lead to accidents). More broadly, it also covers the overall ways in which a particular system might affect road user behavior so as to alter the interaction between the driver, the vehicle, the road infrastructure and other road users (including vulnerable road users such as pedestrians, cyclists and motorcyclists). In each of these areas, various procedures and guidelines have been developed in an effort to ensure that safety problems are minimized. Currently these guidelines are voluntary and as a consequence there are issues of how to ensure compliance with recommended practice. In addition, in some areas, because the systems are so new and there is so little experience on their effects, there is a need to develop further the basic knowledge required in order to develop standards to ensure safety[3].

VII. CASE STUDY

Annually, between 14 000 and 18 000 are killed on South African roads. According to the World Road statistics (IRF, 2006), South Africa has the highest number of people killed in road accidents per 100 000 people. South African cities have a road fatality rate that is significantly higher than cities in other parts of the world. Compared to European cities, the fatality rate is between five and eight times higher (see Fig. 4). According to the World Road Statistics (IRF, 2006), South Africa has the highest fatality rate (per 100 000 people) in the World. A multi-measure approach will be needed to counter this unsustainable road safety situation. Internationally, ITS measures have shown a potential safety improvement. Unfortunately, measured as well as estimated effects in different study areas show vast differences in results. Direct translation of these results to the South African context is, therefore, impossible. South Africa does not have the financial

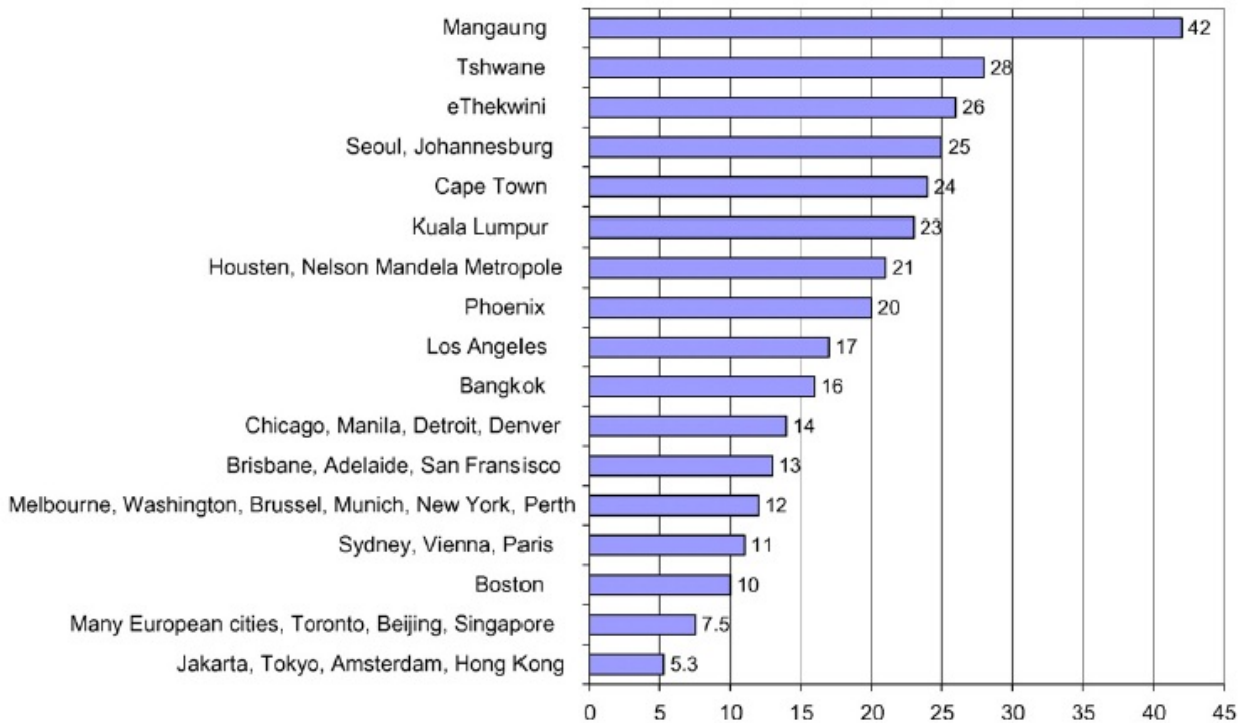


Fig. 4 Road accident fatalities in various international cities (/100 000 inhabitants).

resources to test various ITS measures in practice. As funds for pilot studies are scarce, the use of ex ante studies is a natural step. Traffic flow based microscopic simulation models studies are able to explore the safety effect for Adaptive Speed Control (such as VSL) and CVHS systems. Based on an extensive analysis Paramics was chosen as the microscopic simulation model. Due to the programming of accident avoidance in microscopic simulation models, the potential to model safety implications is limited. Nevertheless, it was concluded that changes in speed, headways and TTC provide an indication for road safety risk changes. Overall it can be concluded that there is a potential road safety improvement due to the implementation of ITS measures in the developed world, based on the estimates for the two selected study areas. The average speed and number of short headways for all bus/HOV scenarios decrease, which is an indication for a reduced safety risk. It was also found that the safety benefit for VSL scenarios is larger if a fixed 80 km/h limit scenario is introduced. The safety risk on the BSH, due to the introduction of ramp metering, decreases. The ramp metering scenario for the N2 is the only scenario that shows an increase in the safety risk.

Although the expectations with regards to ITS measures are generally positive, large variations have been found. Specific local aspects have a large influence on the magnitude of Intelligent Transport Systems. Bus/HOV lanes are suggested not to have a bottleneck, such as simulated on the BSH. Moreover, an analysis of the travel time for SOV is required as it is likely that the travel time increases to unacceptable levels (Vanderschuren, 2006). Ramp metering is only suggested if

the majority of traffic is on the highway at the start of the study area. On the N2, for example, many vehicles will be unable to enter the highway section, which affects the throughput (an indicator not included in this paper) and the remaining network negatively.

VIII. CONCLUSION

The finding of this review has identified several existing and emerging ITS technologies in-vehicle systems that could enhance safety for vehicles. There are advanced driver assistance system, intelligent speed adaptation, driver monitoring system, collision warning and avoidance system, lane keeping and lane-change warning system, visibility enhancing system, seat belt reminder system. Those systems have been discussed in terms of the vehicle safety issues and adaptability. As we mentioned in this article about the benefits and safety impact of ITS in transportation thus the need of countries specially developing countries is appear. The consequence of implementation ITS in South Africa shows the importance of ITS in road safety and enhance the quality and standards of safety parameters.

REFERENCES

- [1] Elvik, R ,” To what extent can theory account for the findings of road safety evaluation studies”, In: Proceedings of the 15th ICTCT Workshop. Retrieved May 26, 2008 from <http://www.ictct.org/workshops/02-Brno/Elvik.pdf.2002>.
- [2] Hkkinen, S.,” Tapaturmateoriati ja niiden kehittuminen. Accident Theories and Development of Theories”, Report No. 36/1978, Helsinki University of Technology, Laboratories of Industrial Management and Industrial Psychology, Otaniemi, 1987.

- [3] INTELLIGENT TRANSPORTATION SYSTEMS AND ROAD SAFETY, European Transport Safety Council, Brussels 1999.
- [4] ITS for Developing Countries, ITS Technical Note For Developing Countries, Toshiyuki Yokota, July 22, 2004
- [5] Luoma, J., Rönkä, P., Penttinen, M., Anttila, V., "Effects of variable message signs for slippery road conditions on reported driver behaviour. Transport," Res. F 3, 75-84, 2000.
- [6] Marianne Vanderschuren, "Safety improvements through Intelligent Transport Systems: A South African case study based on microscopic simulation modeling", University of Cape Town, Department of Civil Engineering, September 2007
- [7] Monahan, Torin. 2007, "War Rooms" of the Street: Surveillance Practices in Transportation Control Centers," The Communication Review 10 (4): 367-389.
- [8] Nilsson, G., "Traffic Safety dimensions and the Power Model to Describe the Effect of Speed and Safety," Bulletin 221. Department of Technology and Society, Lund University, Lund, Sweden, 2004.



Gholamreza Khorasani was born in 1984 in Semnan, Iran. He is student of MSc's Degree at Highway and Transportation in University Putra Malaysia. His research interests are Public transportation, Road safety, New transit system and traffic. He has 2 published conference article. Now, he is the manager of a road company in Iran. He has experience in more than 3 constructed projects in road design and traffic.



Ashkan Tatari was born in 1983 in Tehran Iran. He is student of MSc's Degree at Highway and Transportation in University Putra Malaysia. His research interests are Public transportation, Road safety, pavement management and highway design. He has 1 published conference article. He has experience more than 4 years in highway design and civil.



Milad Rahimi was born in 1986 in Yasouj Iran. He is student of MSc's Degree at Highway and Transportation in University Putra Malaysia. His research interests are Public transportation, Road safety, pavement management and highway design. He has 1 published conference article. He has experience more than 4 years in civil and road design.



Ali Yadollahi was born in 1982 in Semnan Iran. He is student of MSc's Degree at Highway and Transportation in University Putra Malaysia. His research interests are Public transportation, Road safety, pavement management. He has 1 published conference article. He has experience in more than 5 constructed projects in road design and traffic.