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New technology for road safety

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ABSTRACT

Public transport contributes greatly to people's mobility. One of the most significant costs associated with automobile travel is the number of road accidents and fatalities that this type of transportation incurs. Road fatalities in almost all developed countries have decreased over the last four decades.

The aim of the study presented in this thesis was to facilitate improved road safety through increased understanding of methods used to measure driving behaviour, and through increased knowledge about driving behaviour in sub-groups of drivers.

To achieve a more consistent understanding of all potential determinants of road safety , I examined a conceptual framework based on an extensive review of the literature on the social, economic and environmental factors that have been demonstrated to affect traffic fatality , resulting in an analysis of the intelligent transport system technologies.

Index

LIST OF FIGURES

Chapter 1

Introduction

1.1 Background

A well-functioning transportation system is vital on all social levels, from moving goods and enabling trade to facilitating daily mobility and promoting health and social inclusion. Many people sustain serious injuries in road traffic crashes every year, with lifelong consequences both for the victims and their families. Apart from the human suffering, these injuries have a big impact on society as a whole, and the economic cost is also high.

The European Commission has put a new focus on reducing serious injuries. To highlight the importance of reducing the risk of serious injuries, we estimate that for every person who dies on the roads, about five more are seriously injured. Furthermore, the majority of people seriously injured on Europe's roads are vulnerable road users. Their proportion is even higher in towns and cities and protecting them is a priority. In 2014, almost 25700 road fatalities were reported in the EU. This is a decrease by around 1% compared to 2013. For the complete strategy period 2010-2014, the annual number of road deaths decreased by 18%. This means 5700 fewer deaths in 2014 than in 2010. The EU road fatality rate in 2014 was 51 dead per million inhabitants. Sweden, the Netherlands, the UK and Malta have the lowest reported road fatality rate, below 30 dead per million inhabitants. The highest road fatality rates are reported from Latvia, Romania, Bulgaria, Lithuania and Poland with more than 80 dead per million inhabitants.

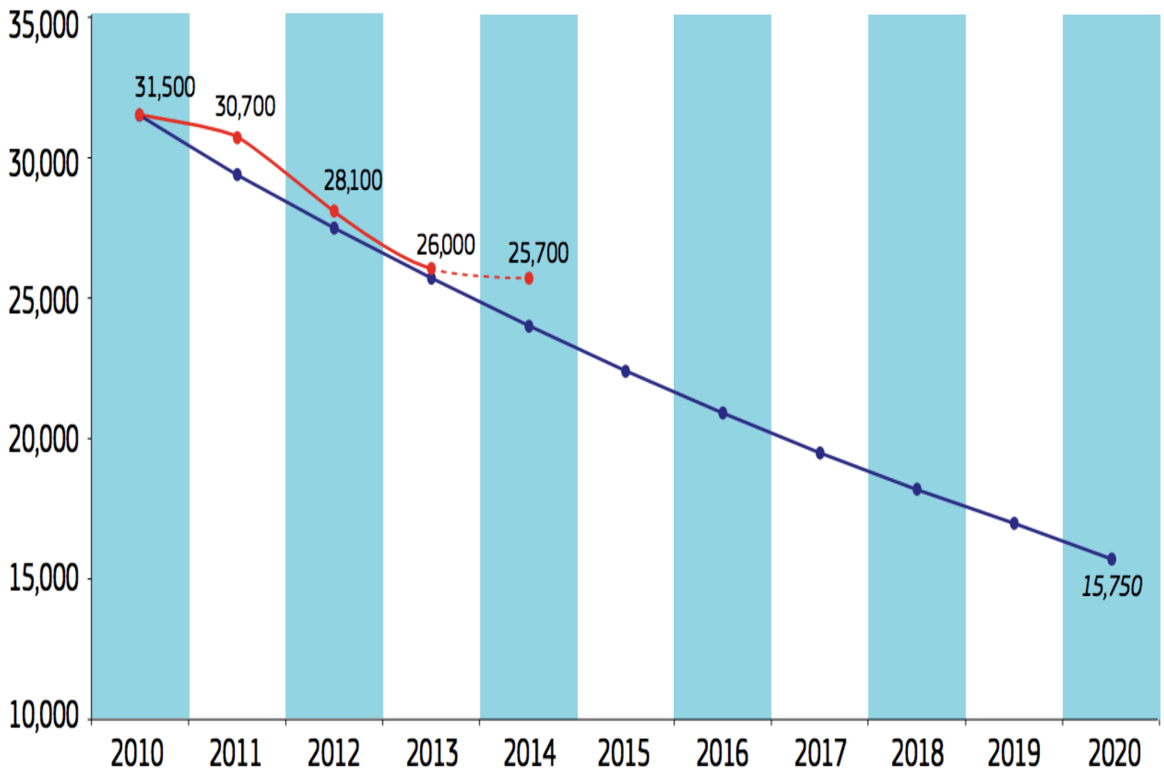

figure 1. Development over time since 2010

In 2014, the provisional figure for the EU in March 2015 is 25 700 reported road deaths. This is around 1 % fewer deaths than reported in 2013 and 18 % fewer than in 2010. This means that the decrease rate has slowed down in 2014, compared to previous years.

While achievements to date are good – cutting the number of annual deaths by almost one fifth since the start of the strategy period 2010-2020 – they are not quite in line with the ambitious target. In order to halve the number of road deaths by 2020, the road fatality numbers must go down at a higher speed from today and onwards.

The overall long-term trend is that the number of road fatalities decreases. However, the year to-year developments differ widely between Member States. Some Member States had an increasing number of road fatalities between 2013 and 2014, for example Slovakia, Latvia and Bulgaria. Other Member States had a significant decrease, for example Finland, Slovenia and Croatia with around 15 % fewer road deaths in 2014 than in the year before.

The development of efficient transport services went through an evolutionary process of adopting environmental and safety considerations in the policy design.

The technology innovation hubs worked on developing devices that could help collect information from the vehicles to identify the impact of growth in the transport industry on the environment. With the creation of computer and information technology, it allowed the innovative inventions to integrate immensely by making the vehicles information-aware, allowing the vehicles to share this information with external systems. Intelligent Transportation Systems (ITS), or the advanced use of Information and Communication Technology (ICT) in the transportation context, offers new tools in the continual effort to develop an accessible, safe, and sustainable transportation system. ITS, which can broadly be defined as the advanced use of Information and Communication Technology (ICT) in the transportation context, is built upon data collection, storage, and processing.

1.2 Motivation

1.3 Project significance

This thesis makes contributions to the road safety literature and methodological techniques, designed to improve understanding of driver behaviour. ITS systems and services have great potential to generally enhance individuals' daily, personal mobility and transportation experiences. For example, advancements in positioning and mobile systems allow for increasingly precise and continual measurements of the locations and movements of individuals and objects over time. These tracking and monitoring capabilities facilitate the collection of position, movement and activity data, which enables further development of services and devices, for instance, to provide information for pre- and on-trip planning. As road accidents have been and are still a major concern that lead to death and fatality, our aim should be to focus our attention not only on drivers behaviour ,but also on the driving environment as well as other factors that influence as well. Based on this the aim of this project is to present new technologies regarding road safety and intelligent transport system.

Chapter 2

Literature Review

2.1 *General*

Currently estimated to be the ninth leading cause of death across all age groups globally, road traffic crashes lead to the loss of over 1.2 million lives and cause nonfatal injuries to as many as 50 million people around the world each year. Nearly half (49%) of the people who die on the world's roads are pedestrians, cyclists and motorcyclists. Road traffic crashes are the main cause of death among people aged between 15 and 29 years. With the emergence of disruptive technologies , public sector organizations are looking for ways to gain visibility into driver and vehicle performance through timely alerts of incidents so that they can take immediate action. The 2030 Agenda for Sustainable Development includes an ambitious target to reduce road traffic deaths and injuries by 50% by 2020. While much progress has been made by governments during the Decade of Action to adopt and enforce new road safety laws on risks such as speeding, to redesign roads with protective infrastructure such as sidewalks, and to ensure that vehicles are equipped with life-saving technologies, governments must rapidly accelerate their efforts to achieve Sustainable Development Goal target. To do so will mean that governments fulfil the commitments they have repeatedly made through various policy instruments and overcome the challenges they have faced, particularly fatalism, the misconstrued notion that road traffic crashes are accidental and nothing can be done to prevent them. It will also mean surmounting a lack of prioritization for road safety generally and a focus on interventions that are not always the most effective.

Modern Intelligent Transportation Systems (ITSs) employ communication technologies in order to ameliorate the passenger's commuting experience. Vehicular Networking lies at the core of inaugurating an efficient transportation system and aims at transforming vehicles into smart mobile entities that are able to sense their surroundings, collect information about the environment and communicate with each other as well as with Roadside Units (RSUs) deployed alongside roadways. As such, the novel communication paradigm of vehicular networking gave birth to an ITS that embraces a wide variety of applications including but not limited to: traffic management, passenger and road safety, environment monitoring and road surveillance, hot-spot guidance, Drive Thru Internet access, remote region connectivity, and so forth. Furthermore, with the rapid development of computation and communication technologies, the Internet of Vehicles (IoV) promises huge commercial interest and research value, thereby attracting a significant industrial and academic attention. Unlike existing wireless mobile networks, vehicular networks possess unique characteristics, including high node mobility and a rapidly-changing topology, which should be carefully accounted for.

2. 2 Global Road Safety

Road safety pertains to the measures taken to reduce the risk of road traffic injuries and death. Through intersectional coordination and collaboration, countries in all regions can work improve their road safety legislation, creating a safer, more accessible, and sustainable environment for transport systems. It is essential that countries implement measures to make roads safer not only for car occupants, but also for vulnerable road users such as pedestrians, cyclists, and motorcyclists.

The Region of the Americas accounts for 11% of global road traffic deaths with nearly 155 000 deaths. It accounts for 13% of the total world population and 25% of the total number of registered vehicles. It has the second lowest road traffic fatality rate among regions with a rate of 15.6 per 100 000 population. In Europe the European Commission has adopted an ambitious Road Safety Programme which aims to cut road deaths in Europe between 2011 and 2020. The programme sets out a mix of initiatives, at European and national level, focussing on improving vehicle safety, the safety of infrastructure and road users' behaviour

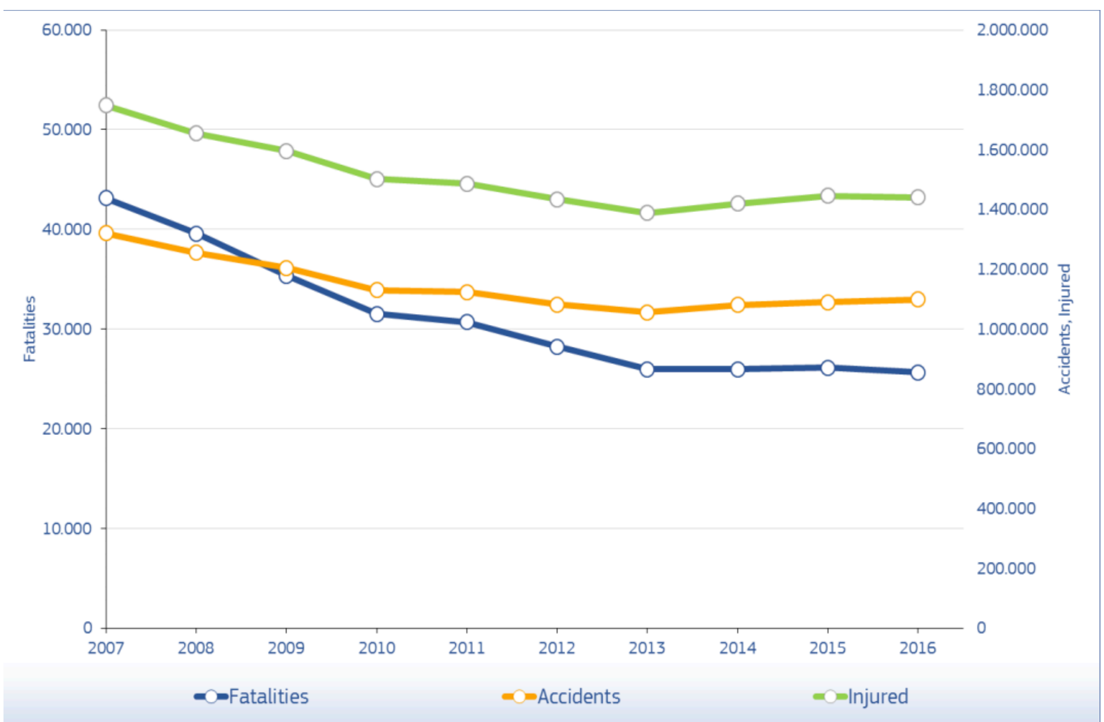

Figure 2. Annual number of fatalities, injury accidents and injured people in the EU, 2006-2015

Road Safety is a major societal issue. In 2011, more than 30,000 people died on the roads of the European Union, i.e. the equivalent of a medium town. For every death on Europe's roads there are an estimated 4 permanently disabling injuries such as damage to the brain or spinal cord, 8 serious injuries and 50 minor injuries.

In 2016, according to the World Health Organisation, road accidents were the eighth-biggest cause of death in the world; deadlier than both diarrhoeal diseases and tuberculosis. Not only is it important to consider road fatalities, but for every fatality on Europe's roads, it is projected that 4 people will become permanently disabled, that 10 shall suffer brain or spinal cord damage, 10 people will be seriously injured and 40 will have sustained minor injuries.On top of this, road accidents incur a large economic impact. In Europe alone, it is estimated that road accidents are a cost to society by a measure of €130 billion annually.

On the other side although only a small proportion of the world's total motor vehicle fleet and total network is in the Asian and Pacific region, 235,000 road deaths occur annually, which is almost half of the 500,000 road deaths that occur annually worldwide.

The number of people injured or crippled through road accidents in the region is difficult to quantify because of underreporting, but it is certainly of the order of 3 million to 4 million each year. Road accident deaths are commonly the second largest cause of deaths for the core age. Vulnerable road users (VRUs) (pedestrians,motorcyclists and non motorized vehicles are particularly at risk and in many countries of the region they constitute the highest proportion of those killed or injured .They require particular attention in the developing of countermeasures and improvements.

While talking about Africa , it has an annual death toll that's significantly higher than the world average. It's also higher than the African average.

According to the Road Traffic Management Corporation's most recent annual report, there were 12,921 deaths on South Africa's roads in a single year. Over the holidays, in particular, serious road accidents are a daily occurrence. The main causes analyzed are : distractions: Not focusing on the road while driving is one of the leading causes of road accidents. Distractions include common behaviours like using a cell phone, eating food or applying make-up. Texting while driving makes you 23% more likely to be involved in an accident, : drunk driving : According to arrive alive, 50% of those who die in road accidents have a blood alcohol concentration above 0.05 gram per 100 millilitres.

Currently, the limit for driving while under the influence is a blood alcohol content of 0.05% or less. Drunk driving carries heavy penalties and frequently results in fatal accidents.

From June 2020, a new law in South Africa will set the legal blood-alcohol limit for drivers to 0%. This means that a single drink could put a driver over the legal limit.

This zero-tolerance limit forms part of the Administrative Adjudication of Road Traffic Offences (Aarto) Act, which was signed into law in 2019.

2.3 World Health Organization (WHO) on road safety

The road traffic injury problem began before the introduction of the car. However, it was with the car – and subsequently buses, trucks and other vehicles – that the problem escalated rapidly. By various accounts, the first injury crash was supposedly suffered by a cyclist in New York City on 30 May 1896, followed a few months later by the first fatality, a pedestrian in London .

Despite the early concerns expressed over serious injury and loss of life, road traffic crashes have continued to this day to exact their toll. Though the exact number will never be known, the number of fatalities was conservatively estimated to have reached a cumulative total of 25 million by 1997 . WHO data show that in 2002 nearly 1.2 million people worldwide died as a result of road traffic injuries. This represents an average of 3242 persons dying each day around the world from road traffic injuries. In addition to these deaths, between 20 million and 50 million people globally are estimated to be injured or disabled each year .There were 1.25 million road traffic deaths globally in 2013, with millions more sustaining serious injuries and living with long-term adverse health consequences. Globally, road traffic crashes are a leading cause of death among young people, and the main cause of death among those aged 15–29 years.

Road traffic injuries are currently estimated to be the ninth leading cause of death across all age groups globally, and are predicted to become the seventh leading cause of death by 2030.

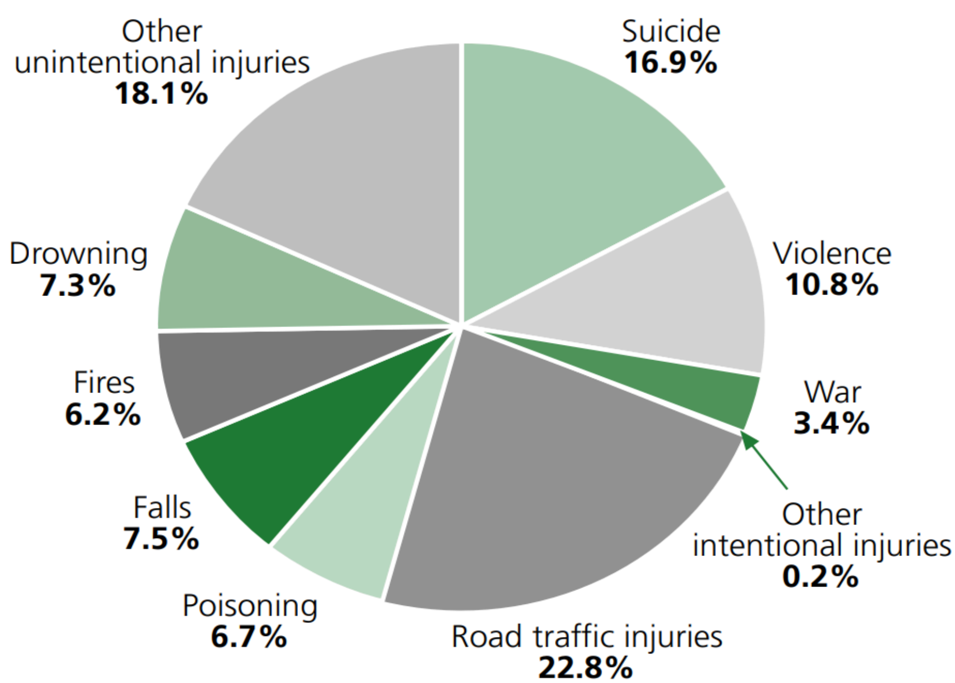

Figure 3. Distribuition of global injury mortality by cause

According to WHO data, road traffic deaths have risen from approximately 999 000 in 1990 to just over 1.1 million in 2002 , an increase of around 10%. Low income and middle-income countries account for the majority of this increase. Although the number of road traffic injuries has continued to rise in the world as a whole, time series analysis reveals that road traffic fatalities and mortality rates show clear differences in the pattern of growth between high-income countries, on the one hand, and low-income and middle-income countries on the other . In general, since the 1960s and 1970s, there has been a decrease in the numbers and rates of fatalities in high-income countries such as Australia, Canada, Germany, the Netherlands, Sweden, the United Kingdom and the United States of America. At the same time, there has been a pronounced rise in numbers and rates in many low-income and middle-income countries.

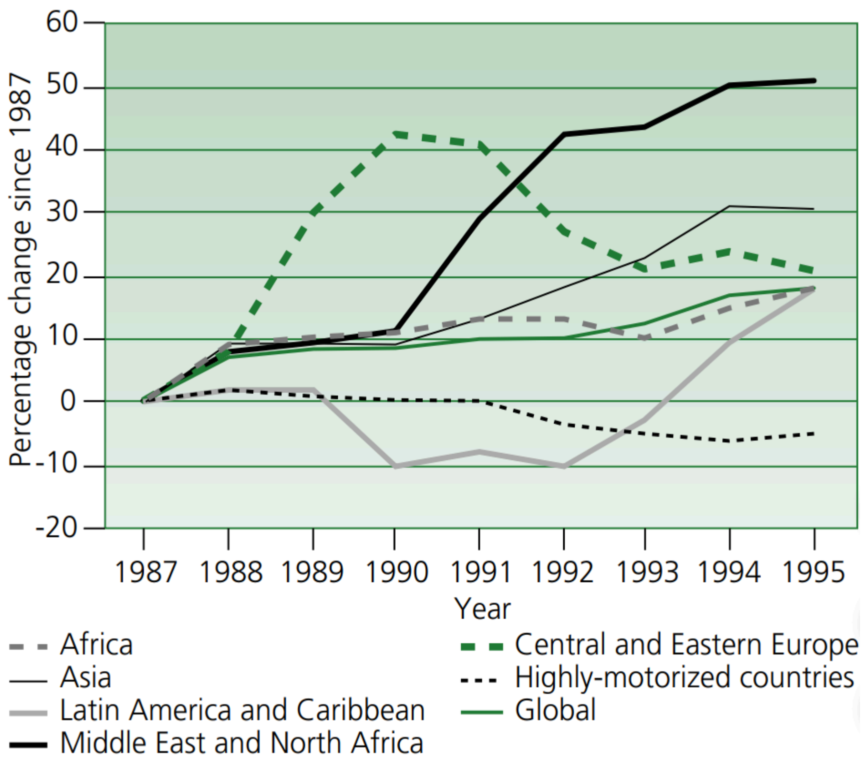

Figure 4. Global and Regional Fatality trends, 1987-1995

The percentage change in road traffic fatalities in different regions of the world for the period 1987–1995 is shown in Figure 3 . The trends are based on a limited number of countries for which data were available throughout the period and they are therefore influenced by the largest countries in the regional samples. Such regional trends could mask national trends and the data should not be extrapolated to the national level. The regional classifications employed are similar to, but not exactly the same as those defined by WHO. It is clear from the figure that there has been an overall downward trend in road traffic deaths in high-income countries, whereas many of the low-income and middle-income countries have shown an increase since the late 1980s. There are, however, some marked regional differences; Central and Eastern Europe witnessed a rapid increase in road traffic deaths during the late 1980s, the rate of increase of which has since declined. The onset of rapid increases in road traffic fatalities occurred later in Latin America and the Caribbean, from 1992 onwards.

2.4 Type of accidents ,position and consequences

There are a variety of road accidents that a driver needs to be concerned about. The reasons for these accidents not only consist of poor driving skills, bad judgment but as well the make, condition and even type of the vehicle in question that caused the accident.

Along with injuries caused by car accidents, motorcycle accident injury is also very common. One can even say that casualties related to motorcycle accident are even more deadly than other injuries caused by automobile accidents on the road. However irrespective of the kind of accident, they are all a cause of concern in regards of physical damage to people and property as well as financial loss.

The most common types of road accidents are :

- *Rear End collisions* : One of the most common types of road accidents is rear end collisions. A typical rear end collision occurs when a car at the back hits or collides into the car at its immediate front. They are more common on heavy traffic roads or roads with stop and go traffic. Rear end collision can cause a significant amount of damage to vehicles, as well as the passengers and drivers. Furthermore, since mostly cars are jam packed on a heavy traffic road, rear end collisions can cause sort of a domino effect and cause damage to cars at the front as well.
- *Individual Vehicle Collisions*: Individual vehicle collisions occur when an individual vehicles gets sidetracked and hits a non-mobile object on the road such as a tree, street light or a road divider etc. These kinds of accidents usually occur due to poor weather conditions such as rain or snow which can cause the roads to be slippery or even occur because of poor judgment or carelessness on the driver's behalf.

Since vehicles reeling out of control happen at high speeds

- *Collisions due to over speeding*: WHO research has shown that an increase in average speed is directly proportional to the chances of an accident occurring, as well as the increased chances of the severity of the accident and the damage it causes. In case of a severe collision risk there is also the risk of pedestrians being hit. While in the chances of the accident being a car to car side impact, the chances of car occupants being injured increases.
- *Accidents due to DUI*: Accidents that occur due to the driver being under the influence of alcohol or other drugs which can lower the inhibitions of drivers and cause them to make poor judgments and careless driving.

These are quite common and drinking under influence is against the law. So if you had had a night out and feel like you might not be up to driving, then let another person drive you or take a taxi or take other means of transport.

- *Distracted Driving*: Although driving while being can seem like a small thing but even losing your focus for a tiny moment can cause a lot of damage. Nowadays technology is the main distraction such as changing the music channel etc. Drivers are constantly checking their mobile phones, GPS other devices for directions. Even passengers in the car or eating, drinking coffee or any other drink can be a reason for the driver to get distracted as well.
- *Ignoring Traffic rules*: Ignoring traffic rules such as jumping red signals, driving over the speed limit, driving in the wrong lane. Ignoring traffic rules not only jeopardizes the life of the driver but also others around them. If you jump a red light because you are late, doesn't necessarily mean you reach your destination in time. In fact ignoring traffic rules will only result in further issues consequently which will make you even more lately for your appointment.
- *Accidents at Intersections*: One of the most common reasons for accidents at intersections occurs when a driver trying to make through a yellow light collides into the active traffic on the other side. These kinds of accidents are also known as T-Bone collisions. These accidents can prove to be fatal if upon collision a car doesn't have functioning air bags or the car occupants aren't strapped with their seat belts.

It is reasonable to mention also the effects and consequences of road accidents . It is obvious that Car accidents can be traumatizing.

You're never truly prepared for the emotional and physical car accident after effects. The effects of it can be long lasting which is why compensation must take into account future expenses and suffering. The mental and emotional injuries after a car accident can include mental anguish, emotional distress, fear, anger, humiliation, anxiety, shock, embarrassment, random episodes of crying, loss of appetite, weight fluctuations, lack of energy, sexual dysfunction, mood swings, and sleep disturbances. Studies indicate that one-third of those individuals involved in a nonfatal accident continue to have the above-mentioned symptoms of emotional trauma a year after the accident including post-traumatic stress disorder, depression, and phobias. Physical injuries that are associated with long-term effects are usually permanent disabilities such as amputations, paralysis, or TBI's which create a diminished mental capacity, but soft tissue injuries that affect the tissue surrounding and connecting tendons, muscles, and ligaments are also usually long term.

2.5 The impact of human behavior on road safety

Car occupant fatalities were found to have occurred predominantly among the young; the passenger fatalities tend to be even younger than the driver fatalities. Contributing significantly to these totals were weekend peaks in fatalities of both car drivers and passengers occurring between 9 p.m. and midnight. Such accidents show a high level of alcohol involvement. Previous research at Nottingham University (Clarke et al., 2002) has shown similar increases in alcohol-related accidents at such times. Alcohol-related accidents, however, may not be the exclusive preserve of drivers under 25. There is also evidence that young male drivers take more risks when driving with passengers, particularly other male passengers. Preusser et al. (1998) found that the presence of passengers was associated with more at-fault fatal crashes for drivers aged under 25 years. This effect was particularly marked where teenaged drivers were carrying two or more teenage passengers.

Chapter 3

Transportation Network Management and Operations

3.1 General

It is a fact that at the beginning of this century the amount of data then available in the entire Internet equals to what is now created in a single second. Mobile phones, social networks, surveys, bank card payments, Global Navigation Satellite Systems (GNSS), online activities, public transport ticketing, location-based services, etc. all produce torrents of data as a by-product of their operations. Comparing the amount of data generated in 2011 with its growth and global population size , it is estimated that on average each person produces 1 GB of content daily. This huge data stream initiated revolution is being referred to as big data. A modern society can be viewed, in part as a system of networks for transportation, communication and distribution of energy, goods, and services. The complex structure and cost of these sub systems demand that existing facilities be rationally designed. Network analysis techniques can be of great value in the design, improvement, and rationalization of complex large scale systems. Transportation network is deemed to represent the supply side of the transportation system to satisfy the movement needs of trip makers i.e. road users in the study area. The transportation network management process includes variety of activities which includes planning, design, construction, operation, maintenance and related research and development. The activities needs frequent decision making to overcome various types of problems. The problems are not well defined and non-structured. The complexity of managing the network is further increased due to multiplicity of modes road, rail, water, air and multiplicity of organization involved at the national, state and local levels.

The road network management problem faced by country is becoming complex. In the total road network of nation, the problems are of inadequate capacity, immediate repairs, operation, management and addition of new links at crucial locations. The services and performance levels of existing road in the country lag far behind the advancement in motor vehicle technology. The maintenance cost of existing road structure is rising, which is serious concern for the authorities responsible for their upkeep under tight budgetary constraints. Transportation systems are commonly represented using networks as an analogy for their structure and flows. The road users' movement and safety on these roads is complex problem. To understand this, the network database created in GIS environment, makes integrated highway information system for various network management purpose including safety and efficiency of passenger and fright/goods movement. GIS database brings information related to networks spatial spread, capacity, inventories, quality and traffic attributes like traffic volume, speed and crash events history.

It is known that the transport environment consists of big data and this is due to the innovation process and also due to the increasing need of the costumers .Both of these are possible thanks to the technologies adapted in order to make people's life easier.

In the transport sector, such tools could improve the use of existing resources and the daily life of citizens. Digitalisation, new technologies and big data have the potential to change the way cargo and traffic flows are organised and managed, they generate business opportunities and pave the way for innovation, new services and business models. It enables cooperation between supply chain actors, better supply chain visibility, real-time management of traffic and cargo flows, simplification and the reduction of administrative burden, and allows for a better use of infrastructures and resources, thereby increases efficiency and lowers costs

Big data is becoming a research focus in intelligent transportation systems (ITS), which can be seen in many projects around the world. Intelligent transportation systems will produce a large amount of data. The produced big data will have profound impacts on the design and application of intelligent transportation systems, which makes ITS safer, more efficient, and profitable. Studying big data analytics in ITS is a flourishing field. This paper first reviews the history and characteristics of big data and intelligent transportation systems. The term big data is used as a general term for referring to data sets so large and complex that traditional data processing applications are no longer adequate. This fundamental change of going from a data-scarce to a data-rich environment seems to infer a shift from relatively "small data" studies aimed to answer specific questions based on sampled data to "big data" studies that aim at probing for relationships and correlations between a wide series of variables and contexts . Big data is often typified by the so-called 3Vs definition. The three Vs define big data as the increase of volume (data scale becomes increasingly big), variety (data come as structured, semi-structured and unstructured data) and velocity (data collection-processing chain needs to be promptly and timely conducted to maximally utilize the potential value of big data).

3.2 Importance of connecting transportation data to the public

Imagine a city where the buses, rapid transit systems, coaches, trams and taxis all work together to provide reliable, predictable and accessible information that helps commuters move from point A to B safely, quickly and efficiently. Unfortunately, the reality is that today's crowded cities face frequent traffic congestion, growing concerns around reliability, environmental impacts and energy consumption, and integration issues between transport systems.

To achieve faster and better ways to get commuters to their final destinations, the ability to share data across all modes is essential. Currently, the majority of cities share data between the different modes of transportation on a quarterly or yearly basis, mainly for the long-term planning of transportation services and infrastructure. Today, the advent of artificial intelligence (AI), big data technologies and hyper computing platforms have given multimodal data-sharing a shot in the arm to go real-time.

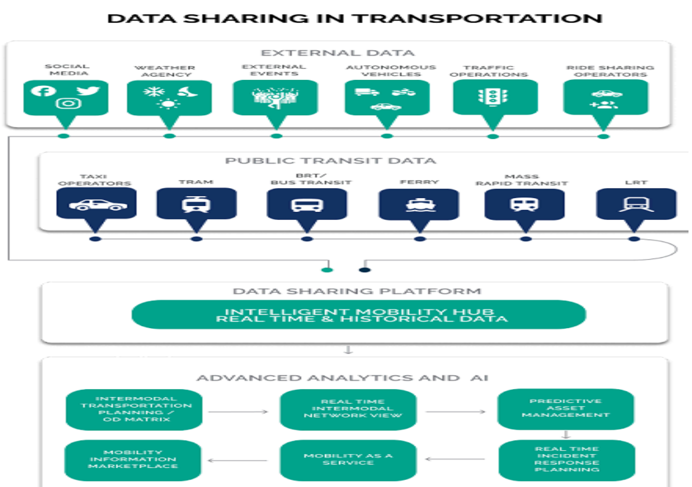

Figure 5. Data sharing in transportation

Moreover, smartphones also enable travelers to actively share information, for instance, about their intended travel plans . Access to this type of information has the potential to improve the decisions and actions taken by public transport actors . Particularly during unplanned disturbances, there is an increased need for more real-time information about travelers . In recent years, unplanned disturbances caused by, for instance, train breakdowns, electrical failures, incidents and people running across train tracks have become a major concern for public transport operators. Parts of these problems derive from aging infrastructures, in combination with increasing demand and limited capacity. If the public transport actors are provided access to real-time information about the affected travelers, they may base their decisions during unplanned disturbances on the needs of the travelers as well as on the resources available.

3.3 Maas as a mobility service

Mobility as a Service or MaaS entails one mobility service platform or application which makes it possible to provide various modes of transport services to the user on demand. Today we experience all kinds of applications for one or two modes of transport. However, MaaS could offer added value facilitating an interaction of MaaS providers into one application offering real-time and on demand ride-, car-, or bike-sharing, public transport, and taxi or car-rental options to the user. Including payment and buying tickets. MaaS therefore covers all mobility segments: from public transport and infrastructure to traffic management and parking, all coming together in urban mobility. Putting the user first. This customised smart mobility service pairs the diverse needs of the user for the changing daily lifestyle. Nowadays, millennials value physical car ownership less than in the past. In London, Brussels, Cologne and Amsterdam drivers used to spend more than 100 extra hours a year in traffic during rush hours. People care more about the environment.   Data from Mobility as a Service platforms could help authorities manage and improve traffic flows. It is now that MaaS and the collection of data can flourish and really add value to both user and the road. According to IBM 90% of the data in the world in 2017 was generated within the last 2 years. This could speed up the transition from solely supplying transport to the user, to an integrated user centric smart mobility system by the use of big data. What Maas offers is an alternative to owning a car in the form of an app that works out the best option for every journey. The service gives customers access to public transport, taxis and car rentals depending on which is most convenient. The aim is to have all modes of transport included in the future.

3.4 First examples of Maas

Successful pilots have already been completed in Amsterdam, the Netherlands.

Amsterdam is leading the way for Mobility as a Service in the Netherlands with successful pilots already completed in the growing Zuidas district of the city and a new app planned for 2020.

As well as being the host city of the largest of all the Intertraffic shows, Amsterdam is increasingly establishing itself as a leader in smart mobility for residents and visitors alike. Over the past few years, it has been the test bed for the experimentation of several Mobility as a Service (MaaS) projects. One of the most recent examples is a pilot known as The Zuidas Mobility Experience. In the Netherlands , six different projects are being trialed:

1. From January 2020, an app providing MaaS services will be available for a trial period of two years with the goal of improving access to the burgeoning Zuidas district in Amsterdam.
2. A similar app intending to stimulate use of alternative modes of transport to cars will also be introduced in the Dutch region of Utrecht.
3. In Eindhoven, in conjunction with a number of employers based in the city, a project is already underway that aims to ensure all business travel there is done sustainably by 2025.
4. The only province in the country with borders to two other nations, Limburg is addressing multimodal possibilities in a cross-border context with the intention of simplifying public transport travel and reducing car use in the process.
5. Accessible travel for less able-bodied individuals is limited in Twente so special attention is being given to increasing MaaS options for customized transport.
6. Traveling to Rotterdam from The Hague Airport is currently only easily done by car. A new project is seeking to develop multimodal options.

Chapter 4

Intelligent Transport Systems in context

4.1 Introduction

Intelligent transport systems (ITS) is a global phenomenon, attracting worldwide interest from transportation professionals, the automotive industry, and political decision makers. ITS is defined as technologies ,systems and services that provide safer and better transport services with the benefits of improving productivity ,safety and service satisfaction.

Early work in ITS was carried out by the Japanese in the 1980s. At that time, the Japanese had not coined a specific name for ITS as it was considered part of traffic control. They later referred to this work as the Japanese Intelligent Vehicle System (IVS) programme. Siemens was doing some pioneering work on route guidance systems in Berlin in the 1980s, with the Europeans referring to the subject as road transport informatics.

The United States picked up on the theme in the late 1980s, referring to the subject as Intelligent Vehicle Highway Systems (IVHS). The Europeans referred to the work they were doing in application of information and communication technology to transport as Advanced Transport Telematics (ATT), only for the United States to . come up with another term, ITS, giving recognition to the wider application of technology to public transport systems as well as private cars and highways. This name seems to have stuck, with many international organizations adopting it.

4.2 The urban setting and its development challenges

The world is industrializing and urbanizing on a global scale that follows consistent patterns. Some 54 per cent of the world's population live in urban areas, creating many challenges related to urban living . The United Nations has projected that two thirds of the world's population will be urban by 2050 – or an increase of 2.5 billion to current urban communities . One in eight people currently lives in one of the 28 so-called mega-cities that hold over 10 million inhabitants .

Many high-growth urban areas can be found in the developing countries of Asia and the Pacific, with the region itself accounting for more than 53 per cent of the world population. According to UN Habitat (2014), in the Asia-Pacific region, India and China alone are projected to add 404 and 292 million urban dwellers respectively to the world's urban population. Most Asian countries are confronted with complex issues in planning to meet a range of challenges in providing adequate infrastructure for water supply, sanitation, energy, transportation, as well as public services for their emerging mega-cities. These future mega-cities will be confronted with a host of challenges linked to housing, safety, employment, and the delivery of public services including urban mobility.

Urban mobility is expected to worsen during the 21st century in developing countries with increased car ownership, and also due to the projected rapid expansion of urban perimeters in under-planned agglomerations. This will cause additional traffic congestion which can be expected to result in additional costs to motorists, as well as increased air and noise pollution, stress and losses to traffic accidents.

Moreover, insufficient mobility between places of residence and of economic activity could further penalise and marginalise the poorer segment of population, limiting their development prospect4 . Inadequate public transport systems compound the problem of urban sprawl and traffic congestion by further encouraging private vehicle ownership and usage. In this context, ICT can play a key role in improving the delivery and efficiency of infrastructure for sustainable development in urban areas. ICT can support the implementation of smart power grids, better water management, effective early warning systems in case of natural disasters and better transport infrastructure, also called intelligent transport systems. This is owed to important innovations and their commercialisation in a number of areas including sensing, detection and transmission equipment, innovations in data storage and processing that allow the rapid and continuous exploitation of “big data”” in urban contexts, improvements and declining costs in geo-positioning systems and of course the advent of mobile telephony (including mobile broadband).

These new technologies and their applications to infrastructure can greatly enhance the efficiency and sustainability of infrastructure services, not least in the field of transport.

The intelligence provided in context-aware systems like public transport system is implemented through channelling the contextual data being collected from the transport infrastructure into prediction systems so that behaviour of the transport system can be forecasted. The predictions, projections and surveys envisage a highly efficient information management architecture that can handle that unprecedented volume of data. Significant efforts have been made in last few years to contribute in context-aware applications regarding collaborative workspaces , context-aware computing [and context-aware social computing .

The ITSs are not only context-aware systems, but they need the collected data to be processed in real-time because the vehicles are moving objects and so information from sensors are continuously changing. This adds an element of complexity since the information is to be processed in real time to reach its end audience, the commuters . In the public transportation domain, the connotation of ITS is synonymous to the advanced public transportation system (APTS), which is defined as a “collection of technologies that increase the efficiency and safety of public transportation systems and offer users greater access to information on system operations.

Lately, in the literature and at various forums, ITS is often used to refer to Integrated Transport Services, thus with more of an emphasis on the user. Intelligent Transportation System (ITS) enhances the performance of modern transportation systems through improved reliability in travel times and in the reduction of the risk of collisions and injuries. Overall there are 3 different used as safety technologies:

- Vehicle based systems
- Infrastructure based systems
- Cooperative systems

4.3 Vehicle based systems

In these types of systems, safety technologies are used inside the vehicle .

Vehicle safety equipment majorly include 2 groups of instruments, on-board sensors, that collect data and on-board units (OBUs) that use that data to compute chances of accident and may generate an alarm or may even take partial control of some features of the vehicle. These systems provide advantage of early warnings to the driver of potential dangers or override in some cases to some degree to prevent the expected collision through the driver's control of the vehicle in attempt to avoid collisions .However, these benefits are only applicable to vehicles equipped with such equipment . When talking about safety features we refer to two types of safety features : active and passive safety features.

Active safety indicates the technology which is used in assisting the preclusion of a crash while on the other hand passive safety refers to components of the vehicle itself like airbags, seatbelts and the chassis of the vehicle that helps to protect occupants in the event of a crash. Active safety features include but are not limited to ABS, traction control and EBD, are meant to avoid an accident.

Overall there are six active safety technologies on which is being worked on for the future :

- **Lane departure warning**: is used when the vehicle is unintentionally sliding out of the designed lane so the driver is warned by an alert system.
- **ESC (electronic stability control**): one of the biggest game changing technology in auto safety in years. ESC is built on top of ABS. The sensors determine when the vehicle is moving in a wrong or dissimilar direction from its pointed destination, and uses the ABS to brake the appropriate wheels to get it back on course.

- **Blind-zone warning:** It senses when another vehicle is approaching your vehicle's flanks, this system alerts the driver with a warning light and/or audible alarm. One factor that might reduce its effectiveness is that when the warning light is on the outboard mirror, some drivers simply don't use.
- **Collision warning with automatic braking**: By making use of a radar similar in working to that of cruise control, this system tries to sense when the traffic ahead is slowing or stopped and generates an alert for the driver with an audible warning and will bring the car to a stop if he fails to react in time.
- **Emergency brake assist**: This system determines when the driver is applying the brakes in a panic situation and applies more brake quicker. Not only might it prevent some crashes but it may reduce the severity of a crash.
- **Adaptive headlights:** These headlamps pivot in response to where the front wheels are pointed, helping illuminate around curves on dark roads.

4.4 Infrastructure based systems

Infrastructure based systems are systems that are made of sensors which are located on the side of the road . Generally they are used to gather all the necessary information that are needed to warn the drivers in order to keep them safe. The difference of infrastructure based systems and vehicle based is that the first one is more advantageous because it can detect factors that the sensors on the board of the vehicles cannot detect. These factors include for example : different obstacles , various road shapes and weather conditions as well. .

4.5 Cooperative systems

Modern vehicles equipped with driver assistance systems can “feel” (e.g. by sensors), can “see” (e.g. by cameras) and in future can “speak” (e.g. by communication systems). The new technology of Cooperative Intelligent Transport Systems and Services (C-ITS) enables these communication processes of vehicles among each other (V2V) and with traffic infrastructure (V2I). It is based on the principle that all cooperative parties (ITS stations, e.g. in vehicles, road side units) (locally) exchange information in an ad hoc network using ITS G5 wireless communication.

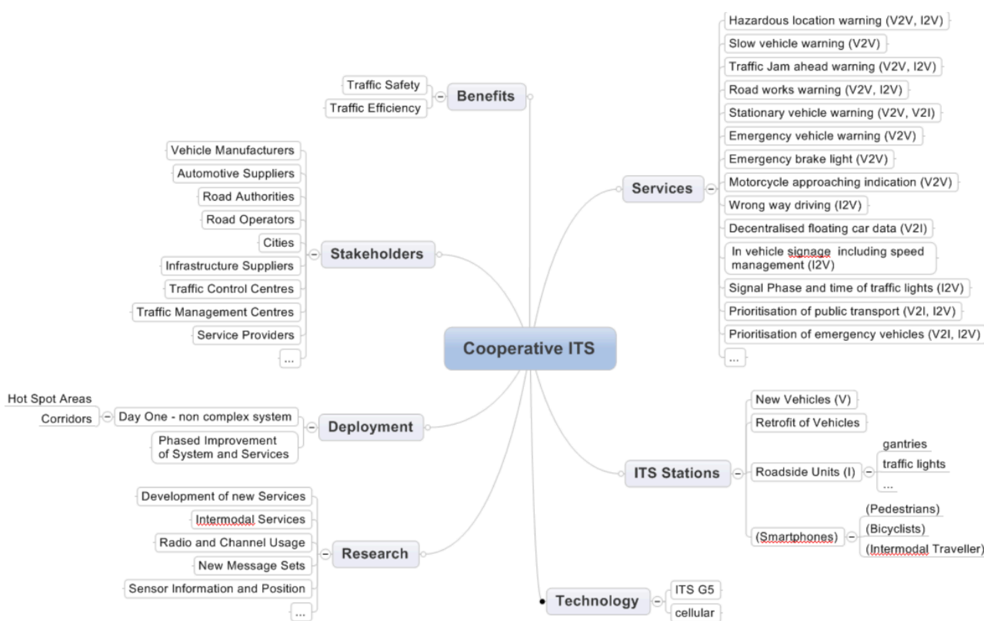

Fig. 6 Most important facts on transport cooperative systems

Every receiver evaluates the data received and considers the information for its data analysis, resulting in strategic warning, tactical advices and information provided to the driver. While vehicles provide data for example about their position, speed and driving direction or event-driven information, such as a defect, road side units deliver data about for example current speed limits, the signal phases and timing of traffic lights or information about diversion.

The analysing receivers integrate those data to a complete picture of the local traffic situation and generate information and warnings directly relevant for the individual driver. Via a Human Machine Interface (HMI), he receives for example information about road works blocking his route or is warned in case of a potential situation, for instance if a vehicle in front of him brakes hard suddenly.

4.6 Advanced traffic management systems (ATMS)

Advanced traffic management systems is generally use in controlling the traffic. It is an integrated solution to manage highway traffic through real time information collection, processing, analysis and finally dissemination to the users, concerned agencies and stake holders. Advanced Traffic Management Systems can be installed in both motorway and urban environments to increase and maintain transportation capacity through the more efficient use of existing infrastructure.

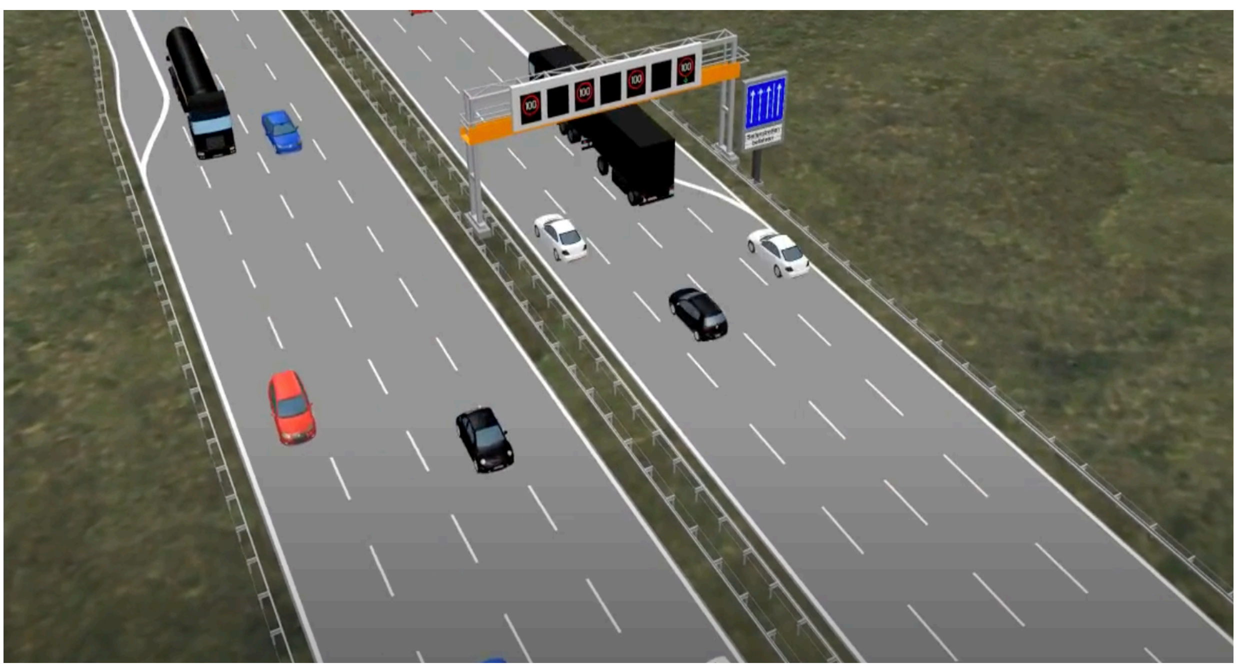

Figure 7. Advanced traffic management system

- Further applications of ATMS:

i. Variable speed control is used to harmonise individual vehicle speeds and control overtaking activity to keep traffic flow fluent at times with high traffic volumes.
ii. Variable Message Signs (VMS) to warn drivers from possibly hazardous conditions (incidents, congestion, heavy rain, fog etc.) and advise of route choices due to incidents can also be simulated. Both traffic-actuated and pre-timed variable message signs with varying degrees of compliance can be simulated at motorway junctions.
iii. Simulate temporary hard shoulder running to provide additional capacity during peak traffic demand.

4.7 Smart traffic signal control system

As the population in the world continuos to grow , that also causes an increase in the number of vehicles and a lack of effective traffic management would lead to huge economic lost such as energy consumption, greenhouse gas emissions, and time lost. With the continuous population growth, traffic congestion has become one of the biggest obstacles restricting the city economic development, it results in high consumptions of fuel, increases the cost of commutes, and also pollutes the environment.

A traffic signal controller, as the most important part of infrastructure in smart city transportation, is the main coordinator for the urban traffic flows. How smart traffic signal control system works is by responding to the traffic conditions changes . This is done by controlling the signal's length by algorithms. The purpose of smart traffic signal control is to increase throughput by minimizing delays and number of stops. In turn, pollution and travel times are reduced as well.

4.8. Ramp metering

Ramp meters are traffic signals installed on freeway on-ramps to control the frequency at which vehicles enter the flow of traffic on the freeway.

Ramp metering reduces overall freeway congestion by managing the amount of traffic entering the freeway and by breaking up platoons that make it difficult to merge onto the freeway. As seen in Figure 7 vehicles traveling from an adjacent arterial onto the ramp form a queue behind the stop line. The vehicles are then individually released onto the mainline, often at a rate that is dependent on the mainline traffic volume and speed at that time.

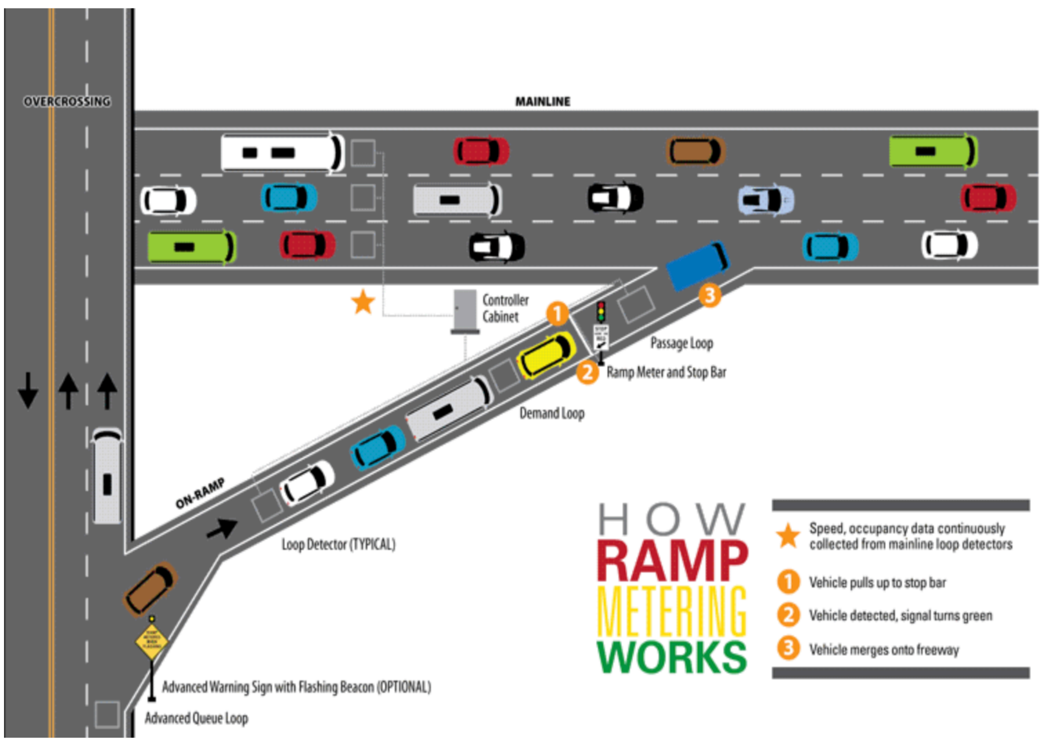

Figure 8. Ramp metering configuration

An agency's goals and objectives for ramp metering should be consistent with regional transportation goals and objectives, which will vary from region to region. Often these goals and objectives are driven by the needs and areas of opportunity for a region. For instance, one region may want to improve safety and another may prioritize increasing mainline speed.

4.9 Incident Management

An incident management system is a combination of equipment, personnel, procedures and communications that work together in an emergency to react, understand and respond. Each of the four factors is necessary in order for an incident management system to be effective.

To maximize the effectiveness of an incident management system, it is important those whose responsibility it is to react, understand and respond, have access as much relevant data as possible about the incident in the shortest possible time. Saving time saves lives.

This is where Rave Mobile Safety's powerful data and communication tools can be invaluable. Each can be used as an element of an incident management system, or the components combined to prepare better, respond faster and communicate more effectively during emergencies.

<u>The objective of incident management system is :</u>

- Increasing the visibility and communication of incidents to business and IT support staff.
- Enhancing the business perception of IT through the use of a professional approach in quickly resolving and communicating incidents when they occur
- Aligning incident management activities and priorities with those of the business.
- Maintaining user satisfaction with the quality of IT services.

It might sound complicated but it does really just boil down to the earlier ITIL incident management objective of "To restore normal service operation as quickly as possible with minimum disruption to the business.

Incident Management Benefits:

The benefits of incident management include, but are not restricted to:

•Shortening the "incident lifecycle" and decreasing downtime, thus maximizing business productivity.

•Resolving incidents before they can adversely impact business operations.

•Making better use of potentially scarce IT resources. Having defined roles and responsibilities and a single, consistent process not only speeds things up but also reduces duplication of effort and wastage.

•Facilitating better collaboration between different IT teams and preventing dropped issues or issues "ping-ponging" between teams.

Figure 9. National incident management system

4.10 Electronic toll collection system(ETCS)

Electronic toll collection system is a system by which drivers can pay tolls without having to stop at a toll booth. is a wireless system to automatically collect the usage fee or toll charged to vehicles using toll roads, HOV lanes, toll bridges, and toll tunnels. The collection of the fees is performed electronically by way of equipment installed in the vehicles and sensors at toll location. collection as well as continuous monitoring of traffic. Electronic toll system utilizes vehicles equipped with electronic tags, wireless communication, inroad/ roadside sensors and a computerized system to uniquely identify each vehicle which electronically collect the toll and provide traffic monitoring and data collection. Functioning of electronic toll collection allow more efficient electronic monetary transaction to take place between a vehicle and toll agency The fact that drivers need not to carry any cash is one of the main reasons why electronic tolling system is becoming popular

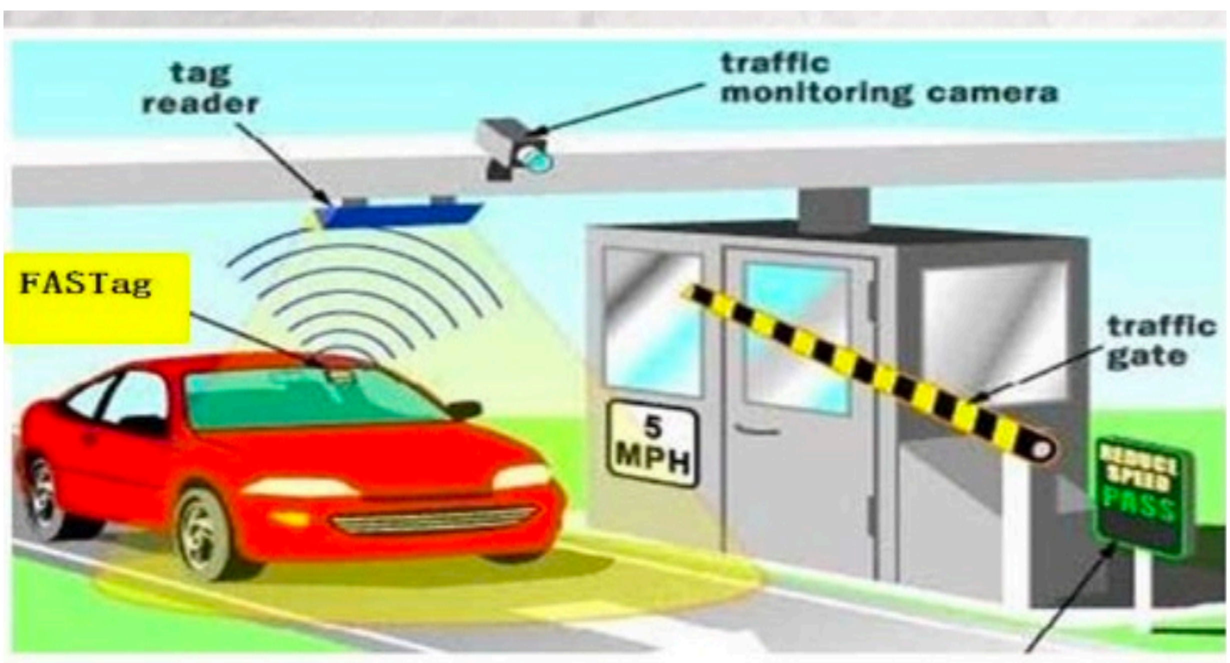

Figure 10. Example of a ETCS

There are many benefits of using Electronic Toll Collection namely; reduce time, reduction in vehicle emissions, increase in lane capacity and convenience to the users.

ETC also helps in controlling the level of congestion with more accuracy, by allowing the road users to use dynamic pricing instead of fixed-step toll schedule. Most importantly, the system allows non–stop service to the road users without bothering about toll rates or money change, same tag is read at toll plaza on all the Highways across the country and we save paper as well as fuel. Electronic toll collection utilizes radio frequency identification (RFID) technology. It contains RFID tag and transceiver, tag can be either active or passive and each tag has a unique identity number. Active tag has their own internal power supply allow a large range, while passive tag use incoming signal from reader thus have a shorter range. Reader contain antenna to transmit and receive signal from each tag. The tag which is sticked at the front glass of the vehicle is detected by the RFID reader and data is matched with the database provided at every toll booth, toll amount is deducted from his account, immediate gate is opened and message will be send to registered mobile number. User can recharge his account at any time. There is another facility of detection of stolen vehicle, database contain stolen directory in which stolen vehicle tag number is stored by the authority, when incoming vehicle data is matched then transaction will proceed and immediately message will send to registered police station, it is another advantage of this system.

A joint study24 conducted by the Indian Institute of Management (IIM) Calcutta and the Transport Corporation of India (TCI) showed that operational inefficiencies encountered by freight transportation vehicles at toll stations in India amounted to a total cost of nearly USD 5.4 billion; with USD 600 million for time wasted in waiting at toll stations across the country, and USD 4.8 billion for extra fuel costs incurred by the slowing down and stoppage of vehicles at toll stations. The findings of this IIM-TIC study were based upon operational efficiency surveys covering 10 major transportation routes of India. In September 2014, the Indian Government launched the first-ever national ETC programme under the name “FASTag”.

The FASTag system utilizes RFID devices that are affixed to the windshield of vehicles to be read by the devices installed in dedicated FASTag lanes at toll stations. The appropriate amount of toll tax, determined by the class of the vehicle, is then automatically deducted from the registered user's account. Under the FASTag programme, ETC systems are operational at an estimated 473 toll stations across India. The first ETC system was opened on the Delhi-Mumbai highway in October last year. After the full deployment of ETC systems nationally, it is anticipated that the estimated stoppage delay at toll stations, ranging between 5% to 25% of the total journey time, will be significantly reduced.

4.11 Electronic road pricing

Electronic road pricing an electronic toll collection scheme first proposed in hong kong as early as in the 1980s to manage traffic by congestion pricing. Singapore was the first to introduce congestion pricing as a tool to control traffic volume. It started by imposing a flat rate under the manually enforced Area Licensing Scheme (ALS) in 1975. The scheme was improved over the years and then upgraded to the current Electronic Road Pricing (ERP) system, which automatically charges motorists each time they pass through heavily used roads during peak hours

- Advantages of Electronic Road Pricing

1. Raises Revenue for the Government. If the governments gets more tax revenue it can mean either:

a. other taxes can fall,

b. the government can spend more on public transport

c. or the budget deficit can reduce.

Nobody likes new taxes, but whether money is collected from new or old taxes makes no difference to the disposable income of the tax payer.

2. Increase social efficiency. In a free market the consumption of cars are overconsumed. When driving people ignore the negative externalities of congestion and pollution. The social cost is much greater than the private cost. Therefore it makes sense for the government to charge a much higher price of driving in congested areas.

3. Congestion is Inefficient Congestion costs the UK economy over £20 billion a year in lost output and wasted time. This should be tackled.

4. Reduce pollution and global warming. Pollution from cars is a significant contributor to CO_2 emissions in the UK. Road charging should encourage people to look for other forms of transport which don't pollute as much.

5. Save Journey Time - If you earn £15 an hour, why would you not like the idea of paying £7 to get home an hour earlier? Who enjoys sitting in a traffic jam?

Disadvantages of Electronic Road Pricing

1. It is an intrusion on liberty. To drive you need countless documents. When you use electricity the electric companies measure exactly how much electricity you use. When you make a telephone call the telecom company know exactly whom you ring and charge accordingly. Why should driving be any different.

2. Govt is just using it to raise money. Is that not a purpose of income tax, VAT and every other type of tax? Raising money from a new tax enables other taxes to be lowered or spending to be increased.

3. Economic output is more important than Global warming. We shouldn't worry about the future, the most important thing is keeping taxes low for the current motorist.

4. Increases Inequality. This is true to an extent. A road pricing charge is a higher % of tax for those on low incomes. But so is the cost of buying a car and petrol. If concern about equality of distribution is an issue the govt can alter other taxes and benefits. A tax which increases efficiency need not be stopped on equality grounds. It is always possible to compensate the effects to others.

4.12 Advanced traveler information System

Advanced traveller information systems (ATIS) have gained worldwide interest as a promising technology for improving the efficiency of urban networks and reducing congestion. It is generally anticipated that the provision of route guidance to travellers will help them avoid congested links in the network, thereby reducing congestion by spreading traffic over space, and possibly time. This proposition has been so well received that technology for ATIS is being developed and tested in numerous locations around the world. The concept of ATIS is to collect and analyze data on the current performance of the highway system, and to derive information that can be disseminated to travellers on a real time basis .Information may be delivered to travellers before they start a trip or while en route. Real time traffic information can be delivered to travellers en route via two means: 1)outside the vehicle, or 2) inside the vehicle. Information delivered outside the vehicle is visual, as in the case of changeable message signs (CMS). Information delivered inside the vehicle may be visual, or it may be audio, or both, e.g Highway Advisory Radio (HAR)and in-vehicle ATE

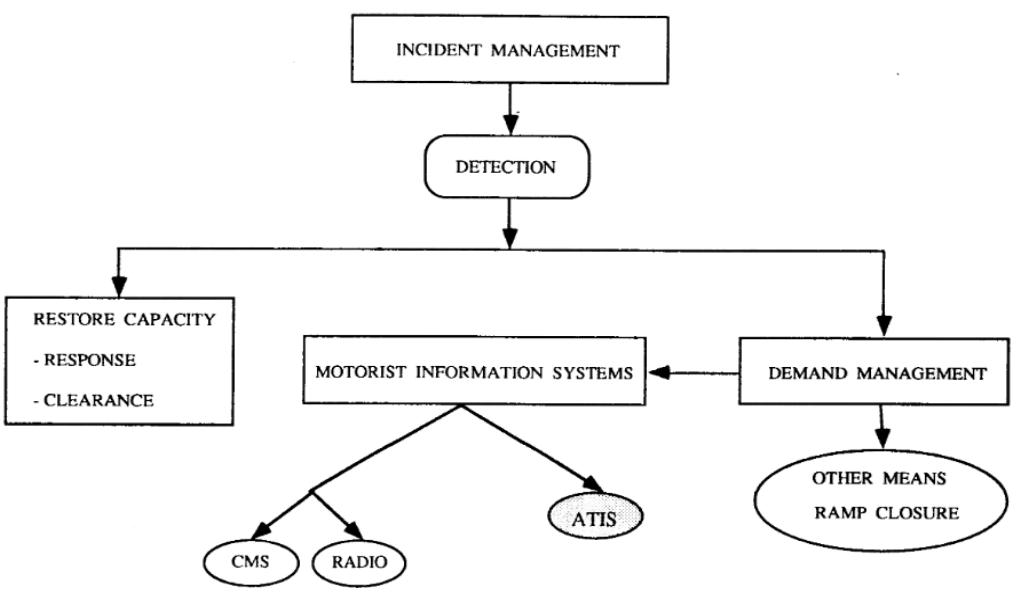

Figure 11. Incident management scheme

4.13 Intelligent speed adaption

Intelligent Speed Adaptation (ISA) is an in-vehicle system that uses information on the position of the vehicle in a network in relation to the speed limit in force at that particular location.

ISA can support drivers in helping them to comply with the speed limit everywhere in the network. This is an important advantage in comparison to the speed limiters for heavy good vehicles and coaches, which only limit the maximum speed. ISA is a collective term for various systems:

The open ISA warns the driver (visibly and/or audibly) that the speed limit is being exceeded. The driver him/herself decides whether or not to slow down. This is an informative or advisory system.

The half-open ISA increases the pressure on the accelerator pedal when the speed limit is exceeded (the 'active accelerator'). Maintaining the same speed is possible, but less comfortable because of the counter pressure.

The closed ISA limits the speed automatically if the speed limit is exceeded. It is possible to make this system mandatory or voluntary. In the latter case, drivers may choose to switch the system on or off.

The currently available ISA systems are based on fixed speed limits. They may also include location-dependant (advisory) speed limits. It will become increasingly possible to include dynamic speed limits that take account of the actual circumstances at a particular moment in time.

4.14 Adaptive front lightning systems (AFS)

Adaptive front lighting systems (AFS) attempt to dynamically adjust the headlights of the vehicle so that the driver has optimum nighttime vision without compromising the safety of other road users.

The AFS uses stepper motors to control the headlight angle when the vehicle steers or the road is not even. Besides, the adaptive system tries to avoid a direct glare to oncoming vehicles. It uses headlights that consist of an array of LEDs.

Depending on the position of the oncoming car, some of these LEDs are automatically dimmed. In this way, while around the oncoming car is illuminated, the driver side is dimmed.

The AFS uses image sensors to detect the position of the oncoming vehicle. The AFS consists of several different building blocks, such as LED drivers, LED matrix managers, stepper motors, imaging sensors, MCUs, etc. To efficiently control the light intensity and direction, these blocks should be fast, efficient and accurate.

4.15 Forward collision mitigation

Forward collision warning (FCW) systems provide visual, audible, and/or tactile alerts to warn a driver of an impending collision with a car or object directly in its forward path. The Insurance Institute for Highway Safety (IIHS) data show that FCW reduces rear-end accidents by 27 percent.

Some systems let drivers adjust the timing of this warning to early, standard, or late. This radar-based system automatically applies the brakes when there is a sudden reduction in the distance with the vehicle in front and helps to avoid a collision or reduce impact damage in the event of a collision.

4.16 Lane changing support

When activated, Lane Changing Support uses radar technology to scan the blind spot on your passenger side for other road users. If it's not safe to change lanes, you're alerted with a buzzer and a flashing icon next to the passenger mirror. Changing lanes always poses a risk, especially if a vehicle in the neighboring lane is going faster. Then there is the blind spot to consider – an area behind the car that is not visible in the external rearview mirrors. Valeo's Lane Change Assist system alerts the driver if there are vehicles in this area or vehicles approaching rapidly from the rear. This information is extremely valuable, especially if the driver suddenly decides to change lane.

Vehicles passing in the opposite direction, or overtaken, are detected but not signaled. The driver receives the information in the form of a signal intelligently integrated into the exterior rearview mirror. The information is indicated immediately and intuitively.The lane change assistance system uses radar sensors that scan the surrounding area using a number of different radar beams. The fully electronic radar does not have any moving parts and operates in nearly all weather conditions.

CHAPTER 5

Adoption of ITS for Sustainable Transportation

5.1 Sustainable Development

According to Bruntland (1985), sustainability is defined as economic development that meets today's generation needs without compromising the opportunity and ability for future generations. There are so many definitions of sustainability, and the experts have been developing the term of sustainable development and sustainable transportation, but the experts increasingly agree that these should refer to a balance of economic, social, and environmental health. Then it can be concluded that sustainable public transport should be in accordance with sustainable development and sustainable transportation . Sustainable development within a business can create value for customer, investors, and the environment. A sustainable business must meet customer needs while at the same time treating the environment well. To many, sustainable business is a synonymous with green business. In fact, the environment is only one aspect of sustainability. It takes much more than environmentally friendly practices for business to be truly sustainable.

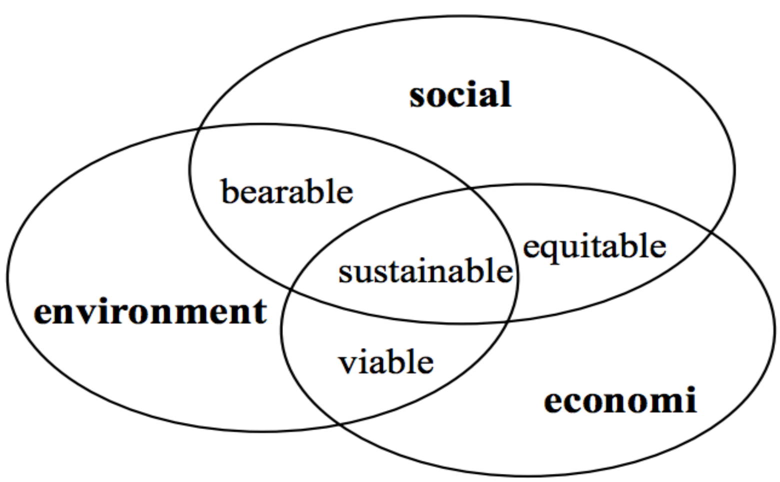

Figure 12. Scheme of Sustainable Development

An issue that has raised concerns relates to the capacity of the global economy to accommodate enduring demographic, economic, and resource consumption growth. Population growth and an increase in living standards allow individuals access to an extensive array of goods and services. Since the 1970s, many statements have been made asserting that the world would be unable to sustain such growth without a possible socioeconomic and environmental breakdown. While these perspectives have been demonstrated to be inaccurate, since resource availability and the quality of life increased, there are concerns that a threshold could be reached at some point, particularly regarding climate change. Under such conditions, sustainable development has been advocated as a priority for future social and economic development.

However, sustainable development is a complex concept that is subject to numerous interpretations since it involves several disciplines and possible interconnections. It is not surprising that the subject is prone to confusion regarding its nature, consequences, and appropriate response. It is agreed that sustainability favors conditions that benefit the environment, the economy, and the society without compromising the welfare of future generations. Still, as history clearly demonstrates, the conditions of future societies will largely depend upon the legacy of current societies on resources and the environment. All forms of assets (capital, real estate, infrastructures, resources) passed on to the next generation should be at least of equal value (utility) per capita. The basic definition of sustainability has been expanded to include three major pillars , or also known as the three Es:

1. Social equity : Relates to conditions favoring a distribution of resources among the current generation based upon comparative productivity levels and the promotion of equal opportunities.

This implies that individuals or institutions are free to pursue their choice and reaps the rewards for the risk they take and the efforts they make. Social equity is usually the most challenging element of the concept of sustainability to define. It should not be confused with redistribution (or socialism) where a segment of the population agrees or is coerced to support another segment.

2. Environmental responsibility. It involves a "footprint," which is lesser than the capacity of the environment to accommodate. This includes the supply of resources (food, water, energy, etc.) and the safe disposal of numerous forms of wastes. Its core tenets include the conservation and reuse of products and resources.

3. Economic efficiency. Concerns conditions permitting higher levels of economic efficiency in terms of resource and labor usage. It focuses on capabilities, competitiveness, flexibility in production, and providing goods and services that supply market demand. Under such circumstances, factors of production should be freely allocated, and markets open to trade.

Sustainability can be expressed at two spatial levels:

Global : Long term stability of the earth's environment and availability of resources to support human activities.

Local : Localized forms are often related to urban areas in terms of jobs, housing, and environmental pollution.

5.2 The importance of developing sustainable transport system in transport system

Having a world population of 7.3 billion people, according to predictions it is aspected to have an increase of almost one billion people in the next 12 years, and it's estimated to reach 8.1 billion in 2025 and to reach 10.9 billion by 2100. The key reason of people migrating cities are the social and environmental problems. The relatively comprehensive city functions can provide local residents with better education, improved health care system, more income and other effective services. s. Those advantages of scale and proximity of cities attract people from rural areas or small towns flooding to megacities. this rapid development can generate inevitable negative effect on cities that no city planners can ignore.

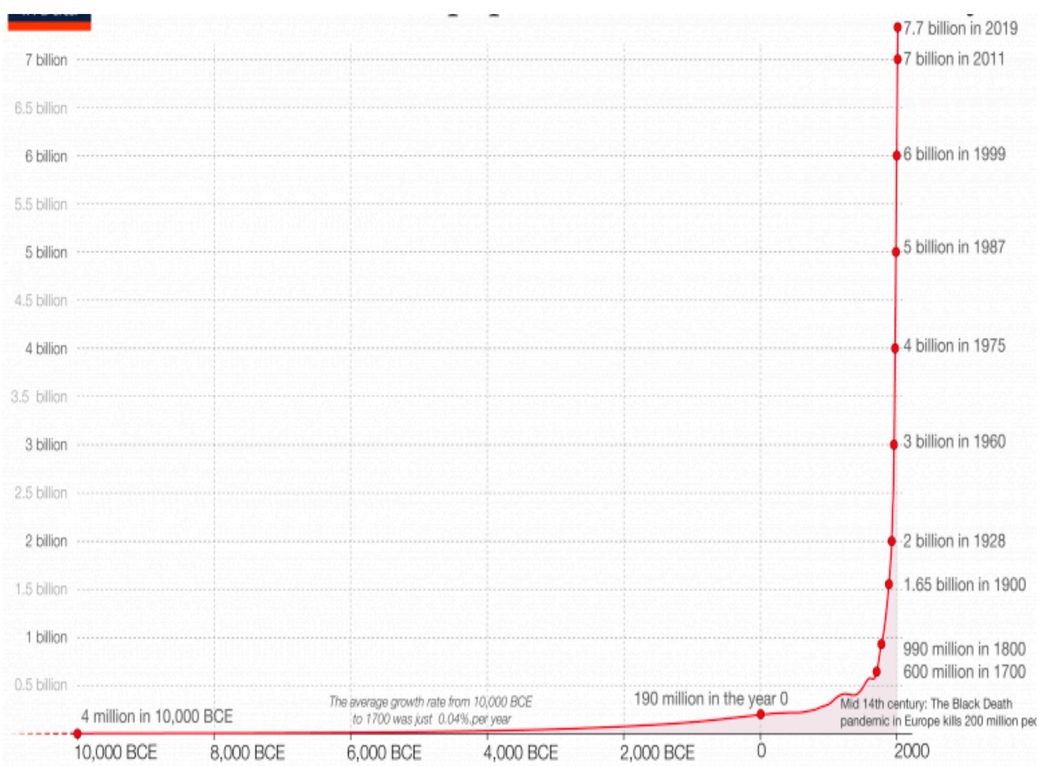

Figure 13. The size of the world population over the last 12000 years

First of all, the intensive use of nature resources such as land, water and energy can lead to all of them run out in a short time. This may significantly affect future generations.

Secondly, the over-stretching of infrastructure increases the density of cities. People have to live within a very small space. Thirdly, social and economic inequalities occur in many countries, especially the developing ones. Thus, urban planning research nowadays more focus on solving city planning problems in developing countries. In order to help creating a sustainable living environment for local residents, city planners make great efforts in developing sustainable cities. For many of them, the most core and important part to build up sustainable cities is to ensure sustainable transport systems in cities. Because a sustainable transport system can help all nature resources be used in an economic and effective way. A sustainable transportation system as one in which fuel consumption; vehicle emissions, safety, congestion, social and economic access are of such levels that they can be sustained into the indefinite future without causing great or irreparable harm to future generations of people throughout the world. The urban lands can be used as roadways and bridges, pipelines and hazmat, railroads, pedestrians, waterways. All vehicles like automobiles, trucking and motor coaches, aviation, public transit, railways, bicycles, maritime can be applied. A sustainable transportation system should take all of those vehicles into consideration.

5.3 Interconnection between sustainable transport and smart cities

Economic growth necessitates flexible transportation which eases access to resources and trade markets. Furthermore, transportation is positively linked to better standards of life through connecting people to places of education, work, health services, and recreation .As such, transportation is a primary concept that actuates social and economic development.

Sustainable transportation is an aspect of global sustainability, which involves meeting present needs without reducing the ability of future generations to meet their needs. The idea of smart cities rotates around intelligent approaches that focus on the needs and interests of people regarding economic development. In other words the concept of smart cities is looking at the long term element of economic development and quality of lifestyle of people living in cities. The idea is to provide improved and smarter public services, which are considered to be not only citizen-centered but also economically viable and sustainable.

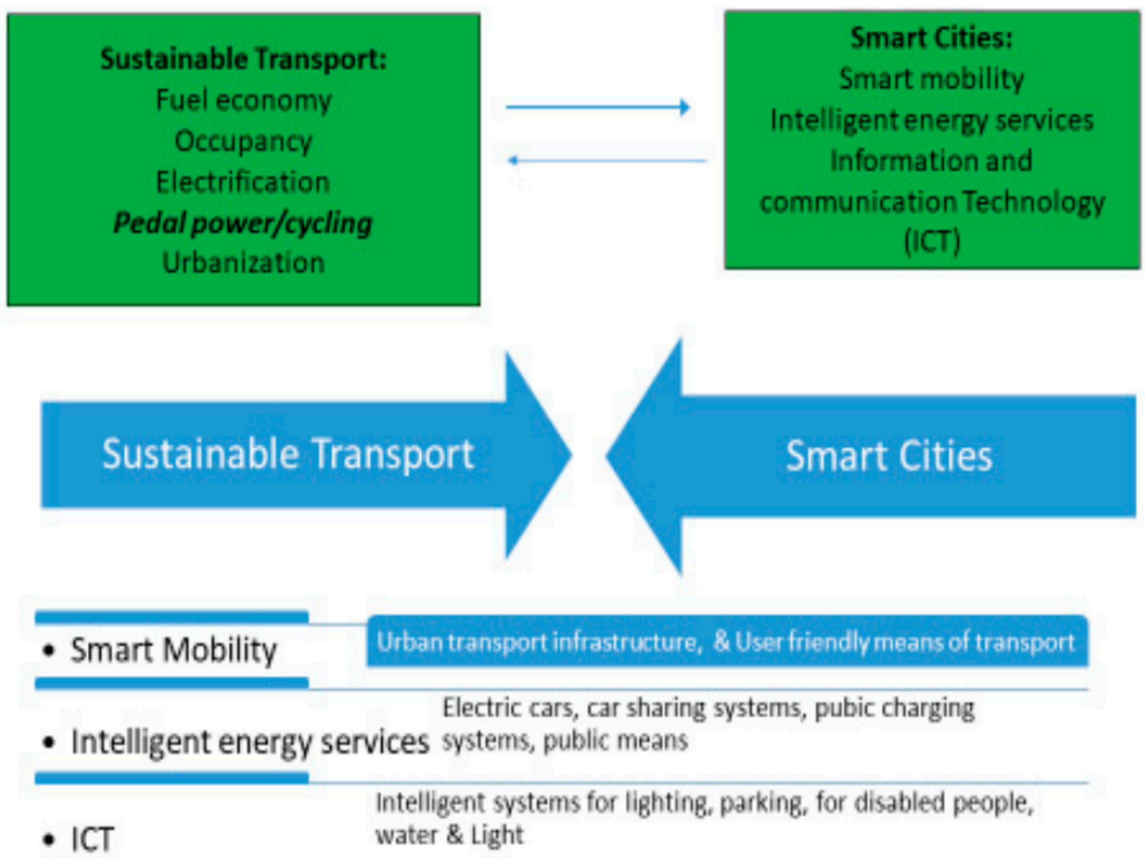

Figure 14. Inter-connection between sustainable transport and smart cities

5.4 ITS and environment

The reliance on motorised transport as an everyday function is a substantive contributor to global climate change . Without significant policy or technological advances, the likelihood of decoupling transport growth from emissions growth would appear slim given that 95 per cent of transport energy is derived from fossil fuels. Principal carbon reduction pathways include supporting low carbon technological innovation and deployment; encouraging modal shift from private car use to less polluting options such as walking, cycling and public transport; advocating more efficient forms of traffic management and driving behaviour; and employing strategies that seek to reduce the need to travel altogether (e.g. spatial planning).

The main areas for debate appear to be between behavioural and technological innovation, and between reform and radical change. Whilst discouraging private car use through comprehensive behavioural measures would assure significant cuts in emissions from transport, a technological reformist approach could be seen to be more politically and socially expedient.

In fact, as scholars maintain a transition to a lower carbon society will almost certainly necessitate changes in and across both dimensions simultaneously: behavioural and technological, reformist and radical. Drawing upon the socio-technical perspective, the different elements- actors, artefacts and institutions- have to be aligned in a particular order for a sustainable transition to a lower carbon alternative to emerge. Intelligent technologies are therefore playing an increasingly important role in the drive for green innovation; however socio-behavioural barriers may still need to be addressed if comprehensive deployment of these technologies is to occur.

CHAPTER 6

AUTONOMOUS CARS – THE NEXT REVOLUTION IN MOBILITY

6.1 General

Traffic accidents are a major source of disability and mortality worldwide. Every year, 1.2 million people die and up to 50 million people are injured . Autonomous or highly aware cars have the potential to reduce these numbers dramatically. However, building a self-driving car that exceeds human driving performance is not easy. While traffic injuries and deaths are large in number, they are relatively infrequent. In the United States, a human driver makes a fatal mistake only once in approximately 88 million miles.

Autonomous cars are predicted to make the jump from science and research to factory floors and consumers in the next few years. Autonomous vehicles are a promising evolution of current vehicle technology and advanced driver assistant systems, and are envisaged to be the sustainable future for enhanced road safety, efficient traffic flow and decreased fuel consumption, while improving mobility and hence general well-being. Research on autonomous vehicles has been growing rapidly in recent years and encompasses different domains, including robotics, computer science, and engineering. Moreover, it should be noted that scientific advances have been made by car manufacturers who do not always publicly disclose the details on their approaches or algorithms, owing to commercial sensitivity. Increased safety, reduced emissions and the possibility of completely new business models are driving the development and most automotive companies have started projects that aim towards fully autonomous vehicles. For industrial applications that provide a closed environment, such as mining facilities, harbors, agriculture and airports, full implementation of the technology is already available with increased productivity, reliability and reduced wear on equipment as a result

6.1.1 Definition of autonomous vehicle

Until now, vehicles have been almost exclusively operated by humans. However, recent advances in sensing technology, computing power, mapping, data processing, and connectivity have made it possible to begin developing vehicles that are autonomous, that is, they can perform a transportation task without requiring a human to control them. So autonomous vehicles (AVs), also called driverless vehicles, according to SAE International (2016) levels 4 and 5 definitions, are the next revolution in transport. In other words they are vehicles which can drive without human intervention or monitoring in an unpredictable, uncertain, and open traffic environment designed, built and populated by and for humans. It represents the highest level of autonomy and thus the ideal, future end state of these vehicles. Another concept related to vehicle automation is connectivity. Two types of communications can be adopted in connected vehicles, i.e., vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications. If not connected, autonomous vehicles will rely on sensors (e.g., radar) to obtain information, such as the distance to the intermediate preceding vehicle. However, the limitations of sensors (e.g., the detection range of radars) will impede driving efficiency or give rise to safety issues. With the help of connected technology, autonomous vehicles will acquire more information (e.g., velocities and positions of vehicles further in front) and be capable of conducting a swifter, smoother, and more reliable driving process.

6.1.2 Benefits of Autonomous Transportation

Higher levels of autonomy have the potential to reduce risky and dangerous driver behaviors. The greatest promise may be reducing the devastation of impaired driving, drugged driving, unbelted vehicle occupants, speeding and distraction.

6.1.3 System-level impacts of automated vehicles

Transport system is a broad concept. Considering the groups which are directly involved or indirectly affected, there are at least five stakeholders from whose perspective the system could be evaluated, namely users, service operators (or infrastructure providers), government, non-users and the rest of economy outside transport (De Palma, Lindsey, et al. 2011).

Though developed rapidly, road transport systems give rise to a series of issues and various undesirable effects are incurred, such as accidents, congestion, emission, crowding, etc. The high demand for transport activities makes the accumulation of negative effects significant. According to statistics, road goods transport is about 1,805 billion ton-kilometer and passenger transport by buses and coaches are estimated to be 551 billion passenger-kilometer. Road transport is responsible for 883.2 million tons green-house gas emission, and 25,651 people died because of road accidents in 2016 (European Commission 2018). Moreover, the intense and frequent interactions among different stakeholders makes the assessment of system efficiency difficult.

For instance, users expect for more mobility and reliability from the service operator, the service operator wants less expense and more profit, and the government intends to internalize the transport externalities, which usually involve contradicting objectives. Therefore, the analysis of transport systems is inherently complicated. The impacts of autonomous vehicles are not transparent and sometimes controversial, which further increases the complication of the problem. Since autonomous vehicles are not yet implemented in real world, the accuracy of the system prediction heavily relies on the assumptions made on automation technology, user behavior, etc. As a promising technology, the effects of autonomous vehicles have been actively explored in recent studies. The following (non-exhaustive) benefits and challenges have been recognized in literature.

- **Road capacity and congestion**. Autonomous driving is expected to enable short headways between vehicles, which will increase traffic throughput. Higher average speed, evener inter-vehicle gaps, less disruptions originated from unreasonable human driving behaviors are anticipated, which helps to relieve congestion. A field experiment carried out on a single-lane circular track shows that stop-and-go waves can be diminished by controlling only one AV in a group of 20 conventional vehicles, which suggests the possibility of managing traffic flow with less than 5% AVs acting as actuators before large penetration of AVs in traffic stream (Stern, et al. 2018). However, negative influence on traffic flow and road capacity by means of simulation is also reported in literature, mainly related to AV penetration rate, control strategies, and interactions with conventional vehicle in mixed traffic (Kerner 2016, Kerner 2018, Calvert, Schakel and van Lint 2017).

- **Energy and environment**. Less energy consumption and emission due to smooth speed profiles can be achieved by autonomous driving (Fagnant and Kockelman 2015).

- **Safety.** Technologically, being equipped with various types of sensors, data processors and control systems, an autonomous vehicle should be able to maneuver itself in different road and traffic conditions. Ideally, the autonomous driving system is more accurate than human perceptions, reacts more smoothly and swiftly than human drivers, and operates continuously provided that the vehicle is powered and functions properly (i.e., higher efficiency from withstanding tedious driving process without taking breaks). Therefore, autonomous driving is supposed to be safer than human drivers, especially in avoiding road accidents related to fatigue, alcohol, drugs, etc. (Fagnant and Kockelman 2015).

- **Generalized cost.** Firstly, the change in generalized cost originates from driver cost saving. Depending on the automation level, driver cost can be partially or completely eliminated by semi-automation or full automation, respectively. For private autonomous car users, this means they can spend their in-vehicle time more productively than concentrating on driving. Even if in the scenario of semi-automation where human drivers are still needed in complex traffic conditions, the driver cost can still be reduced in general. For service providers, the direct result is the labor cost saving. However, the vehicle cost might increase due to extra modules and functionalities required by autonomous driving.
- **Business model.** The population of private car users might increase, especially among those without driver's license. Autonomous vehicles might boost the market of shared mobility and companies may invest more in autonomous taxis. It is also possible that people do not own private cars in the future and shared mobility services (including public transit, car rental, taxis, etc.) will be flexible enough to satisfy all types of demand requests. However, there are also nonnegligible negative impacts, which are highly dependent on the utilization business model and public's response to autonomous vehicles. For instance, in the shared mobility scenario, car ownership may be reduced but people may rely on on-demand service more than public transport and car usage may increase, whereas in the business-as-usual scenario, more people may own autonomous cars, which may deteriorate congestion, but each vehicle will be used less frequently than in the former scenario (Cavoli, et al. 2017).
- **Job opportunities**. The predictable indirect social benefits are also pointed out in previous studies, such as increased job opportunities in automotive, freight transport and electronics manufacturing industry. However, unemployment might also happen as a negative impact on professional drivers, insurance sector relying on income from automobile insurance premiums, etc. (Cavoli, et al. 2017).

6.2 History and background of autonomous vehicles

The dream of autonomous or driverless cars is probably as old as the car itself. Autonomous cars have appeared in science fiction literature numerous times with some dating back to the early 1930s. General Motors presented their vision of the future city on the 1939 New York World's Fair, with over 40 million visitors, in the Futurama exhibition (Ferlis, 2007). A scale model, over 3000 m2 in size, of a 1960s city with automated highway systems seamlessly connecting all parts of the city could be viewed by visitors traveling on moving seats around the exhibition and in 1950s America's Electric Light and Power Companies were running an ad with a futuristic automated highway. Now almost 80 years later we know that these visions never became reality and today's dreams of automated vehicles have changed little compared to the visions presented back then. However, compared to the available technology now and then the dream is much more achievable. With the digital revolution in the 1960s and the pioneering work in artificial intelligence by Moravec (1990), the first steps towards intelligent and autonomous robots where taken. However, it was not until the 1980s with the pioneering work of Dickmanns and Zapp (1987) were the first steps towards driverless cars capable of operating on normal roads were taken. With the Eureka PROMETHEUS Project (PROGRAMME FOR A EUROPEAN TRAFFIC OF HIGHEST EFFICIENCY AND UNPRECEDENTED SAFETY) the platform was further developed and cumulated with Dickmanns et al. (1994) work on a Mercedes 500 SEL that demonstrated autonomous driving during real conditions on a three lane highway in Paris with vision tracking of other vehicles, lane changes and lane tracking capabilities at speeds over 130 km/h. Carnegie Mellon University were at the same time experimenting with their Navlab platform and achieved basic autonomous operation on highways using a camera based vision system (Thorpe et al., 1988, 1991). Building on results from PROMETHEUS, Broggi et al. (1999) again demonstrated autonomous operation on highways over a 2000 km long track in Italy with the ARGO vehicle.

The groundbreaking Grand Challenges conducted in 2004 and 2005 that was sponsored by DARPA are often seen as the starting point of the intense efforts in autonomous driving we see today. The robots were presented with a previously unknown, over 200 km long, track through areas around the Mojave desert with difficult terrain and narrow gravel roads. A predefined GPS path was laid out and the vehicles had to navigate inside a driving corridor around the path at speeds up to 80 km/h without any manual intervention while negotiating stones, bushes, fences, ditches and other obstacles present around the road. In the first challenge in 2004 none of the robots managed to finish the course but Carnegie Mellon University's vehicle Sandstorm managed to travel the farthest distance and completed 11.78 km of the course. Since the competitions, impressive progress has been made and several self-driving car projects have been started including probably the most famous being the Self Driving Car project at Google that so far has logged almost 2.5 million km of autonomous operation in various driving situations including dense inner city traffic with only minor incidents (Google, 2016). Other impressive efforts include the Bertha project by Mercedes in collaboration with Forschungszentrum Informatik and Karlsruhe Institute of Technology (Ziegler et al., 2014b), the Public Road Urban Driverless Car Test (PROUD) by University of Parma (Broggi et al., 2015) and the Stadtpilot project (Nothdurft et al., 2011). Building on the success and inspiration from many of these projects almost all major car manufacturers have now launched projects involving autonomous vehicles and there is a race to be the first company with an autonomous car on the market. Many start-up companies are also focusing on the technology and are challenging the more developed brands on the market with new business models and innovative ideas that could change the way we use transportation services today.

6.3 Autonomous vehicle as the solution for transportation's problems

In order for a vehicle to be able to drive itself without the need of a driver , four interdependent functions should be taken into consideration. Those are : Navigation, motion planning , situation analysis and trajectory control.

6.3.1 Navitgation: Navigation can be defined as the guidance of a vehicle from a starting point to destination, and positioning, a closely related discipline will provide the means whereby the optimal route from a current location can be found. Both navigation and positioning are important aspects of vehicle navigation systems. Nowadays navigation of a vehicle is achieved by using satellite navigation systems, typically GPS.

In addition, the vehicle has to retrieve data related to road types, settings, terrains as well as weather conditions in order to have the most suitable route. Navigation is the method for determining position, speed, and direction of the object. That is mainly classified into two groups: physical model-based methods (PMMs) and external data-based methods (EDMs). Examples of PMMs are inertial navigation systems (INS) and dead-reckoning navigation.

They determine the existing position of an object by measuring various changes in its state, such as velocity and acceleration. The global navigation satellite system (GNSS) is an excellent representative of EDMs. Methods to determine longitude and latitude using polar stars or the sun considered as EDMs, which is utilized in the spacecraft nowadays. .

PMM and EDM have duality. The accuracy of PMMs is exponentially proportional to the cost, and the error increases over time.

The navigation equipment in ground vehicles and the orbit propagator in spacecraft are designed to complement each other, considering the properties of tools such as the INS/GNSS. Some types of navigation systems include:

- PMMs : Representative PMMs include dead-reckoning navigation (DR) and the inertial navigation system (INS). They determine the current position by measuring the vehicle's own velocity and acceleration in addition to initial position data. Due to the nature of PMMs, the error increases with time.
- Dead-reckoning navigation (DR) :Dead-reckoning navigation is a method of estimating the current position using the moving direction, velocity, and time. It considers errors according to true north and magnetic north. In the case of ground vehicles, only their own velocity needs to be considered, but aircraft and ships must calculate positions by considering ocean currents, wind, and so on. In fact, all navigation systems currently use this dead-reckoning method. Because the accuracy of this method decreases as time and distance increase, celestial navigation is used to determine the accurate position, and then the dead-reckoning method is used from that point forward. The traditional dead-reckoning method used a plotter (a protractor attached to a straight ruler) or a flight computer to determine position. At present, it is calculated automatically using an electronic flight computer.
- GNSS: The global navigation satellite system (GNSS) estimates positions through the GNSS dedicated satellite orbiting the earth. The global positioning system (GPS) is open to the public and is frequently used. The satellite has a precise time and sends its own position and time information every moment. The GPS receiver calculates the straight distance between the satellite and the receiver considering the incoming velocity of signals

- Inertial navigation system (INS): The Inertial Navigation System is a stand-alone navigation system that continuously calculates the position, direction, and velocity of the main body through its own accelerometer, rotation sensor, and arithmetic unit, without receiving any external information. Although GPS offers a precise navigation system, it has limitations in space, deep seas, tunnels, and similar places because the GPS operates only when it can receive signals from the satellite. Furthermore, INS can avoid GPS jamming issues. Because an INS is a PMM, the error increases with time. Moreover, the price increases exponentially as the precision is enhanced. One critical factor in an INS is the accurate entry of the initial position and velocity.

6.3.2. Motion planning:

An important part of any mobile autonomous system is the motion planning layer.

But on the other side Motion Planning (MP) for autonomous on-road driving is a challenging problem due to different reasons like :

(1) The optimal solution (trajectory) exists in high-dimensional space, yet real-time constraints must be met in finding it;

(2) Trajectory solutions must adapt to complex and unpredictable traffic;

(3) Perception data, which are critical to high-speed driving, are partially observed, noisy, and lagging. Motion planning deals with, searching a feasible path, taking into consideration the geometry of the vehicle and its surroundings, the kinematic constraints and others that may affect the feasible paths. It is also determined as vehicle's ability to determine the correct course of motion (speed, direction) within a certain pre-defined period of time, so that the vehicle keeps going its lane and its pre-set direction determined by navigation, without colliding with static and dynamic objects that are identified by situation analysis.

Effectively, programming an autonomous vehicle's motion planning means teaching the vehicle how to analyse the gathered data and based on that react in different situations. Most importantly motion planning for autonomous vehicles in urban environment enables self-driving cars to find the safest, most convenient, and most economically beneficial routes from point A to point B. Finding routes is complicated by all of the static and maneuverable obstacles that a vehicle must identify and bypass. Today, the major path planning approaches include the predictive control model, feasible model, and behavior-based model. I order to understand how all this process works firstly we must clarify some terms for a better understanding of the entire process :

- **Path**: is a continuous sequence of configurations beginning and ending with boundary configurations. These configurations are also referred to as initial and terminating.
- **Path planning**: involves finding a geometric path from an initial configuration to a given configuration so that each configuration and state on the path is feasible (if time is taken into account).
- **A maneuver planning** : aims at taking the best high-level decision for a vehicle while taking into account the path specified by path planning mechanisms.
- **Trajectory planning** :or trajectory generation is the real-time planning of a vehicle's move from one feasible state to the next, satisfying the car's kinematic limits based on its dynamics and as constrained by the navigation mode.

Path planning for autonomous vehicles becomes possible after technology considers the urban environment in a way that enables it to search for a path. Put simply, the real-life physical environment is transformed into a digital configuration or a state space. Path planning technology searches for and detects the space and corridors in which a vehicle can drive.

6.3.3 Situation analysis

In the situation model, information of in-car sensors is used to build up a representation of the environment around the ego vehicle. On top of the situation model, a situation analysis is established to detect the current driving situation according to the given description of driving situation.

6.3.4 Trajectory control

The vehicle autonomy can be accomplished by three main : The perception and localization, the trajectory planning and ACC (Adaptive Cruise Control). The first key step is the perception of the environment surrounding the vehicle using exteroceptive sensors such as cameras, lidar, radars, velodyne, etc. In this step, the lane boundaries, the lane markings, the pedestrians and eventually the road traffic participants and all the possible obstacles are detected.

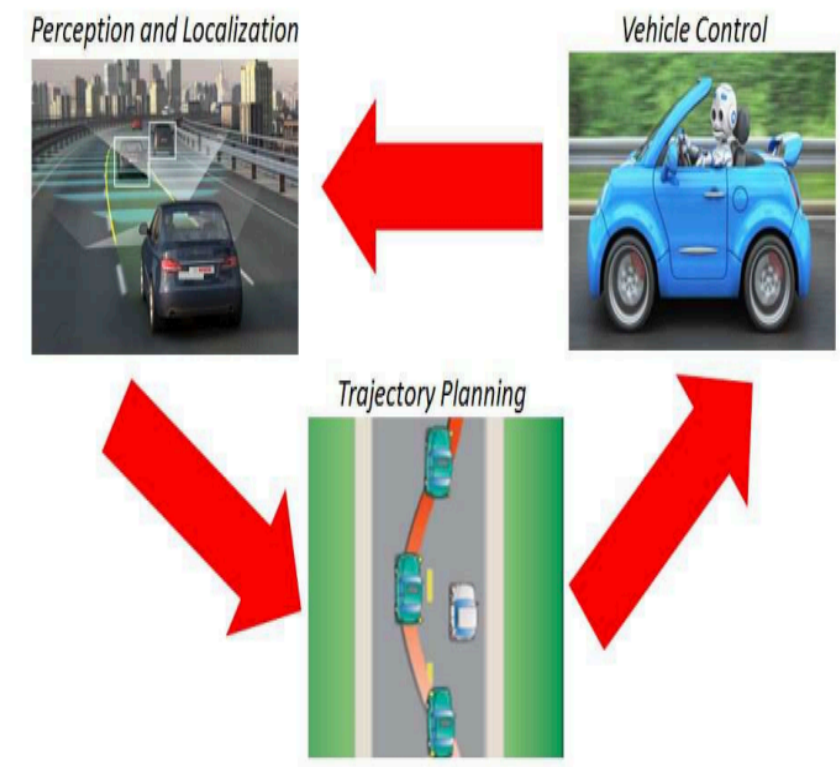

Figure 15 . Trajectory planning and tracking for autonomous vehicles

The second essential step is the trajectory planning. In this level, we make use of the perception data to plan a secure and smooth trajectory for the vehicle. The trajectory planning objective is to provide the vehicle with a secure trajectory constrained by the vehicle dynamics limits, the navigation comfort and safety, and the traffic rules. For the trajectory tracking problem, it is generally considered as a lateral control, which mainly considers the accuracy of the reference trajectory under a constant velocity. However, the velocity of an autonomous vehicle is not constant actually, and this requires us to consider not only the accuracy of the trajectory tracking but also the velocity tracking problem.

Once the desired trajectory is generated, the next step is to control the vehicle in order to track this trajectory with the desired speed profile also defined by the planning module.

The vehicle control is indeed the control of the vehicle actuators, such as the steering wheel, the accelerator and the braking force, in order to manage the vehicle motions.

6.3.5 Adaptive Cruise Control (ACC)

Adaptive cruise control (ACC) is an available cruise control advanced driver assistance system for road vehicles that automatically adjusts the vehicle speed to maintain a safe distance from vehicles ahead.. It is an add-on intelligence to the present cruise control system. It is also called as Autonomous cruise control, Predictive cruise control or Radar cruise system.

The vehicle is equipped with a radar system under the bumper which detects when there is a car in the same lane and the desired speed is set by the driver as usual with cruise control. Once the car is detected, the distance between the cars can be adjusted accordingly to maintain a safe distance.

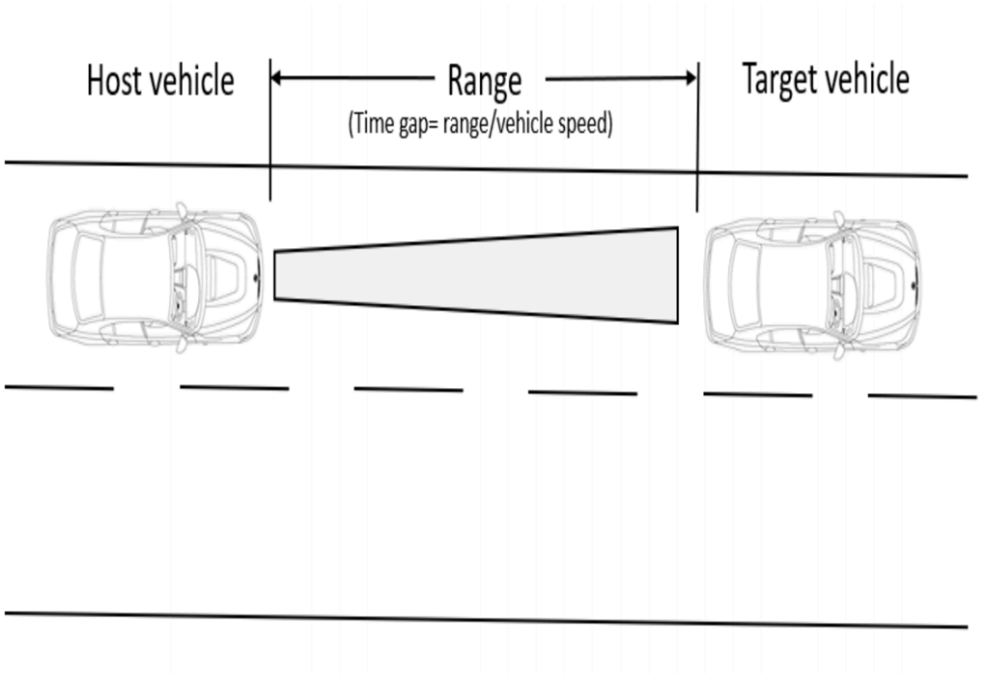

Figure 16. Advanced Cruise Control Concept

ACC functions by sensory technology installed within vehicles such as cameras, lasers, and radar equipment, which creates an idea of how close one car is to another, or other objects on the roadway. For this reason, ACC is the basis for future car intelligence. Sensors play a key role in ACC and almost all ADAS systems. Here, instead of RADAR we can use LiDAR, infrared cameras according to the necessity. These sensory technologies allow the car to detect and warn the driver about potential forward collisions. When this happens, red lights begin to flash, and the phrase 'brake now!' appears on the dashboard to help the driver slow down. There might also be an audible warning. Advantages of using advanced cruise control rely on the increase of road safety, as cars with this technology will keep the adequate spacing between them and other vehicles. These space-mindful features will also help prevent accidents that result from an obstructed view or close following distance. Similarly, ACC will help maximize traffic flow because of its spatial awareness. As a driver, you don't have to worry about your speed, and instead, you can focus on what is going on around you.

6.4 External sensors

Autonomous vehicles would be impossible without sensors: they allow the vehicle to see and sense everything on the road, as well as to collect the information needed in order to drive safely. Furthermore, this information is processed and analyzed in order to build a path from point A to point B and to send the appropriate instructions to the controls of the car, such as steering, acceleration, and braking. Moreover, the information collected with the sensors in autonomous vehicles, including the actual path ahead, traffic jams, and any obstacles on the road, can also be shared between cars that are connected and this is also called vehicle-to-vehicle communication, and it can be an incredibly helpful resource for driving automation. The majority of today's automotive manufacturers most commonly use the following three types of sensors in autonomous vehicles: cameras, radars, and lidars. When talking about cameras ,different type of cameras are used such as :

1. Stereo cameras that simulate a pair of eyes

In the case of stereo cameras, two digital cameras work together. Similar to the stereoscopic vision of a pair of eyes, their images enable the depth perception of a surrounding area, providing information on aspects including the position, distance and speed of objects. The cameras capture the same scene from two different viewpoints. Using triangulation and based on the arrangement of pixels, software compares both images and determines the depth information required for a 3D image. The result becomes even more precise when structured light is added to the stereo solution. Geometric brightness patterns are projected onto the scene by a light source. This pattern is distorted by three-dimensional forms, enabling depth information to also be determined on this basis.

2. ToF cameras measure the speed of light

Another method is time-of-flight , which determines distance based on the transit time of individual light points. Achieving centimetre accuracy calls for rapid and precise electronics. Time-of-flight technology is highly effective in obtaining depth data and measuring distances. A time-of-flight camera provides two types of information on each pixel: the intensity value – given as grey value – and the distance of the object from the camera, known as the depth of field. Modern time of flight cameras are equipped with an image chip with several thousand receiving elements. This means that a scene can be captured in its entirety and with a high degree of detail in a single shot.

3. Eagle-eyed vision

A further aim is to reduce the number of cameras required. Until now, a whole host of cameras and sensors all around the vehicle, or a rotating camera on the roof, was needed to generate as wide a viewing range as possible. At the University of Stuttgart, the widening of a single camera's field of view was modelled on the eye of an eagle. An eagle's eye has an extraordinary number of photoreceptors in its central fovea – the part of the eye where vision is at its sharpest. Additionally, eagles have a second fovea at the corner of their eye, allowing for sharp peripheral vision. Scientists have developed a sensor which all but emulates an eagle's eye across a small area. Research was carried out under the umbrella of the SCoPE research centre at the University of Stuttgart and was able to be put into practice thanks to the very latest in 3D printing technology from Karlsruhe-based company Nanoscribe. The researchers in Stuttgart imprinted a wide range of micro-objective lenses with different focal lengths and fields of vision directly onto a high-resolution CMOS chip.

The smallest has a focal length equivalent to a wide-angle lens, two lenses have a medium field of view, and the largest lens has a very long focal length and a small field of view just like a typical telephoto lens. All four images created by the lenses on the chip are electronically and simultaneously read and processed.

3. Radar and Lidar

Automotive RADAR and LIDAR are two examples of sensor technologies used to observe the environment and detect objects surrounding the host vehicle, in order to enable ADAS. Naturally, the use of sensors in order to enable systems intended to protect and support the driver or improve their comfort entails stringent requirements; not only in terms of performance, but reliability and robustness as well. This has led to the continued development of sensor technologies, with developers seeking to additionally provide more compact and cost-effective alternatives to surrounding sensing; autonomous driving being the end goal, therefore entailing stricter requirements. Although both RADAR and LIDAR sensors are used for the same purpose, i.e. measuring the radial distance towards a target and determining its velocity relative to the host vehicle, they differ with regards to their functionalities, components, operation and various other aspects, leading to individual strengths and weaknesses. For example, RADAR is known for its impressive detection range, whereas LIDAR is known for its enhanced accuracy and resolution. These contrasting characteristics therefore indicate that either sensor may be preferred over the other in certain situations; perhaps in which one may perform better than the other, or due to other factors and aspects. This paper aims to analyse and compare the two sensor technologies and their use in passenger vehicles with respect to these various factors and aspects, in order to provide an insight into different cases in which one may be more suitable than the other. In general, a single sensor cannot definitively achieve all automotive requirements within all situations. Thus, a combination of sensors is recommended, in order to benefit from their individual strengths and ensure continuous system functionality and availability to detect the surrounding environment.

6.5 Different levels of automation

There are different levels of autonomy in the self-driving cars allowing the driver to control the key functions or depend on the machine to make its own decision. Here are the 5 levels of automation that a self driving car can have :

0. No Automation (Level 0):

The full-time performance by the human driver of all aspects of the dynamic driving task, even when enhanced by warning or intervention systems. At this level, the driver is in complete and sole control at all times.

1. Level 1: driver assistance

At this level, the driver still handles most of the car's functions but with a little autonomous help. For example, a level one vehicle might provide you with a brake boost if you edge too close to another vehicle, or it might have an adaptive cruise control function to control your distance and speed. Likewise, Level 1 autonomous vehicles might have a park assist function, where a beeping sound alerts the driver to an approaching obstacle. Level 1 autonomy is common in most cars today, and a typical example would be the 2018 Nissan sietra, with its Intelligent Cruise Control feature.

2. Partial Automation (Level 2):

The driving mode-specific execution by one or more driver assistance systems of both steering and acceleration/deceleration using information about the driving environment and with the expectation that the human driver perform all remaining aspects of the dynamic driving task. At this level, the system handles lane holding and lane changes in special applications.

The driver must continuously monitor the system. Examples of this level includes: adaptive cruise control and autopilot capabilities along certain roadways and locations.

3. Conditional Automation (Level 3):

The driving mode-specific performance by an automated driving system of all aspects of the dynamic driving task with the expectation that the human driver will respond appropriately to a request to intervene. At this level, the driver no longer needs to continuously monitor the system but must be available to take over when needed. An example of this level would show a system performing lane holding and changing in specific cases; the system detects limits and asks the driver to take over with sufficient warning.

4. High Automation (Level 4):

The driving mode-specific performance by an automated driving system of all aspects of the dynamic driving task, even if a human driver does not respond appropriately to a request to intervene. At this level, vehicles do not require a driver in special applications; automated systems can handle all situations in the specific application case. An example of this level would show an automated vehicle operating in a specific or controlled environment.

5. Full Automation (Level 5):

The full-time performance by an automated driving system of all aspects of the dynamic driving task under all roadway and environmental conditions that can be managed by a human driver. At this level, the driver is not expected to take control of the vehicle at any time.

Level	Name	Definition	Execution of steering and acceleration/ deceleration	Monitoring of driving environment	Fallback performance of dynamic driving task	System capability (driving modes)
Human driver monitors the driving environment						
0	No Automation	The full-time performance by the human driver of all aspects of the dynamic driving task, even when enhanced by warning or intervention systems	Human driver	Human driver	Human driver	N/A
1	Driver Assistance	The driving mode-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the human driver perform all remaining aspects of the dynamic driving task	Human driver and system	Human driver	Human driver	Some driving modes
2	Partial Automation	The driving mode-specific execution by one or more driver assistance systems of both steering and acceleration/deceleration using information about the driving environment and with the expectation that the human driver perform all remaining aspects of the dynamic driving task	System	Human driver	Human driver	Some driving modes
Automated driving ("system") monitors the driving environment						
3	Conditional Automation	The driving mode-specific performance by an automated driving system of all aspects of the dynamic driving task with the expectation that the human driver will respond appropriately to a request to intervene	System	System	Human driver	Some driving modes
4	High Automation	The driving mode-specific performance by an automated driving system of all aspects of the dynamic driving task, even if a human driver does not respond appropriately to a request to intervene	System	System	System	Some driving modes
5	Full Automation	The full-time performance by an automated driving system of all aspects of the dynamic driving task under all roadway and environmental conditions that can be managed by a human driver	System	System	System	All driving modes

Source: SAE International (2014)

Table 1.1: Levels of Driving Automation Definitions

6.6 Automated vehicle Platooning as part of vehicle to vehicle communication

Truck platooning involves a number of trucks equipped with state-of-the-art driving support systems. The vehicles move in a group or platoon with the trucks driven by smart technology and communicating with one another. Truck platooning offers potential innovation for the transport sector globally. Grouping vehicles into platoons is a method of increasing the capacity of roads.

Vehicle platooning is known as a part of vehicle to vehicle communication (or V2Vt) . V2V communication allows sharing of local vehicle signals such as speed and sensor data among vehicles in the platoon. The shared signals are used in the control algorithms of the platoon. The platoon forms a cooperative system where sensing, control algorithm and actuation are distributed throughout the platoon and data is communicated between vehicles. Platoons decrease the distances between cars or trucks using electronic, and possibly mechanical, coupling.

This capability can allow many cars or trucks to accelerate or brake simultaneously. Vehicles can follow each other more closely than with human drivers, because less reaction distance is needed than human drivers require. With the rucks braking immediately, with near-zero reaction time, platooning can also improve traffic safety. Vehicle platooning is a typical application of semi-automation. A platoon is a string of vehicles that drive together.

The leading vehicle in the platoon is referred to as platoon leader, and the rest are platoon followers. Unlike inadvertent platoons which result from traffic signal control or congestion, the vehicle platooning in this context is an outcome of deliberate planning. Being equipped with adaptive cruise control (ACC) or cooperative cruise control (CACC) modules, platooned vehicles should be able to maintain short inter-vehicle distance safely while driving at high speed levels.

Moreover, all vehicle members in the platoon should be able to response to environmental stimulations simultaneously (if latencies are neglected), including accelerating, braking, cornering, etc. Platooning is also a cost-saver as the trucks drive close together at a constant speed. This means lower fuel consumption and fewer carbon dioxide emissions. According to Europian Truck Platooning , platooning efficiently boosts traffic flows thereby reducing tail-backs. The platooning application requires that V2V communication is used in addition to local sensors in each vehicle.

Using V2V implies that data can be sent directly from the source rather being indirectly measured locally with sensors. Detecting platoon movements via only local sensors is prone to lag and to accumulate errors. This is because local sensor measurements are only based on the adjacent vehicle, i.e. there is no “look ahead” e.g. of intended movements. For example the lead vehicle can directly send requested acceleration as measured at the pedal rather than having a following vehicle measure the acceleration with its local sensors. With local vehicle sensors a change in acceleration has to “propagate” through the platoon from the lead vehicle to each of the following vehicles and be detected. This affects, for example, the minimum gap size that can be safely achieved. Without V2V it has to be larger gap to allow for the slower response. Using only local sensors can lead to lateral and longitudinal instability, increasing oscillations, and unsafe behaviour of the platoon.

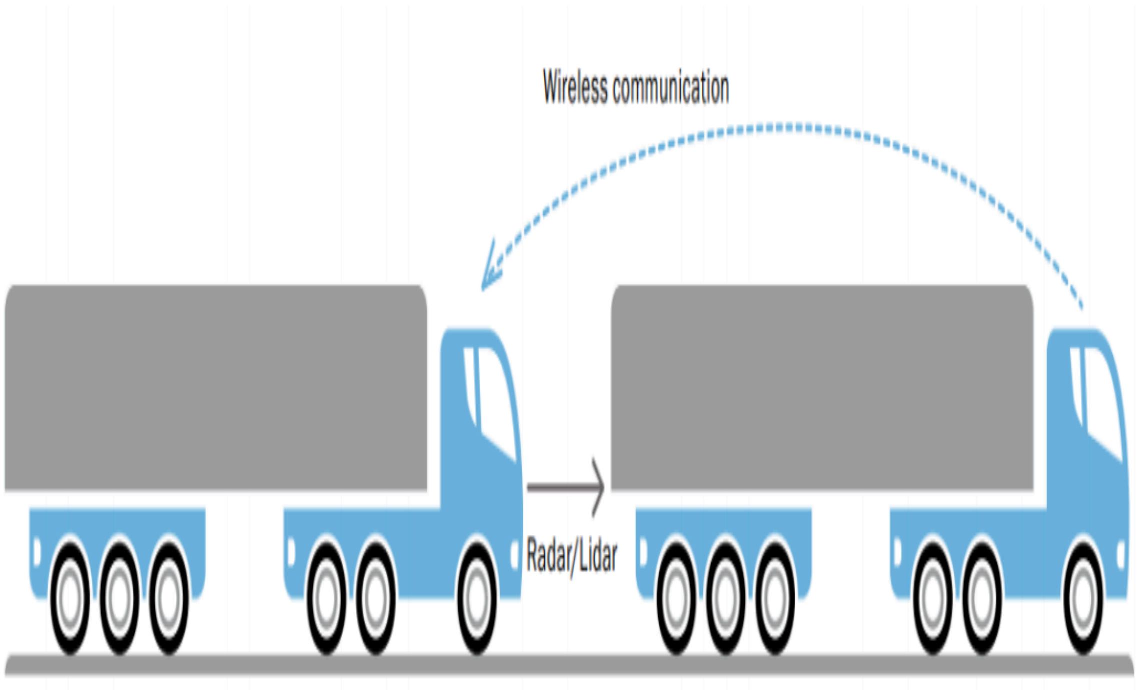

Figure 17. Simplified representation of platooning

6.6.1 Advantages of vehicle platooning

- Efficiencies in traffic speed and fuel economy should lead to lower freight costs
- When moving away from a stop, e.g. traffic has halted due to an obstruction or traffic light, a platoon will move away all at the same time. Humans wait until they see the vehicle in front move, then move away, and this delay compounds over a number of vehicles. Studies have shown that this form of moving away can be up to five times more efficient in terms of the number of cars moved through a specified point from rest.
- The accident rate may reduce because, in theory, vehicles in the platoon are aware of what each other is doing. However, these benefits are already coming to modern vehicles that brake for you if they perceive a threat that you don't take action on
- Initially all vehicles will have to have a driver ready to take control of the vehicle, but eventually fully automated vehicles will be able to take complete control and the driver becomes a passenger that is able to eat, work, watch a film, or sleep
- One motivation behind coordinated vehicle platooning is to take advantage of the lower air pressure by driving closely to the vehicle in front than driving independently, i.e., the slipstreaming effect. As a result, the air drag will be reduced and less power will be required to maintain the vehicle speed. Therefore, energy savings will be incurred due to the decreased air resistance. Since air drag depends on square of velocity and vehicle frontal area, the slipstreaming effect is evident in the case of commercial ground vehicles, especially when driving at high speeds on highways. According to (Hucho 2013), a platoon made of three commercial vehicles will experience a 32% reduction in air drag coefficient for the second vehicle, while driving at 80 km/h with the inter-vehicle distance 20 m. The reduction on the third vehicle can be up to 40%.

- Another motivation of vehicle platooning is labor saving, which is made possible by CACC and V2V communication. Theoretically, for platoon followers, the semi-automation system can take charge of the driving process under substantial circumstances, so that human drivers can attend to other activities. If human drivers can be removed from platoon followers completely, the cost for on-board drivers can be eliminated from the operating cost. In bus transit, labor cost accounts for a large proportion of the total annual cost and the removal of drivers means the possibility of serving more demand and lifted level of service

CHAPTER 7

DATA COLLECTION AND PRIVACY

7.1 Privacy

Questions relating to privacy issues abound in the deployment of many ITS technologies, including incident management, automated red light enforcement, electronic toll collection, and even drowsy driver sensors. While citizens in different regions around the globe value privacy to varying degrees, people are generally uncomfortable with the idea of government collecting data about their movements and using video surveillance as a means to law enforcement. This can be a large barrier to implementation in open political systems that place high value on individual freedoms and rights.

Rieman (1995) explores ITS' part in intensifying the surveillance society and the potential, subsequent impact of "total visibility" on individual behavior and society as a whole. Glancy (1995) discusses the use of ITS to "manipulate" individuals' transportation choices and behavior; and that road transportation-related ITS enables both "Big Brother" and "Little Brothers", where many private-sector companies can collect personal data. ITS can infringe on personal privacy in a variety of ways. Though information can be used to great benefit, it can also be abused. With incident management systems, for example, there are concerns about the ability to record a particular vehicle at a given time without the consent of the operator. Red light enforcement technology is highly susceptible to privacy issues, because computers collect driver information and pass violations on to law enforcement agencies. Electronic toll collection raises questions about vehicle location tracking and transaction records hidden within a database. Even potential users of drowsy driver sensors are wary of constant surveillance and a record of driver behavior There are many facets of privacy to be considered when constructing a legal framework for ITS deployment. The following list of issues is adapted from a paper written by Phil Agree, researcher on privacy and ITS at the University of California, San Diego. Agree argues that agencies need to construct rules for the collection, dissemination, and protection of the information gathered through ITS technologies.

Standards – Technical data standards can be established in such a way that they inherently protect privacy.

Secondary use – To protect privacy, drivers should be able to opt out of secondary uses of their information, namely for marketing purposes. Marketers have the potential to target drivers based on where they drive or the real-time location of their vehicle.

Law enforcement – The privacy concern is that drivers may be ambushed for other infractions through data collected via ITS (for example, speeding tickets issued by calculating speeds from toll collection data). To address this issue, public input is required during planning to establish the degree to which law enforcement agencies can track citizens' movements.

Commercial applications – ITS applications with the fewest privacy protections are those for commercial vehicles. Trucking companies now monitor their vehicles and drivers through GPS and other surveillance technology. The privacy concern is that this might set a precedent for consumer applications as well.

Security – Wireless interception, external attacks, and insider leakage are potential security problems. In addition to using encryption technology, agencies can increase system privacy by decreasing the sensitivity of information being transmitted.

Individually identifiable information – Many believe that using ITS requires individual identification of people or their vehicles. To solve this problem, anonymous methods should be explored to their full potential.

Choice – There are privacy arguments on whether ITS should be voluntary or mandatory. Even when ITS is not mandatory by law, it may be mandatory in practice due to lack of alternatives.

Participation – To protect privacy, the public should be able to participate in discussions on ITS with the industry and the government.

Strategies – There are multiple strategies for protecting privacy. Among these are legislation, system design, and standards.

Protecting the privacy of users is a concern that has varying degrees of importance depending on a region's political environment. Strategies for dealing with privacy are to solicit public discussion, enact protective legislation, design systems with privacy in mind, and develop a set of principles. The widespread collection of vehicle and driver information may always raise privacy questions, but with careful planning these questions do not need to slow the deployment of ITS technologies.

7.2 Privacy threats

- Unauthorized use of location data and location-based services: This threat could be considered as unauthorized use of tolled highways pretending to have a position of a neighbor vehicle which is not situated on a highway or unauthorized access in a car park

- Disclosure of unwanted information: As an example, consider a case such as if a person leaving the house empty for a long trip by car or by boat (which may enable house burglaries); how often an employee, supposed to be at the office, is visiting places by car (which may lead to loss of social reputation); how often a spouse is visiting places that he/she has never mentioned to his/her relatives (which may cause family crises), etc.

- Tracking malware applications: A vehicle-installed software could contain malware to "steal" the tracking patterns of the users inside the vehicle, i.e., the user positions and speeds in time; such information, if sold to car dealers, could adversely affect the price of a vehicle, e.g., in function of the types of roads where vehicle and how often it was driven, etc.

- Scrambler attack: An additional measure to achieve a higher level of anonymity in vehicular systems is the utilization of dynamically changing identifiers (from MAC to application layer), so-called pseudonyms . The effectiveness of this approach, however, is clearly reduced if specific characteristics of the physical layer (e.g., in the transmitted signal) reveal the link between two messages with different pseudonyms.

In contrast to other physical layer fingerprinting methods, it does not rely on potentially fragile features of the channel or the hardware but exploits the transmitted scrambler state that each receiver has to derive in order to decode a packet, making this attack extremely robust. The most straightforward solution is to employ a cryptographic pseudo-random number generator, possibly seeded by a large number of entropy sources in a vehicle (e.g., engine start time, sensors data, SNR, vehicles nearby, etc.). Another solution is the deployment of constant network-wide scrambler values.

ambler values. As compared to security threats, privacy issues always had more involvement by the actual humans. One option to improve privacy in ITS systems is to utilize the solutions with strong anonymity propertiesor frequently changing pseudonyms . Some researchers foresee that Software-defined networking (SDN) will become an ultimate enabler for overcoming previously listed security and privacy problems of ITS supporting both V2V and V2I scenarios.

7.3 Information

TS technologies use information to improve traffic congestion, safety, efficiency, and the environment. They must necessarily deal with large quantities of data as a result. Since the role of public transportation agencies has historically been in the realm of infrastructure and operations, many agencies are ill equipped to manage ITS information. Almost always these are not purely technical problems, but rather difficulties associated with the institutional capacity to handle such data.

7.4 Future perspective

Recently introduced General Data Protection Regulation (GDPR) policy broadly states that profiling and processing the location information of an individual could be done concerning personal aspects which are naturally related to person's movement and location data. According to , it could be done only when EU law regulations or the Member States demands or allows it, or "with the explicit consent of the data subject." Thus, tracking and monitoring the data of the user's vehicle also falls within this regulation. However, the definition of personal location data should be treated more carefully especially for cases when the identifiability of the said individual could be established. This way, the GDPR aspects related to the protection of personal data also should be taken into consideration while operating with personal location data.

In the ITS case and focusing on conventional GNSS systems, all the supported systems are controlled by the authorities, namely military for GPS and GLONASS and, in contrast, civilian Galileo in EU, which makes the implementation of GDPR more complicated. In order to overcome this issue, European Telecommunications Institute (ETSI) is actively developing a standard EN 303 413 aiming to overcome the interoperability of those systems. However, the corresponding questions remain unclear from the telecommunications side especially while speaking about 5G . Moreover, location-related data may be stored in the environments potentially not controlled by the operators themselves.

Industrial giants, such as Huawei, already rise the question on how to address the challenges of private positioning in future networks . One of the fundamental principles to be followed is by following the GDPR Article 25, i.e., to implement a privacy-by-design approach to achieve privacy from the commencement of the system perspective.

Aiming to achieve the above-mentioned, we have shown different location estimation techniques for ITS scenario in this paper. The existing protocols for the information exchange between the vehicle and the base station during the localization process were analyzed . Subsequently, it was presented an improved protocol for the data exchange, where much attention was paid to the security of signaling information transmission. Using the modified protocol, the vehicle can also rely on the location data without disclosing the identity, and thus the privacy could be generally improved. In real life, the selection of the protocol highly depends on the application needs. If the system architect wants to have maximum anonymity, it is recommended to utilize the modified protocol, but it is the most difficult one for implementation. The optimal option is to use a protocol with a property of anonymity but BS-based. The complexity is not much higher compared to others, and there are no complex operations.

CHAPTER 8

CONCLUSION

The main focus of the research that I presented here on my thesis was on the variety of different road safety technologies that are used by creating a bigger level of safety and the preservence of that safety in the future. On one side in this thesis I put some emphasis on data and data collection in relation with the transportation system as this creates a better approach to the assessment of the applicability of such technologies on different areas. Moreover the intelligent transportation system was described as an excellent solution for many transportation challenges. Intelligent Transportation Systems (ITS) in road vehicles is predicted to enhance traffic safety and mobility considerably. Hence, transport policymakers in most countries are increasingly become interested in possibility of extensive implementation of ITS devices in real traffic environment. Successful deployment of these systems on large-scale mainly depends on potential consumers' willingness to use these technologies. A more detailed observation was given to the classification of the intelligent transportation system

Another importance in this thesis was given to autonomous vehicles and technologies as a new challenge for the future. A description of its main parts as well as different level of automation were described . Autonomous and 'connected' vehicles are regarded as the solution to impending environmental and safety issues, but as more of these automated cars hit the road, so do the potential dangers they bring.

When fully 'self-driving' cars will become available to the general public (maybe by 2030/2035), they will require even smarter processing power to cope with the unique scenarios that can occur during a dynamic, totally automated car journey. These scenarios include longitudinal challenges, such as keeping a safe distance from the car in front and lateral challenges like pedestrians, other vehicles and various objects moving in front of the car. All of this will require split-second decisions from reliable software and hardware that can only be achieved if the vehicle has been designed to be both safe and secure.

Another topic which I wanted to include in my thesis was a topic regarding the privacy of using intelligent transportation system. Today, the technology is penetrating most of the modern digital systems . Billions of interconnected devices are already deployed, and many would join them soon in the race towards smart interconnected world . One of the promising paradigms is the utilization of Intelligent Transportation Systems (ITS), which is driven by one of the biggest markets being automotive . The technologies covered by ITS are usually split into two major groups: vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) . In an attempt to cover the challenges from both groups, a new trend called vehicle-to-everything has recently emerged, focusing on interconnecting cars with other surrounding objects. Different standardization communities are already working hard to standardize the technological requirements, thus aiming for the same goal: to develop a unified ecosystem that would allow reliable, fast and secure communications between vehicles and roadside infrastructure. Such technologies are actively developing aiming at being deployed in the oncoming decade.

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