

**CYPRUS INTERNATIONAL UNIVERSITY
INSTITUTE OF GRADUATE STUDIES AND RESEARCH
CIVIL ENGINEERING DEPARTMENT**

**INVESTIGATION OF THE COMPATIBILITY OF
HIGHWAY DESIGN FOR ELECTRIC (EV) AND
CONNECTED AUTONOMOUS VEHICLES (CAV) IN
TURKEY**

(MSc THESIS)

SELMA İZBELİ

NICOSIA-2020

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DEPARTMENT OF CIVIL ENGINEERING**

THESIS APPROVAL CERTIFICATE

The thesis study of Civil Engineering Department graduate student Selma İZBELİ with student number 21711384 entitled **Investigation of the Compatibility of Highway Design for Electric (EV) and Connected Autonomous Vehicles (CAV) in Turkey** has been approved with unanimity/~~majority of votes~~ by the jury and has been accepted as a Master of Civil Engineering Thesis.

Thesis Defense Date: 14/8/2020

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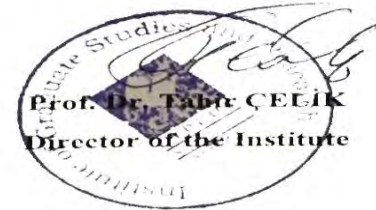
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I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

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ACKNOWLEDGEMENT

I would like to thank primarily my supervisor Asst. Prof. Dr. Göktuğ TENEKECİ, my advisor Asst. Prof. Dr. Mohammed Ali MOSABERPANA, department chair Asst. Prof. Dr. Ayşe PEKİRİOĞLU BALKIS and director of the institute Prof. Dr. Tahir ÇELİK for their support and help when completing my master thesis process. The time and effort they devote to me is very special to me. They shed light on my way in this difficult process.

I also would like to thank my family that I have come to this point with the support in my education life. I want to say thank Rafi ABDUL KARIM and all of my research assistant colleagues, for whom I consulted during the research process.

I would like to thank department of Civil Engineering in CIU for teaching me all engineering knowledge and Turkish General Directorate of Highways. In this research, they provided me with the necessary information. With this thesis, my knowledge and my desire to work in this field have increased. I hope my study will help other researchers as well.

ABSTRACT

Nowadays, Growth in world population brings the transportation problem so the number of vehicles in traffic is increasing every day. Increase in the number of vehicles with internal combustion engines has increased the amount of harmful gases released into the environment. The greenhouse gas produced by traditional vehicles has increased by approximately 239 billion tons in the last half century. One of the sector, which cause these gases to emerge, is road transportation vehicles. In order to reduce greenhouse gas emissions and not to consume fossil fuel reserves, there has been an increased interest in alternative new fuel technology in the automotive industry instead of traditional vehicles. Electric vehicles are at the top of these vehicles. The concept of “autonomous” has been added to this sector segment by applying it to these cars, which are widespread in many countries, in their technological developments. Those vehicles recently begun to produce these vehicles have emerged in Turkey while existing highways need to be inspected for these vehicles.

Autonomous vehicles are expected to be one of the main types of disruptive technology that will impact on travel behavior and the transport infrastructure. Roads have been designed over the last century to provide a safe, accessible and efficient environment for the navigation of human drivers in modern vehicles. The influence of enhanced driving behaviours, such as accurate lane guidance and almost instantaneous response times within autonomous vehicles, will transform the planning and design of road infrastructure. This study focusses on the future steps of intelligent transport system and the suitability of Electric (EV) and Connected Autonomous Vehicles (CAV) in the infrastructure of a select corridor of highways in Turkey. In addition, it includes network analysis, mapping system and performance measurements.

Keywords: Electric and Connected Autonomous Vehicles, Intelligent Transport System

ÖZET

Günümüzdeki küresel nüfus artışı ile araba kullanım miktarının artmasına neden olmaktadır. Dizel motorlu araç sayısındaki artış, atmosfere yayılan zehirli gazların hacmini arttırmaktadır. Son yarım yüzyıl içinde geleneksel araçların ürettiği sera gazı yaklaşık 239 milyar ton artmış bulunmaktadır. Bu gazların büyük oranda ortaya çıkmasına neden olan sektörlerden biri de karayolu ulaşım araçlarıdır. Sera gazı salınımının azaltılması ve fosil yakıt rezervlerinin tüketilmemesi için otomotiv sektöründe geleneksel kullanımlar araçlar yerine alternatif yeni yakıt teknolojilerine ilgi artmış bulunmaktadır. Bu araçların başında elektrikli araçlar gelmektedir. Bir çok ülkede yaygınlaşan bu arabalara, teknolojik gelişmelerinde uygulanmasıyla “otonom araç” kavramını da bu sektör dilimine eklenmiştir. Türkiye’de üretilmeye başlanan bu araçların yakın zamanda yaygınlaşacağı izlenimi verirken mevcut karayollarının incelenme gereksinimi ortaya çıkmıştır.

Bağlantılı otonom araçların seyahat davranışını ve ulaşım altyapısını etkileyecek ana teknoloji türlerinden biri olması bekleniyor. Geçen yüzyıl boyunca yollar, modern araçlarda insan sürücülerinin navigasyonu için güvenli, erişilebilir ve verimli bir ortam sağlamak üzere tasarlanmıştır. Doğru şerit kılavuzu ve otonom araçlarda neredeyse anında tepki süreleri gibi gelişmiş sürüş davranışlarının etkisi ile yol altyapısının planlanması ve tasarımı değişiklik gösterecektir. Bu çalışma, akıllı ulaşım sisteminin gelecekteki adımlarına; Elektrikli (EV) ve Bağlantılı Otonom Araçların (CAV) Türkiye'deki otoyolların belirli bir koridorunun altyapısında uygunluğuna odaklanmaktadır. Ayrıca, ağ analizi, haritalama sistemi ve performans ölçümlerini içerir.

Anahtar Kelimeler: Elektrikli ve Bağlantılı Otonom Araçlar, Akıllı Ulaşım Sistemi

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ABBREVIATIONS

ADAS	Advanced Driver Assistance Systems
ANPR	Automatic Number Plate Recognition
API	Application Programming Interface
AR/ VR	Augmented Reality/ Virtual Reality
AV	Autonomous Vehicle
CAV	Connected Autonomous Vehicle
C-ITS	Cooperative Intelligent Transport System
CO₂	Carbon Dioxide
COP	Common Operational Picture
EDS	Electronic Control System
ERTICO	European Road Transport Telematics Implementation Coordination Organisation
EV	Electric Vehicle
GDH	General Directorate of Highway

GLOSA	Green Light Optimized Speed Advice
MaaS	Mobility as a Service
MOBESE	Mobile Electronic System Integration
MTMC	Ministry of Transport, Maritime and Communications
MTV	Motor-Vehicles Tax
RFID	Radio Frequency Identification
RSU	Road Side Unit
SCT	Special Consumption Tax
TEP	Tons of Equivalent Petroleum
TSR	Traffic Sign Recognition
USMS	Urban Security Management System
V2I	Vehicle to Infrastructure
V2P	Vehicle to Pedestrian
V2V	Vehicle to Vehicle

V2X	Vehicle to Everything
GIS	Geographic Information System
GPS	Global Position System
IT	Information Technology
ITS	Intelligent Transport System
LoS	Level of Service

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION TO VEHICLES

Increases in population and welfare in developed and developing countries have also led to an increase in the number of vehicles on the road. The fact that fossil fuels will be exhausted in the near future has accelerated the orientation of human beings dependent on fossil fuels in transportation to electric vehicles in recent years. When it comes to electric vehicles, they are all kinds of vehicles driven by an electric motor. The history of electric vehicles, which are very popular today, actually dates back to the first cars operating with mechanical energy in the early 1800s.



First Self-powered
Cars Steam Engine,
1769



Mercedes, 1903



Chevrolet, 1954



TOGG, 2022

Figure 1.1 History of Cars

Source: (IKB, 2018), (Hürriyet, 2018), (Zorlu, 2018)

The first idea the automobile, which came to the stage of history with the passenger genius carriage drawing of Leonardo Da Vinci- 15th century, the effective genius of the Renaissance period, appeared as a private property in the early 1900s. The cars began with the invention of steam machines, the return of the Industrial Revolution. The use of steam machines developed for industrial purposes has been transformed into an engine prototype and used in ships and trains, and later, the internal combustion engines started to work with petroleum, making it fast, stronger and more inexpensive. As a result, large motor companies were established and the motor industry has improved in this regard. The importance of motorized forces in the course of war in World War II revealed that the "New World" would be formed around this technology.

After the European geography, which changed after the end of the World War II in 1945, achieved political recovery, it also brought economic advances to the fore and achieved these breakthroughs by reflecting the technological developments used in the war to private life. Some companies in America, Germany, France have been the cornerstones of this market. In the early days, the states that wanted to bring public transportation on the spot used cars for this purpose, but people started to buy cars as private property for easier and faster transportation in times of living standards. (Yolcu 360, 2019)

Electric vehicles (EVs) have become widespread since electric vehicles do not force the range of their electric vehicles. Electric vehicles are three times more expensive than other vehicles. There is a travel to long distances with the construction of new roads, the lack of refueling and the high speeds compared to other vehicles. It was overshadowed by internal combustion engine vehicles.

Especially in the last 10 years, electric cars have entered our lives again. However, it is not a dream to predict that this time they will be the future of road transport history. A model, which was produced in 2006 by a company in the United States, which was founded in 2003, and launched in 2008, is the first electric car in real terms and has achieved sales success above the estimates. Despite the high price of this electric vehicle, it has reached large sales figures and has led other companies of conventional

vehicles to focus their attention on this area. Almost all brands today have an electric vehicle model. One of the questions that this research seeks to answer is whether the roads we have are sufficient or not according to the developing sector.

The word "autonomy" is a combination of the Greek words auto and rule (nomos). As a rule, any self-governing system is autonomous. Of course, there may be different levels of self-management (just executing the order, making self-decisions). The history of autonomous systems in vehicles goes back to 1478 in mechanical systems and until 1920 in electronic and software systems. Following the first remote controlled radio-controlled driving technologies made by the US company in 1925, electronics preventing slipping and skidding during braking in the 90s. Technological innovations such as brake control system, cruise control system that keeps the vehicle steady at the determined speed in 2000s and automatic parking assistant were developed. These are technologies that support drivers, but they are systems in which cruise control is still human (KENDÍ, 2017). There is a distinction between connected and autonomous vehicles. CAVs are able to connect with each other through what is termed as V2V or Vehicle-to-Vehicle Communication, Road Side Units (RSUs), traffic control signals and other technical equipment or tools. At the end of the day, the automobile is part of an Intelligent Transport System (ITS) where both automobiles and communication networks are linked, enabling traffic data to be readily accessible to assist with coordination and improved protection. However, it is important to remember that it does not automatically mean that CAVs may or may not need a human operator in transport (ITF, 2018).

With the adaptation of developed technologies to cars, vehicles that meet all kinds of needs of people and provide convenience have become the lifestyles of people by getting out of the means of transportation. The fact that cars have an important place in human life has also been a driving force in the development of this need. Vehicle technology has also improved technologically in this regard and has been maximized with the applications included in the vehicles. Applications such as parking sensors, remote controlled vehicles, vehicles operating with fingerprints, autopilot, cruise

control are simple examples of this development. The ecology of the world, which is subject to change, has brought about its change in its available resources and created environments that will enable people to find new ways. The first examples of internal combustion and the cars used with the processing of oil opened the door for studies to find new energy sources by decreasing the oil reserves in the foreground plans. The occurrence of vehicles equipped with renewable energy sources has been an indicator of this. Today, increase in the global population is generating a transport challenge such that the number of cars on the road is growing every day. With the population growth, urban development and industrialization, energy consumption is increasing day by day. The world population is expected to reach 9 billion in 2040 with an increase of 1.6 billion. This situation provides more people with energy supply reveals the necessity. In the world economy, approximately 3% growth is expected in the next twenty years (G.Çağıl, 2012). According to the studies of the International Energy Agency, the world primary energy demand (if current energy consumption rate and policies continue), which is now 14 billion tons of equivalent petroleum (TEP), has increased by 45% over the next 20 years to 20.3 Billion TEP levels will be reached (Gazbir, 2014). The highway sector, which is the largest percentage, constitutes 39% of petroleum use in the world. The reduction in fossil fuels used today encourages the use of alternative energies and related sectors are being developed.

In term of environmental pollution and greenhouse emissions, EVs and CAVs are also safer than traditional vehicles. Just how clean depending on the type of vehicle and the energy source. If EVs and CAVs are powered by the cleanest energy systems, the emission from Vehicles is equal to that of vehicles above 100 miles per gallon. When powered completely with renewable energy, such as solar or wind, the charging and operation of an EV can be almost emission-free (Gambino, 2015). The Figure 1.2 explained the types of energy used for vehicles.

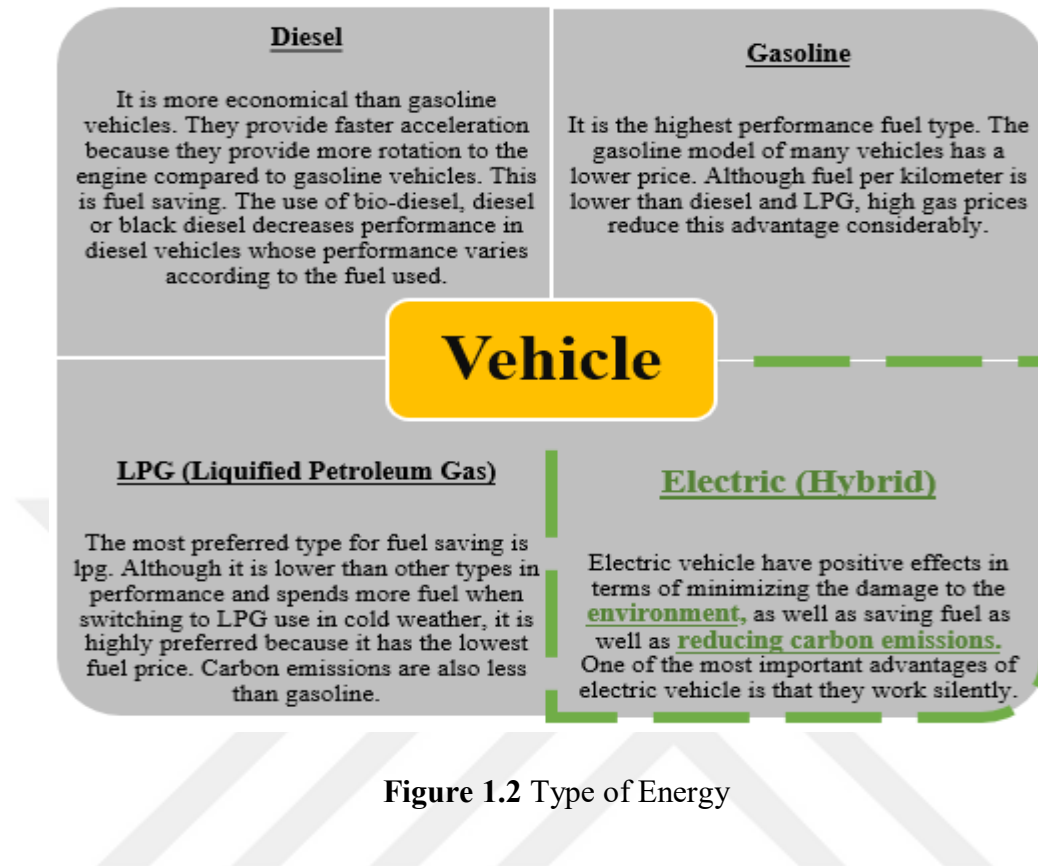


Figure 1.2 Type of Energy

Source: (S.YILMAZ, 2018)

The transport sector accounts for 26% of Turkey's total final energy demand. As such, it is located in front of the agricultural sector, behind the energy consumption of industry and buildings. Carbon dioxide (CO₂) as one of the largest contributors in terms of emissions to follow the emissions of electricity generation and industrial sectors and of all emissions in Turkey constitutes more than one-fifth. The main reason for this is that the energy composition of the transportation sector mainly includes petroleum products (its share in total consumption is more than 99%). The share of electricity consumption in the overall final energy composition of the transport sector is 0.4% and renewable energy is 0.5% in 2030. By the year between one million to two million and correspondingly of electric vehicle charging points with a total of 1 million charging infrastructure implementation to be placed. The number of Turkey's electric vehicles and charging infrastructure as well as maintenance considering that quite conceivable that a low level target is difficult to achieve these numbers. According to the information announced from in Turkey, national smart vehicles have been

complete to dizayn. The vehicle has its own unique lines, will be able to fully meet the standards of EuroNCAP, one of the world's leading automobile safety test companies. Authorities expect the domestic car to leave the EuroNCAP tests with 5 stars in 2022. Apart from this, some of the prominent aspects of the car are as follows (Zorlu, 2018):

- Domestic car will be constantly connected to the internet
- It will allow advanced autonomous driving
- Can charge up to 80% in less than 30 minutes
- Zero emissions, it will leave a clean world for future generations
- It will appeal to the global market with its advanced technological features.

Accordingly, the preparations of highway infrastructure for CAV & EV should be started. In this study it is analyzed according to certain criteria for Turkey's road infrastructure.

1.2 AIM AND OBJECTIVES OF THE STUDY

The aim of this study focuses on the highway infrastructure design for Electric (EV) and Connected Autonomous Vehicles (CAV). Inspecific, the a selection of highway network in Turkey is selected to perform the necessary investigate for compliance and adaptation process.

This study conducted by EVs and CAVs researched the answers to those questions, followed by three additional questions:

- i. What are the consequences for road networks of the EVs and CAVs?
- ii. Is the existing EVs and CAVs road infrastructure ready for drive those vehicles?
- iii. Which problems emerge from the differences found between the current road structure and the necessary infrastructure by the EVs and CAVs?

1.3 PROBLEM STATEMENT

With this much development of technology, has led to a focus on highways and smart roads have replaced traditional highways. Pilot regions were selected in many parts of the world and CAVs and EVs were introduced. In electrical and autonomous vehicles research conducted by Bogazici University in Turkey on a national scale, it reveals that the people of Turkey want to purchase EV and CAV. No research has been conducted to explore the requirements of transport network design and development of road network with respect to EV or CAV. According to the survey, the number of EV and CAV will increase by 56 times in four years to 140 thousand. preparation for the new technology of the Republic of Turkey highways According to these results, it is necessary to identify the infrastructure requirements (B.Bagatır, 2018).

1.4 LIMITATIONS

Inspection of the road infrastructure is detailed and needs to be examined. Especially for CAVs and EVs. The transportation network in Turkey is immense and can be categorised for urban and rural networks. Therefore, there is also a need for limitations in the analysis that can be conducted. Normally, the infrastructure framework can be separated by digitally and physically, but in this study, comparisons and analyzes are made on the basis of the topics in the Methodology Chapter. Highways in Turkey were discussed during the study. When this highway is being identified, high-traffic roads where regular road journeys are used and new technology is chosen. Pilot regions for CAVs and EVs can be chosen in the following years. The selection of network is specifically focused on rural networks as these provided more uniform design features compared to urban networks where shows significance variations in network standards. The Figure 1.3 shown below introduces the selected highways network for this study in Turkey. According to statistics, the traffic volume of Ankara-Istanbul highway is the highest road.



Figure 1.3 Map for Turkish Highways

Source: (KGM, Turkish Motorway Maps, 2019)

1.5 METHODOLOGY

The methodology to be followed presents the basic infrastructure, compatibility of road with new technology in Turkey and to compare some of the pilot studies from other countries who represents good practice. Considering the simple modification of the existing infrastructure, it is necessary to examine the road suitable for future vehicles. Therefore, the methodology includes the review and compatibility of these categories; Traffic Management Measures; Road Design, Marking and Traffic Signs; Safe Harbor Area; Digital Communication and Service Station/ Rest Area; Road Surface; Crossing and Junction.

The opinions and guidelines presented in this study, in particular with regard to the adaptations to infrastructure needed for the installation to CAVs and EVs, are focused on initial review and analysis and should be regarded as points of consideration that could direct further study into Turkish Highway Infrastructure.

The Figure 1.4 explained the role of this study in taking the first steps in the future development of transportation systems and networks. The aim of the study is to identify the difference between the existing infrastructure and the infrastructure needed by EVs and CAVs. After this step, some criteria of future road will be determined by guiding for future planning.

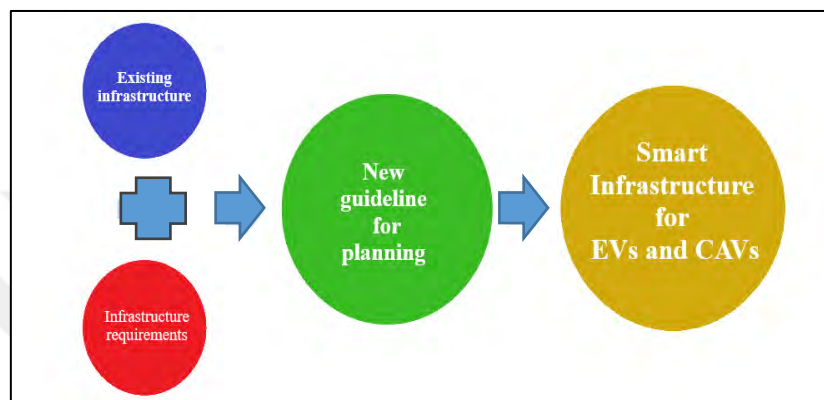


Figure 1.4 Scope of Thesis Methodology

Source: (TS-Catapult, 2017)

1.6 THESIS LAYOUT

Chapter one provides general information about; history of EVs and CAVs and, the main details of this thesis such as the aim and contribution. Chapter two presents the main criteria for planning infrastructure. The requirements of the infrastructure to be planned and the guiding details obtained from the pilot countries are examined, describes the current status of the existing highway infrastructure in the Republic of Turkey by examination of EVs and CAVs requirements on the parameters in this section. The three methodology of the thesis is explained in Chapter. The chapter mainly description of the highway to be studied and there is a comparison of the infrastructure of the countries have been prepared for these vehicles and the current position of the Turkish highways in these rankings. Chapter four shows the results of the all analysis. Chapter five reveals the conclusion of the thesis and discusses the future work.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION TO CONCEPTS

Technology entered our lives in many areas from phones to tablets and artificial intelligence to the internet of things. AR / VR glasses, smart watches and internet-connected refrigerators etc. Now it is time for smart roads and highways. As a matter of fact, electric vehicles are becoming more and more widespread abroad, and in 5 years, autonomous vehicles with artificial intelligence without a human driver are planned to be in traffic. Nowadays many cars have computer-assisted parking assistance. Here, the advanced technologies mentioned above will be used in the construction of smart roads. Engineers have developed smart ways to wirelessly charge and repair electric vehicles (EVs). Artificial intelligence highways will reduce traffic accidents and alert drivers to road congestion and landslide. It will also provide real-time road condition powered by sensors for driverless vehicles. Through to smart ways, autonomous vehicles (CAVs & AVs) will talk to each other.

Electric vehicles (EVs) are capable of operating emission-free and even solving many environmental and safety problems related to fossil fuel vehicles. Charging time period and driving range are among the major problems to the adoption and application of EV technology in the world (Maglev, 2011). CAVs have the ability to communicate between drivers and the environment. Improving mobility may maximize access to educational places, employments, hospitals etc. , as well as minimize stress and give passengers time back (Lexology, 2018). While CAVs are at a pretty early stage of growth, it is more unclear than understood if their widespread adoption will be accomplished – although there is considerable debate among their supporters as to whether a substantial proportion of vehicles on the transport network would be CAVs, increasing from several years between now and 40 years or more. For example, Somers & Weeratunga suggested that there would be no major penetration of the car market

by autonomous vehicles by 2040 (A. Weeratunga & K. Somers, 2015). Strategic affairs officer of a German automobile company has announced that a completely autonomous car with no driver would not be accessible within 30 years (S.Hill, 2016).

Research conducted by Boğaziçi University on a national scale in electric and connected autonomous vehicles in Turkey, Turkey reveal that the people want to buy EVs and CAVs. According to the survey, the number of EVs and CAVs will increase by 56 times to 140 thousand in ten years (B.Bagatır, 2018), if the road conditions will be suitable for these vehicles. Turkish Government ideology is ``Smart cities are built by Smart Systems`` (Isbak, 2015). According to this ideology; Ministry of Turkish Transportation, Maritime and Communication entered in a fast way research ups and Intelligent Transportation Systems (ITS) adaptation has begun on the roads. For example Traffic Management System, traffic light and road markings, crossing etc. Although there are limited applications for CAVs and EVs launched in metropolitan cities, it has become important to examine the situation on road routes between cities. In next chapter examined Anatolian Highway which is route of the most crowded two cities in Turkey. In this chapter compared between applications in all Turkey which has been start and the other countries that have expressed step guidance is available.

2.2 THE BASIC TERMINOLOGY AND DEFINITIONS

In the wider sense of connected vehicles, it is important to explain what autonomous vehicles are and to find them. For the considerations of this study the following are categorized as Electric Vehicles (EVs), Connected and/or Automated Vehicles (CAVs);

2.2.1 ELECTRIC VEHICLES

(also called an EVs)

Electric Vehicles are powered by one or more electric motors or traction motors. An electric vehicle may have been powered by electric from off vehicle supplies by a

converter network or may be self-contained by a battery, a solar panel or an energy generator to transform fuel to electricity. (A.Faiz, S.Weaver & M.Walsh, 1996)

2.2.1.1 ADVANTAGES OF ELECTRIC VEHICLES

- The biggest advantage of electric cars is fuel savings. An electric car needs monthly electricity as much as an average family of three.
- There is up to 30% SCT (Special Consumption Tax) difference between electric cars and gasoline and diesel competitors. In addition, MTV (Motor Vehicle Tax) is not collected from electric cars. (in Turkey)
- Electric cars generally have higher technological features than fossil fuel competitors.

2.2.1.2 DISADVANTAGES OF ELECTRIC VEHICLES

- Charging times of electric cars can be extended up to 10 hours. In addition, their range varies greatly depending on the road and driving style.
- It is thought that this problem will disappear with the increase in the studies on electric car technology.
- Prices of electric cars are often more expensive than their counterparts.
- Since some of the electric cars are not officially sold, there may be problems with maintenance and spare parts.

2.2.2 AUTOMATED VEHICLES

(also known as autonomous, self-driving or driverless vehicles / AVs)

Vehicles with a growing rate of innovation may use on-board sensors and devices to identify their geographical location and local landscape to make it possible for them to travel without human assistance. (TS-Catapult, 2017)

2.2.3 CONNECTED VEHICLES

(also known as Cooperative Intelligent Transport Systems (C-ITS)/ CAVs)

Vehicles with a level of connectivity which allows them to connect with their external conditions (which include infrastructure and other vehicles). It would provide the driver / automated control system with information on the road, other conditions of connectivity facilities.

Extending the above-mentioned high level definitions, this research is focused on the following categories of CAVs:

- Advanced Driver Assistance Systems (ADAS) for privately held road based passenger vehicles;
- Partially automatic private highway-based passenger vehicles;
- Fully automated road-based freight vehicles;
- Fully autonomous road / road-based public transportation (TS-Catapult, 2017)

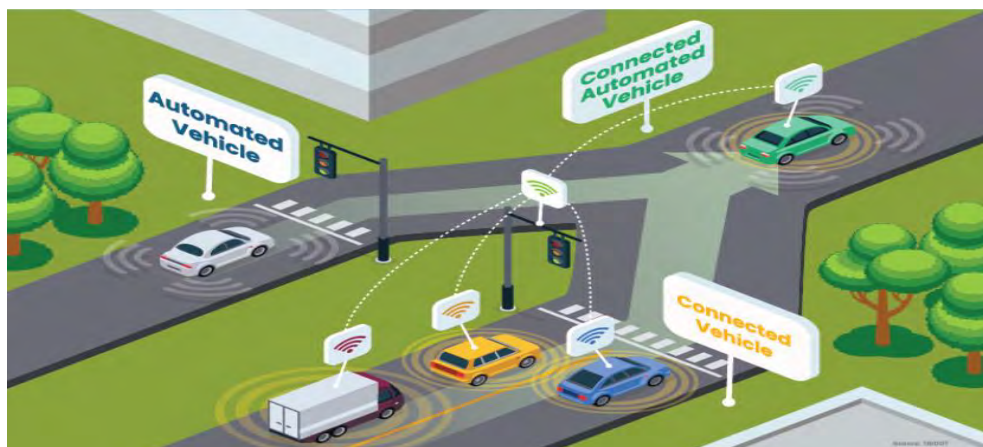


Figure 2.1 Example of ITS

Source: (E.Hill, 2019)

2.2.3.1 ADVANTAGES OF AVs & CAVs

- It provides fuel economy as they perform the most suitable ride according to road, traffic and load conditions.
- They have a higher view than the human view provides safe transportation.
- It fully complies with the traffic rules and can work 24 hours a day.
- Taking into account the most suitable route, traffic density calculates, saves time and path.
- Vehicle maintenance as it realizes optimum use it allows the costs to be reduced.

2.2.3.2 DISADVANTAGES OF AVs & CAVs

- Today's technological level are still around 7-8 thousand dollars. Since each vehicle uses more than one of these sensors, unit costs are quite high.
- Since the number of companies producing sensors is still limited and they do not have sufficient infrastructure for mass production, the delivery times of the sensor orders take months.
- The maximum of the driverless vehicles of the highway infrastructure of many countries, including Turkey, are not in a condition where it can be used with performance. Faded lane lines, rough roads, missing traffic signs are issues that can adversely affect the driving performance of vehicles without a driver.
- The sensors located in the bumper area of the vehicles are affected by light touches, bumps and frictions that can occur frequently during urban use, and their replacement or repair becomes mandatory. When this situation is combined with the high costs of the sensors, the maintenance and repair of driverless vehicles increases its costs considerably.

2.3 THE BASIC FRAMEWORK FOR SYSTEMS

The main frameworks at the existing level of evolution are as follows:

- Connected vehicles are vehicles that have used specific connectivity technologies (wireless, internet, GPS) to connect with the driver, and also other vehicles (V2V), highway infrastructure devices (V2I) and pedestrians (V2P), frequently referred to as V2X. Increased networking will produce important performance and safety improvements.
- Autonomous vehicles are those in which vehicle performance requires different levels of driverfeedback to manage driving, acceleration, and stabilization. Classifications for the levels of autonomy are listed in Table 2.1.
- The integration of Mobility as a Service (MaaS) and vehicle autonomy generates considerable interest with regard to the potential of multimodal transport. For passengers increasingly passing away from vehicle ownership and charging for multimode transportation on demand, away, it is obvious that whole new generation of autonomous transportation services will develop in cities, both in the public and private (F.Davidson & E.Selk, 2017).

Table 2.1 Description of Levels

Level	Name	Description	Example
0	No Automation	Human driver completely controls the vehicle	N/A
1	Driver Assistance Park Assist	Individual activities that assist steering or acceleration/deceleration are partially automated	Park Assist
2	Partial Automation	Several, simultaneous activities that assist steering or acceleration/deceleration are partially automated	Traffic Jam Assist
3	Conditional Automation	In certain driving scenarios, all dynamic driving activities are automated but human is expected to intervene when requested	Automated Motorway Driving
4	High Automation	In certain driving scenarios, all dynamic driving activities are automated and vehicle can cope without human intervention except when requested	Urban Automated Driving
5	Full Automation	Always and everywhere, all dynamic driving activities are automated with no need for human intervention	Full end-to-end Journey

Source: (F.Davidson & E.Selk, 2017)

The time chart is shown adoption of CAVs and AVs by coming years (See the Figure 2.2 below). In Corporate Partnership Board Report shows that estimated historical processes of automatic vehicles and other technological activities. The expectation of automated pathway will be ready in 2030.

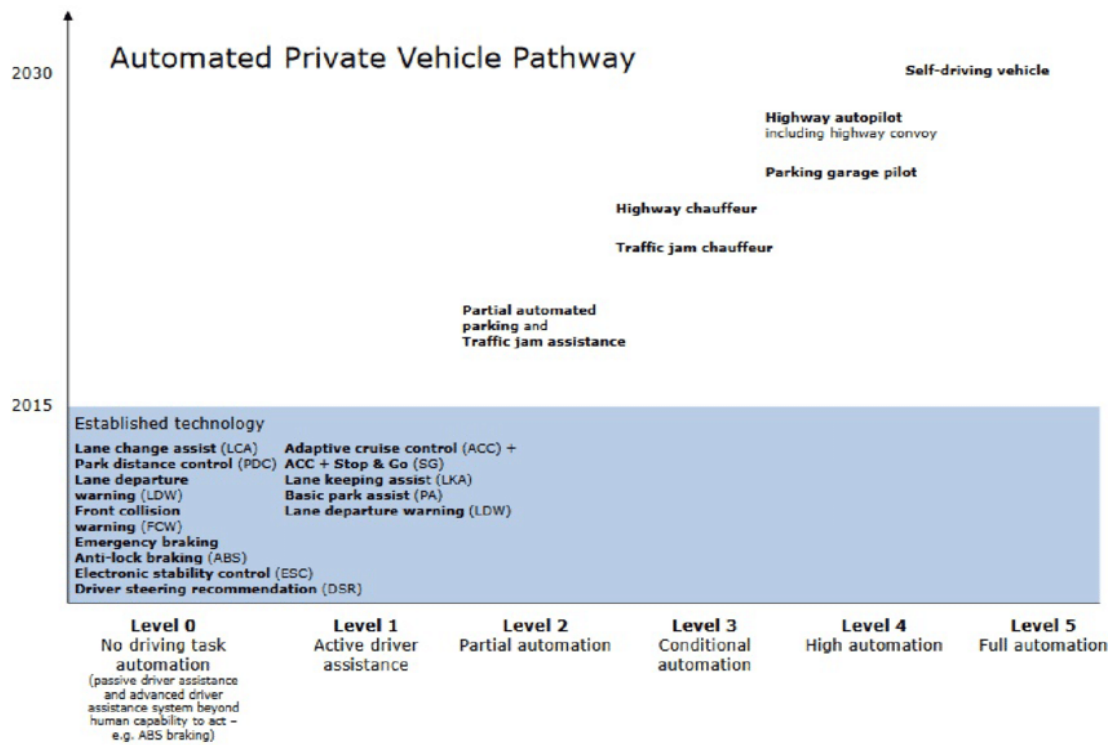


Figure 2.2 Automated Vehicle Levels

Source: (CityMobil2, 2015)

2.4 KEY ASPECTS OF NETWORK FOR AUTONOMOUS VEHICLES

The following aspects are prepared by taking guidance from `` Intelligent Transportation Systems Strategy 2014-2023 in Turkey `` compatibility with decisions taken by some developed and has been examined (AUS, 2014). The study included a total of six different aspects listed as follows:

- Traffic Management Measures;
- Road Design, Marking and Traffic Signs
- Safe Harbor Areas;
- Digital Communication and Service Station/ Rest Area;
- Road Surface;
- Crossings and Junctions;

2.4.1 TRAFFIC MANAGEMENT MEASURES

Future engineering focuses, in part, on creating traffic networks much more reactive to real- highway situations – either by reducing waiting at junctions and pedestrian crossings in low traffic situations or by quickly identifying and applying expected responses to road accidents. This new service being tested in France, GLOSA (Green Light Optimized Speed Advice), advises drivers how hard they need to use on the road to avoid being kept in red light. Unfortunately, many of the advantages of smart management systems might be lost in the process as traffic levels start to increase. Moreover, as disruptions such as accidents and road works will still be the primary sources of traffic accidents, development in network reliability will continue to have long term benefits.

Investment in intelligent traffic control systems usually has a pay-back of less than one year in terms of tangible gains, such as shortened transit delays. In addition to traffic signals – gradually connected to a broader variety of traffic control techniques, including promoting tidal flow lanes and reducing air pollution- other aspects of traffic management schemes include:

- ANPR (automatic number plate recognition) devices for tracking real time traffic flow as well as civil law enforcement.
- Lane occupancy, ramp entry and variable lane speed control.
- Beacon-based data processing from smartphones and GPS units.
- Dynamic communications networks connected to real-time data and pre-planned scenarios.
- Identification of over-height vehicles.
- E-call services offering phone alerts or linked vehicles.

- Direct data acquisition and sharing through application programming interfaces (APIs) with applications and navigation systems.

Increasing emphasis on live data is significant, as the retrieval of "floating" data directly from vehicles is cheaper and more effective than investment in traditional systems such as induction loops embedded in road surfaces. Social media are also a primary way of evaluating network efficiency as well as communicating with consumers.

Developing massive data sets also increases the ability of network providers to anticipate how road networks will respond to changes in traffic trends. This data will be highly useful as the activity of road networks is undermined by emerging modes of travel and technology (F.Davidson & E.Selk, 2017). Almost all CAV technologies are required to depend on accurate mapping of the road network and to compare the information received from sensors with those specific information in the maps to perform tasks such as location and lane identification. Road works can modify the layout of the road, modifying where the vehicles are supposed to drive. For human drivers, perception and the ability to analyze traffic signs allow them to navigate such locations. Though, CAVs do not have the intellect to properly perceive a new environment, and as such may also have problems navigating through such locations. In view of these difficulties, attention must be given to the future, concept, development and operation of traffic management measures (TS-Catapult, 2017).

In order for autonomous vehicles to behave and comply accordingly, the traffic regulations (static or dynamic; compulsory or recommended) must be digitized and become 'electronic rules' capable of being encoded in vehicles. Developing innovative automatic driving functions relies on them. For managing traffic, the road manager wants to be able to convert his mobility solutions into a modern unified language, so that it could be shared with other stakeholders in the road business. The distinction between government and management levels is important to define, as the concept of connectivity choices precedes its organizational execution.

Upgrading traffic or traffic management strategies along main roads or urban networks offers the optimal context for recognizing the value of cooperative, integrated and autonomous mobility and understanding the effect on the functions and boundaries of road managers, traffic planners, transportsuppliers, vehicle manufacturers and stakeholders in the area of physical and digital infrastructure.

The basic concept is that autonomous vehicles are often connected vehicles effective of integrating with traffic management. Cooperative traffic control has the based on specific criteria (C-ITS, 2017):

- Communication- the sharing of relevant traffic control related data should be bi-directional for the purpose of understanding or enforcement.
- Performance – traffic flow requirements are generally understood and analyzed.
- Collaboration – actions by both the public and private sectors should be comparable, distributed and executed in compliance with pre-arranged agreements.

Cooperative traffic management systems would need to be excellently-organized, because they draw on the joint contributions of those participating in the in the value-added service chain, both from the public and private sectors.

There is a need for flexible and replicable resources to be used in the whole European road network. These resources will offer ample autonomy for city councils, regardless of their scale or accessibility strategy, and also for traffic planners and road operators to execute services in any possible scenario.

In order to supporting public authorities take on the role of ensemble operator and convert their connectivity plans into 'standardized exchangeable data,' the Improved Traffic Management Working Group of the C-ITS System has developed a particular range of essential resources that need to be built for digital traffic management strategies (C-ITS, 2017):

- i. The first component includes of a road classification to be made in accordance with network flow hierarchical structure: not necessarily the shortest direction would be the quickest or the best. This method would allow public authorities and road planners to easily express their opinions on the current road network structure and the desired alternatives. It might be helpful for re-directing traffic over a zone that is being polluted, using GLOSA (Green Light Optimized Speed Advisory) or for design profiles for different road usage classes, e.g. freight, electric vehicles or public transportation.
- ii. The second component is a geo-fencing method. For turn, this would help the cities convert strategic development into traffic-related data processing, avoiding travelling through residential areas or close to public services, e.g. school, hospital. Network operators should connect to all these areas and add simulated delays on top, so that the connectivity system suggests an alternative way, more inline with the public authority's requirements.
- iii. The flow performance needs to be identified and measured in order to control traffic. Creating a network efficiency Level of Service (LoS) is therefore the third component necessary. LoS will depend on the road category or type of accident, but should be measured in the light of a mixture of two more obvious primary performance measures: speed and volume. This can be obtained by roadside units, loops, e.g. such as by means of unique test vehicle data.
- iv. The fourth and last component is the trigger and the point at which data identification is converted into motion. At this level, the need to participate in a cooperative traffic management system becomes critical in maintaining appropriate safe and effective traffic flow. The trigger requirements need to be frequently accepted, since the cooperative traffic management systems are the result of a mixture of coordinated actions by private participant.

At last, in order to produce possible the coordination of cooperative traffic management systems, it important to create a Common Operational Picture (COP) to provide the stakeholders with a standard outline and a geographical sense of the road system. The COP must have a visual display, at the top of the map, allowing

the display of suitable traffic management related data in conjunction with the layers of the specified basic components. The COP may play a key role in the rerouting of services, e.g. in detecting the need for additional limitation, or in promoting extra traffic on different routes. The research project develops integrated traffic control of connected and autonomous vehicles on the basis of the same concepts. The main object is win- win- win (See below). Traffic management ecosystems have been established on the basis of defined criteria (SOKRATES, 2018):

- Win for the road passenger – Successful traffic control relies on the individual passenger's approval. Passengers should only follow traffic control rules that are well coordinated with the various parties making up the rules and can also be easily communicated to them by a "one stop shop" of traffic information. Passengers should be able to traffic control managers, provide input on actual traffic flows and service quality.
- Win for urban traffic management centers – Traffic management centers should be able to greatly improve traffic management activities for a wide variety of road users with custom made, reliable details, modern connectivity networks and sensor- feed back methods.
- Win for private service providers – Information systems should be extended to provide integrated door-to door passenger assistance. The programs should be consistent with the policies of regional, collaborative traffic control. Nonetheless, the actual delivery of services to passengers (being their costumers) must remain under the control of the service provider in a dynamic business.

To accomplish the 'win- win – win' condition above, a range of simple principles and specific agreements must be formed between the above mentioned components. It has been done around three concepts (See the Figure 2.3 below):

- i. Intelligent navigation
- ii. Local speed and lane guidance
- iii. Local data and safety alerts



Figure 2.3 Lane Guidance

Source: (Smart Navigation, 2018)

In order to determine how stakeholders may work together to provide use scenarios, a theoretical framework has been developed, describing the options for cooperation. The classification of the intermediary was discussed on the basis of use scenarios and cooperation frameworks. The intermediary is supposed to play a role in the management, collection, merger, quality control and general model sharing of data. A collection of standard intermediary function alternatives has been identified and defined (SOKRATES, 2018).

Selected highway is the highest the traffic volume section in Turkey. The distinction for LoS should be evaluated according to flow-capacity for each- road type. LoS is a qualitative measure that helps to increase the service level of vehicles. The countries that have seen the best practice of LoS use procedures are the UK and Australia (LoS, 2009). This service system is monitored based on the following measurements.

- Two-lane roads
- Multilane roads
- Free sections of the highway
- Freeway entrances (integrates), exits (divers) and flowing lanes

- Cycle services
- Pedestrian services

These services raise awareness in the road safety community of the value of new technologies that aim not only to assist the driver, but also to realize parts of the driving function and accelerate consumer demand for safer vehicles. These services to be used provide safe driving area for CAVs and will help safe traffic flow for other members (cyclist, pedestrian, human driver etc.).

In Turkey, these systems are established and operated by the General Directorate of Highways (KGM-TR), the General Directorate of Security and local administrations that are responsible for the management, operation and control of traffic. Consequently, Traffic Management Centers have been established in Izmir, Mersin, Istanbul and Ankara. There are meteorology sensors, variable message signs and cameras connected to these centers. Traffic management centers have been established for the management and operation of traffic in many metropolitan municipalities, especially in Istanbul. The Traffic Control Center has been established by the Istanbul Metropolitan Municipality in order to ensure the continuity of traffic flow, to use the road network capacity effectively, to monitor traffic in real time, to control and manage. This center installed the signaling system, traffic measurement system, traffic monitoring camera system etc. in different points of the cities. Traffic data are obtained from intelligent transportation systems. From these data, traffic information is created through advanced software algorithms and transferred to various platforms such as Mobile Traffic (See below Figure 2.4), variable message systems, Web applications. On the other hand, Urban Security Management Systems (USMS) centers are created within the scope of USMS (MOBESE- TR Mobile Electronic System Integration) established and operated by the Ministry of Interior in provinces and districts. These centers can be evaluated within the scope of intelligent transportation systems application with their security functions as well as the imaging function they provide.



Figure 2.4 Mobile Application in Turkey

Source: (KGM, 2019)

With the system, images taken from mobile and fixed cameras installed at different points and serving 24 hours, to reach USMS-Centers with fiber-optic cables and wireless (WI-MAX) technology. Those cameras using for security of cities. For example with the PRS (Plate Recognition System), the vehicles that detect a violation of red light and speed are automatically detected by automatic reading of their license plates while driving in traffic, and then penalties are applied (AUS, 2014). Electronic Control System (EDS=TR) is a control system developed for the control of traffic flow and optimization of transportation, for the urban life to be in accordance with the rules, with a certain normative structure, and for ensuring the safety of life and property by preventing accidents caused by traffic-disrupting vehicles. EDS covers the detection of the violating vehicles by means of sensors, determining the license plate of the vehicle with image processing software and subjecting it to the penalty stipulated in the relevant law. EDS cameras have been actively working in 16 cities since 2016 (See below Figure 2.5). According to the government, installation is planned in 81 cities in the near future. Support for traffic safety has increased digitally with 455 cameras located in Istanbul. These cameras service as; 159 red lights, 97 safety lanes, 41 average speeds, 21 opposite directions, 92 parks, 16 tram roads, 9 offset scanning, 3

pedestrian crossings, 6 return prohibition violation detected and 11 mobiles (as vehicles). With the system, awareness is created that individuals' defective behaviors are constantly monitored and detected. At the points where the system is applied, it has been observed that rule violations are reduced by 90% in a short time (Isbak, 2015).

ITS Strategy Report 2014-2023 within the scope of on the decisions taken (AUS, 2014);

``Action 3.2.2: Traffic lights and signs to improve traffic flow efficiency regulation.``

This is one of the basic elements expected to be prepared for COP. Completion of this work will be in 2023. The procedures to be applied are as follows; based on real-time or traffic volume planning undulating green corridor signalization will do the optimization, the action plan period in urban centers will be at least one corridor, proceeding to adaptive green wave applications. In addition, fluidity will be increased with adaptive junction control systems that will detect traffic volumes from all directions in busy corridors and optimize the circuit time accordingly and ensure coordination with other neighboring junctions. This action will be implemented in a different design for public transportation vehicles as well. (AUS, 2014)



Figure 2.5 Map of EDS in Turkey

Source: (EGM, 2019)

2.4.2 ROAD DESIGN, MARKING AND TRAFFIC SIGNS

In principle, roads and highways were designed for humans by providing reliable and stable features to satisfy users' needs and reduce trouble. With time, CAVs and technology integrated into roads and highways infrastructure may lead to future designers applying criteria intended to serve vehicles and technology. Until that time, geometric design concept and methodology will remain focused on human needs, modifying continuously over time commuting with advancements in technology that result in safety benefits.

Many scientific studies and documents on CAVs focus capacity considerations and benefits on segments of roads and highways, intersections and the wider existing road network connected with auto-parking or a shared economy where individual vehicle ownership would be lower. Most of the major priorities coming from CAVs, however, are connected to safety results. The compatibility of CAV with roadway infrastructure creates significant opportunities for reducing the type, number and accidents related to (B.RAY, 2017):

- User Categories (operational efficiency between small and large services, emergency services etc.)
- Vehicle and Road (conflicts of intersection or support with prudent speed and performance)
- Contextual Problems of Land Use (rural, urban, center of town)

The geometric layout of the roads will continue to be based on and expand upon principles of human nature. As technological innovation, automobiles can adapt current design methods and benefit from more efficient and cost-effective designs. Most of those analysis about CAVs have to do with operational effectiveness. However, taking into account the public health and the social costs of serious and fatal accidents, success in safety would be a critical outcome of adaptation. This may start with focusing on the most vulnerable road users in guidance of multi - modal development and design first. Several CAV innovations rely on simple and accurate

road marking and signs to manage their region, making signs and markings well maintained critical. Severe degradation or unusual use of road markings can confuse CAVs or even lead an accident.

The traffic sign design and performance is critical for both road users and autonomous vehicles. While there are international and regional guidelines, including instructions on sign face design and sign use, there are variations in the governance structure for road ownership and management between different properties, roads and networks. In comparison to the Traffic Sign Recognition (TSR) schemes, this also results in signal inconsistencies that may possibly create issues for human drivers (B.Johnson & M.Rowland, 2018).

Ensuring effective sign designs and procedures for both human drivers and camera vision-based TSR systems during the transformation process would take a creative solution from both public and private sectors and highlight the need for effective interaction within the sector. Potential solution for current facilities – review of sign placing is strongly urged. Combining audited camera-based drives into infrastructure assessments will require road authorities to assess if the current location of the sign is appropriate to TSR systems. A review of signage quality criteria and requirements will make it easier to optimize the construction of the sign face (B.Johnson & M.Rowland, 2018).

It is expected that roll out of most changes is undertaken in a managed and progressive manner which coincides with the replacement life of existing signage. This roll-out would also give preference to signs that have a negative effect on automated vehicles over for those who are not read at all, particularly in cases where these signs that compromise the safety of road users as innovation progresses into TSR operated vehicle speeds (B.Johnson & M.Rowland, 2018).

Lane marking might continue to be retained as the automatic lane usage control in the coming future. It is possible that human drivers and camera-based driving devices would continue to be eliminated from the transport system before line marking is made

redundant for autonomous vehicle processes. Also, it is important to realize that line marking is a public safety issue, not just a problem of road maintenance, and for both automatic and non-automated vehicles (B.Johnson & M.Rowland, 2018)

The traffic signs are green in Turkey. A font similar to the American Highway Gothic is used. It has at least 6 lanes, all of which are 3.75 m wide, with the exception of some old motorways.

Despite the high speeds, the bend and slope standards of the motorways are very high, especially in comparison to the state roads, in order to provide safe travel and minimize fuel consumption. For this reason, there are many viaducts and tunnels where the geographical conditions are difficult on the motorways and the cost per kilometer is higher than the other roads (wikimedia, 2016).

2.4.2.1 THE RULES ON THE ANATOLIAN HIGHWAY (FOR PASSENGERS)

- Stopping, parking, making a turn and driving in reverse on the highway is strictly prohibited.
- In compulsory situations, you may stop at the rightmost special purpose lane (shoulder) by taking the necessary measures and without risking traffic and life safety.
- Pursuant to the decision made by GDH (General Directorate of Highways), the highest minimum speed limit for highway users is 40 km/h; the maximum speed except for the limits allowed by geometrical standards and the limits indicated on related traffic signs is 120 km/h for passenger cars. All pedestrians, animals, bicycle riders, non-motorized vehicles, rubber-tired tractors, construction equipment are prohibited from using the highway.
- The wire fencing or walls that are built along the highway boundary lines were built for the purpose of preventing such exits; therefore, it is strictly prohibited to break, demolish, cut or otherwise destroy these barriers.

The specified rules will help to better understand and analyze the system to be made in Turkey. The following Figure 2.6 shows several signs of the Vienna Convention implemented in different countries:

ROAD SIGNS	Great Britain (GB)	Greece (GR)	Netherlands (NL)	Poland (PL)	Serbia (SRB)
Stop (and give way)					
Give way (to traffic on major road)					
No entry for vehicular traffic					

Figure 2.6 The Countries Standard of Road Signage in Europe

Source: (R.Nuyttens, 2018)

CAVs focus on markers and road signs to guide them when traveling. The following Figure 2.7 provides an example of line markings that are in disrepair.



Figure 2.7 Example of Poor Maintenance of Road Markings

Source: (TS-Catapult, 2017)

A related issue exists from poor road sign service. Although the sign in Figure 2.8 is an example of a warning that a CAV, and actually a human driver, might be having trouble understanding.



Figure 2.8 Example of a Bad Condition of Road Sign

Source: (H.Mitchell, 2016)

ITS Strategy Report 2014-2023 within the scope of on the decisions taken about standardized of traffic sign and lane marking system. After this decision, Ministry of Turkish Transportation, Maritime and Communication had implemented lane warning system and applications completed with the arranged traffic signs and lane markings in 2015 for all country (AUS, 2014). However, some traffic lines and signs are deterioration due to drivers or weather conditions. More frequent maintenance and control are necessary for autonomous vehicles to read easily.

2.4.3 SAFE HARBOR AREA

In total highway pilot mode, automobiles can pass at high speeds and the human driver will be disconnected from the driving activity. This is likely that the driver is not able to recover control of a vehicle until it reaches the end of the operating frame. It may be attributed to a variety of factors, such as (TS-Catapult, 2017):

- Driver falls asleep, suffers some debilitating incident (e.g. heart attack) or becomes otherwise distracted;
- CAV system malfunction or mechanical problem;
- Deterioration of environmental conditions;

- Detection of incident ahead, such as disabled vehicles in the carriageway, which CAV is unable to negotiate.

In this case, the vehicle may need a safe area to rest and wait for the driver to be ready or for factors to change to the rating that the automatic control system is capable of continuing (See the Figure 2.9 below).



Figure 2.9 Emergency Area

Source: (Roads.org, 2017)

Typically, rough shoulders have been built along the highways, which offer a continuous line of protection for automobiles to stop in an urgent situation (See the Figure 2.10 below).



Figure 2.10 Continuous Rough Shoulder

Source: (Roads.org, 2017)

In recent decades, a number of parts of the highways have been upgraded to All Lane Running in the UK (this is continuation and further advanced version of the smart motorway concept developed in the Netherlands). In this kind of highways, the hard shoulder is generally turned into a driving lane, and the stable line currently allocated by the hard shoulder is transformed into a regular slashed line. Lane one (Previously, the hard shoulder) is only accessible to overhead traffic and fixed by edge of console sign in the case of an accident.

Different points have been made about the adequacy of the Emergency Refuge Areas and the fact that they are being abused as mentioned below (HCTC, 2017):

“Abuse of the level of emergency shelter is unethical. If combined with the lack of these places, this can lead to a driver being forced to stop on a live lane in the event of a breakdown.”

Many of the highways have been modified to 'Dynamic Hard Shoulder Running,' which entails maintaining the strong white line to signify the existence of a hard shoulder, thus opening the hard shoulder to general traffic at peak hours by means of overhead signs. High-speed double and single carriage roads actually do not require the establishment of safe harbor areas.

Drivers are presumed to be completely disconnected from driving activities in extremely and completely automatic CAVs. In certain cases, though, CAVs can require human interaction. This involve unexpected scenarios such as:

- The in-vehicle device senses a fault that can compromise its reliability.
- Unexpected road situations that the CAV cannot properly control.
- Unexpected weather conditions that the CAV is not well prepared to manage.

In these situations, CAVs would require safe locations nearby to be used before unexpected events are cleared or human interference is ensured (TS-Catapult, 2017). The position of these safe destinations should be well prepared. They should be

frequently enough to satisfy the urgent requirements of the CAVs and wide enough to place at least two cars. They will be well controlled in order to discourage their abuse. They must also be well mapped, and the precise positions of the vehicles should be identified to prepare to avoid them properly. Service stations can be good road destinations, with areas allocated for safe CAV rest. Although the duration of service stations may not be adequate to satisfy the pressing requirements of the CAVs to stop, safe shoulders should be positioned in-between to allow the CAVs to draw apart.

According to Turkish Traffic Safety Manual, distance should be between 0.5 m to 3.00 m. This distance varies depending on traffic volume and economic factors (GDH, 1998). This distance is 2.5 m (width=Rough Shoulder) on the Anatolian Highway. Despite the presence of some technological systems, it is limited. There is a navigation application for traffic flow and accident situations that can be found online from mobile application. But Turkish Roads need to geographic mapping system, like GIS, for V2I. The vehicle should know the condition of these areas beforehand and if there is density or work in these areas, the vehicle should determine the route.

2.4.4 DIGITAL COMMUNICATION AND SERVICE STATIONS- REST AREAS

Some of the opportunities of CAVs would be improved by communication between vehicles and the larger system. Wireless communication systems within urban areas can allow vehicles to communicate with traffic control systems in real time, exchanging information such as signal phase and timing and live traffic conditions. By this information, CAVs should be able to refine their frequency and route in order to decrease travel times and total congestion.

Transportation agencies and local authorities play a key role in this by introducing the requisite digital communication networks, facilitating efficient and safe communications between vehicles and traffic management systems. Further than the basic networks, they will understand the structures and technical requirements that will ensure that the possibilities presented by the connected vehicles are completely

achieved. Connecting with CAV developers on this is a successful reference stage (Atkins, 2016).

Service stations perform a significant part in supplying drivers with a convenient place to stop, rest, refuel and use toilet facilities. It is important to understand how their function could be changed by going towards vehicle automation. Service stations should have an adequate high capacity and a more suitable safe harbor location. If the driver of the vehicle had fallen asleep whilst the engine was driving itself, it would be better to wake up in the service station car park, with all the shopping and toilet facilities open, before progressing with the trip. In order to do so, the driver must provide access to the service station and the parking area of the CAVs, so some modification to the current service station and the parking area of the CAVs will need to be required, so some change to the existing service station design will need to be rendered in order to do that.

Another concept is to consider using service stations as a platform for urban transport, through the introduction of additional public transport systems by 'automated motorway taxis' fleets. This theory could be worth exploring because CAVs are able to work within the more regulated atmosphere of the motorways and have been less able to operate consistently in the more complicated urban world for some time to come. Passengers may use public transportation, a taxi, a walk or a bicycle to the service station and then take an electric motorway taxi to continue their trip. This basically re-imagines the network of highways as the roads of a new public transit system, with service stations as the current subway stations.

These are expected that several CAVs will be electrically operated and that service stations would need to be able to charge CAVs within manually driven vehicles. It could be worth exploring wireless charging stations that automated CAVs would reach and utilize without the need for human interaction. Highway officials may start working together with service station operators to explore these and other alternatives. There may be an opportunity for service station operators to provide facilities that would target the growing demand for CAVs in the years ahead (TS-Catapult, 2017).

2.4.4.1 THE SERVICE AREAS SPACING

There are two types of on-line service areas envisaged. Type 1 Service Area (full service area) can be a large scale service area providing an amenity building (including a convenience shop, restaurant, washrooms and tourist information), fuel facilities, parking. Type 2 Service Area (rest area) can be a small scale service area providing parking, picnic and toilet facilities, but without a main amenity building or fuel facilities.

Service areas should serve traffic travelling in both directions on the roadway. This can be done by locating separate facilities on either side of the roadway or locating one facility accessible from both. Facilities located on either side of the roadway are not required to be directly opposite each other. The scale of individual service areas will vary based on traffic volumes and local factors. An example of local factors would be the need for increased levels of Heavy Commercial Vehicle (HCV) parking at service areas near ports. Access and egress to and from on-line service areas will usually be directly from the mainline carriageway. Service areas are expected to continuously develop to meet evolving standards and needs of road users. Examples of such future needs may include (NRA, 2014):

- Increased parking facilities based on traffic volumes.
- Requirement of parking with improved accessibility for industrial vehicles.
- The ability to book safe and secure parking in advance in line with the ITS Directive.
- Increased levels of facilities in order to comply with future European and National policies.

There are service areas standardized as A, B, C and D type on the Anatolian Highway:

Type A: Parking area, motel, fuel station, spare parts sales, car maintenance place, car wash place, rest, food and beverage sales

Type B: Parking area, fuel station, spare parts sales, car maintenance place, car wash place, rest, food and beverage sales

Type C: Parking area, fuel station, spare parts sales, rest, food and beverage sales

Type D: Parking area, resting and dining opportunities

Hazardous locations (such as tunnel entrances, curves), intersections and service areas are illuminated (wikimedia, 2016).

2.4.4.2 CHARGING NEED

There can be a common assumption that the CAVs are electrically driven. If the market shifts in this direction, investing in more charging stations would increase the efficient operation and acceptance of CAVs. This includes preparation by the authorities for appropriate sites for the installation of such stations. Places can involve well-visited sites such as service stations and shopping centers. Several municipalities are extending their charging networks by allowing vehicle owners to add home chargers and get discounts and/or tax credits in return (LADWP, 2018).

Alternate charging methods that can handle self-employed cars without a human being on board are also worth pursuing. Some of these alternatives may be the idea of 'driving on motion.' Techniques are currently being investigated to power electronic vehicles wireless network (T.Knoss, 2018).

This involve the use of in-road charging sheets capable of transferring wireless energy to in-vehicle batteries. Roads electrified by rail tracks are another promising option. Such electric railways transmit energy wireless network to the vehicles that travel on them. This approach is presently being implemented in Sweden for a distance of 2 km, with the government aiming to extend in the future. (Guardian, 2018).

The electric vehicles expected in 2022 around 140 thousand, if enough charging stations provided in Turkey. (Indigo, 2018) The biggest problem that comes to the fore

here is the construction of charging stations for electric vehicles. Unfortunately, Figure 2.11 shown the fact that there are not enough stations in the cities to provide fast charging of the vehicles causes this problem to increase day by day. Especially the difficulty of accessing these charging stations as well as the distance of some of the stations in the city emerged as an important problem to be solved. According to the decision of the General Directorate of Highways (GDH) last year, there should be an electric charging station in each petroleum station. However, this plan has not been implemented yet.



Figure 2.11 Charge Station in Turkey

Source: (Google Map, 2020)

2.4.4.3 PARKING

One of the anticipated advantages of CAVs is the possibility of dropping off their passenger right at their destinations, then going to a parking area on their own. This requires some changes to the current parking lots and meters infrastructure.

Since CAVs do not have people on board, they may not be subject to traditional payment systems at parking lots and on-street parking. Automated payment systems should be made simpler. The entrance gates at parking lots and the parking meters on streets should be capable of recognizing vehicles. This can be handled through the use

of an RFID (Radio-frequency identification) reader at these points, and an RFID tag on each vehicle. The reader will be able to automatically retrieve the vehicle license plate number stored in its tag. An alternative to the RFID technology is to use a camera at the points designated for vehicle recognition. The camera can scan the license plate numbers of parking vehicles for recognition. Furthermore, this vision based strategy can face restrictions on its usage in on-street parking. In these situations, cameras may have obstructed / limited visibility of the vehicle cover. For payment, vehicle owners may, for example, pay for their parking using online payment methods (AVIN, 2018).

There are parking areas in Turkey are not sufficient for the cars. In some areas, there is free parking at the roadside within certain time periods. But this is a temporary solution. Considering the population of 82 million people in the country, it was calculated that the one vehicle for every four people and one car for every seven people. When the number of vehicles and the capacity of the parking area was compared, it was determined that an average of 13 vehicles was used a parking area in Istanbul, and 100 vehicles were used in Ankara (B.Inselel, 2019). According to these statistics, existing parking spaces are not enough. A new project is required for the parking areas along with the charging stations that need to be installed for EVs and CAVs. The design rules of existing parking areas and newly planned areas should be developed. These issues should be focused on, such as the camera, charging stations and the number of parking spaces consider charging duration to avoid volume.

2.4.5 ROAD SURFACE

It has already been noted that AVs are likely to require road markers, signage and signals to be maintained at a far higher degree than is currently the case. It is also likely that road conditions would also need to be repaired to a higher quality. Of example, a pothole in a road lane holding vehicles in a platoon, where vehicles follow each other very near, may be potentially very dangerous.

The detrimental impacts of autonomous driving on the pavement system can be loosely classified as;

- a) Impacts due to decreased wheel,
- b) Impacts of platoon driving.

Reduced wheel circling means that cars travel precisely at the same position in the crossroads of the route, while people drive roughly 40 cm apart on 3.5 m long lanes. In the case of automobiles, this could lead to intensified rutting of studded wheels in the Nordic countries. For other nations, this allows the surface of the concrete to be smooth and issues with low friction. With heavy goods vehicles, the reduced wheel-wrapping can lead to considerably faster pavement fatigue, particularly where the bound layers are relatively thin (< 200 mm), but would also have a long-term impact on thicker pavements. Platoon driving, on the other hand, can lead to problems pumping on roads with low subgrades and permanent deformations due to increased pore water pressure during the spring thaw season (T.Saarenketo, 2018).

Some governments have started to invest in smart pavement due to the wide benefits it can bring to roads (M.Cheng, 2018). With the availability of CAVs, such benefits would be augmented. Smart pavement can track vehicle locations and provide CAVs with related alerts when necessary. They can also use the tracked locations for detecting on-road emergencies and traffic conditions and report them, so authorities can take timely action. Smart pavement can also share location information with CAVs to enhance their on-board localization equipment in obstructed areas where GPS is not reliable.

The currently popular smart pavement products depend on the use of sensing fiber cables that are capable of detecting strains in the pavement. Accelerometers are also embedded in the pavement to detect vibrations and predict the directions of passing vehicles. Magnetometers are used to estimate the vehicle size to predict its type. Electricity is provided from the grid through power-over-Ethernet connections, which are also used to provide connectivity to the pavement (A.Nordrum, 2018).

Although it seems complex to deploy, smart pavement comes with an additional advantage, which is the flexibility to be manufactured off-site and brought to the deployment site as ready-to-wedge concrete slabs.

In Turkey, damage road surface is determined by engineers. Although some technological steps have been taken regarding this issue, it has not yet been fully implemented. It is one of the decisions taken according to ITS Strategy Report 2014-2023. The application period is planned to end in 2023 (RTMEU, 2019).

2.4.6 CROSSING AND JUNCTION

Crossings and junctions are one of the basic part of the transportation network. In this section, two categories to be examined are defined and the elements required for CAVs are discussed.

2.4.6.1 CROSSING

There are very important road safety advantages for pedestrians and bicycles from the prospect of an autonomous vehicle, there is also potential risk that eliminating the human aspect (from human driver to pedestrian) will cause confusion and pressure. When increasingly automated vehicles are a mode of transportation with visible mode sharing, they may need to be controlled in a manner compatible with the road preference, depending on the time of day and the importance of the venue. Highly automated cars, e.g. geofence, offer the ability to channel 'traffic' away from traffic-sensitive streets, such as the major shopping centers and industrial areas. A large combination of automatic and non-automated vehicles, without adequate supervision and maintenance, may pose potential risks to pedestrians, cyclists and motorcyclists (B.Johnson & M.Rowland, 2018).

A focused investment plan could be required to enhance the automated vehicle experience with pedestrians / cyclists, helping to make their actions more reliable for automated vehicles. This may involve dedicated cycling lanes on important cycling corridors and signposting of intersections and slipping lanes along main pedestrian

paths. That will be a long-term initiative that ends in the short term, with the goal of increasing the continuity of user activity and facilities (B.Johnson & M.Rowland, 2018).

Sometimes there may be serious problems between pedestrians and drivers. Infrastructure installed sensors and V2I connectivity to linked autonomous vehicles may aid, but should be built to provide reliable, operation-critical knowledge that is not guideline. Signal-controlled crossings are supposed to be easier to navigate by linked autonomous vehicles than other types of crossings (TS-Catapult, 2017).

Below are some risk groups listed for unprotected users (often electrical vehicles) from autonomous vehicles (B.Johnson & M.Rowland, 2018):

- Electrical vehicles do not make any noise or little.
- Decreased eye contact with a human driver to pedestrians / bikers.
- For automated vehicles, the speed limit may be traveling faster than human drivers.

There are some studies to prevent such risks. CAVs are being trained to detect pedestrians at crossings. However, field tests show that CAVs may fail to detect pedestrians in some cases. Until the detection becomes 100 percent reliable, CAVs should be assisted from the infrastructure at crossings to guarantee such detection. This can be handled either through road-embedded or mounted infrastructure. For example, magnetic or pressure sensors can be embedded in crosswalks to carry out the detection. Another example is to detect pedestrians using infrared sensors or cameras mounted at traffic lights or electric poles. Warning lights can be added at crossings as flashing beacons to warn approaching vehicles when crossing pedestrians are detected (Flir, 2017).

2.4.6.1.1 ZEBRA CROSSING

The Zebra crossing could pose a risk to the CAVs. One issue, especially from the point of view of the CAV, is knowing who has the right of way. Vehicles are expected to

halt as the pedestrians reach the zebra crossing, but the pedestrians can wait for the approaching vehicle to slow down considerably (to ensure that it does and does stop) before the crossing. If these rules were applied literally by all parties, then either pedestrians would never be able to cross on busy roads or there would be a stalemate whilst one waits for the other. It is left to the judgment of the pedestrian (who may be a child with limited ability to judge) as to whether a vehicle has enough time and distance to comfortably stop without hitting them on the crossing.

Technically, the ideal solution to zebra crossings would be to replace them with marked crossings that are much more deterministic and do better to prevent pedestrians from either walking out or even running out of the crossing. However, it may not be feasible or cost-effective to eliminate or modify them.

The other issue is pedestrian detection. This could be done from post mounted infrastructure, or from the approaching vehicle. The issue with a vehicle based strategy alone is that it may fail to detect pedestrians under some conditions, not least due to the limited field of view from the vehicle. A technically superior solution would be to do the detection from the infrastructure with vehicle based detection also used as a final resort in case a pedestrian runs out onto the crossing. Time-of-flight and infrared camera pedestrian sensors are being developed for infrastructure installation, providing accurate and stable weather and light conditions as well as field of view when properly installed. Infrastructure-based traffic identification is now also standard practice. This makes having the crossing itself as the one source of the truth to perform the crossing arbitration seem an attractive option for an assured system (TS-Catapult, 2017).

2.4.6.1.2 SIGNALLED CROSSINGS

The approaching CAV would need to be sure of the signal status. Pedestrians may not wait for the correct signal phase and may cross late or early and run out to try to make it in time before cars pull away. Electric vehicles will not have the running engine revving or restarting as an early indicator that vehicles are starting to move off. For

these reasons, much of the same logic is needed as for Zebra crossings where pedestrian will attempt to cross at will so it can be treated as a traffic signaled Zebra crossing. It is also suggested that the flashing amber phase is removed entirely since with pedestrian detection the red phase can be extended as long as required. Having the ambiguity of the flashing amber phase only provides opportunity for problems leading to the vehicle needing to detect itself if there are any stragglers on the crossing which may be prone to error. Different vehicle would potentially have different implementations of this and it could be better left to the infrastructure with wider and dedicated sensing capabilities to make the final judgement to proceed if clear (TS-Catapult, 2017).

Pedestrian Crossing (Electronic Control System) is a system that aims to maintain pedestrian crossing superiority in uncontrolled pedestrian crossings Figure 2.12. In Turkey, if there are pedestrians in uncontrolled pedestrian crossings, drivers often do not comply with this rule, although vehicles must stop and give way to pedestrians. With the pedestrian crossing violation detection system, it automatically records drivers who violate this rule. Continuously monitored passages are recorded with high resolution IP cameras. These cameras are monitored remotely by an automatic plate number reading system.



Figure 2.12 Pedestrian Crossing (Electronic Control System)

Source: (Isbak, 2015)

2.4.6.2 JUNCTIONS

The junctions considered within this report include signal controlled, priority controlled, level crossings, with further consideration to what happens when a signaled junction has a fault failure.

Modelling studies have found that, particularly at high flows, roundabouts are more efficient for automated vehicles with V2V communications than are traffic signals (R.Azimi, G.Bhatia, R.Rajkumar & P.Mudalige, 2013).

2.4.6.2.1 SIGNALLED JUNCTIONS

At signalized junctions, the primary difficulty is to be able to detect the symbol condition and to wait for the red signal and at any stage not to move the red signal past. The mechanisms of recognition were split into two categories. The first is to use algorithms to see lights in the same manner that human drivers do. The second is to use a simplified method of V2I radio communication. The incremental provision of traffic signals to vehicles wireless network needs to be established in order to be ineffective. The basis of the information is still unsuccessful, but how it is disseminated may not be the case and more research and improvement may be needed. In addition, contact must be permitted to fail (be absent as expected) without any negative effects for the approaching automobile. In order to allow this to happen, the vehicle needs to understand when to anticipate a connection. In order to achieve so, the vehicle network has to know that it is on the digital map to understand that it is entering the signal junction and that it has to provide a real-time signal update for the junction so that it can stop the vehicle if this knowledge cannot be accessed for some purpose whatsoever. This positions a high degree of reliance on the quality of the wireless mapping and on optimization efficiency (TS-Catapult, 2017).

2.4.6.2.2 PRIORITY CONTROLLED JUNCTIONS

Priority-controlled junctions are another big problem for which it is challenging to provide a general approach beyond that of continuing with caution. Moving towards

wirelessly controlled junctions, probably signaling junctions, will help to overcome the technological problem, but could be impractical in practice. Communication devices can be used to support wired autonomous vehicles. Instead than depending exclusively on the suite of sensors within the car, they could connect to the mast-mounted cameras around the intersection to get a much clearer view of the traffic coming from various directions (TS-Catapult, 2017).

Smart junction is actually in its simple definition; These are the junctions where the times that will be given to each direction of the junction change dynamically after the vehicle densities in all directions are determined by using vehicle counting cameras or vehicle counting sensors at the signaled intersections. In other words, they are the systems where the “green light times” of the traffic lights are determined automatically according to the vehicle volumes. In normal signalized junctions, vehicle counts are made manually for any hour of the day and the most appropriate green times are determined and loaded on the junctions controller. Since these times are fixed, the times do not change in changes in vehicle density. In smart junctions applications, time varies according to the intensity and waiting times at the intersection are minimized. Minimizing the waiting times of the vehicles at the crossroads not only saves time, but also reduces environmental damage by reducing fuel and emissions.



Figure 2.13 Example of Smart Junction in İstanbul

Source: (Asya, 2019)

Smart junction, min five years, is actively used in more than 50 cities in Turkey. The smart junctions, not only time optimization, but also intensity and vehicle counting,

monitoring and management of the entire junction from the central system, remote detection of malfunctions and taking precautions can be done. In Turkey, average waiting times reduced by 30% because of smart junction (junction structure and can vary from 3% to 50% according to the capabilities shown).

The equipment to be used for each intersection in smart junction applications are as follows (Asya, 2019):

- “Vehicle Counting Camera” (Smart Camera) up to the number of directions
- Smart Junction Management Module
- Intersection Monitoring Camera
- Smart Junction Controller
- Smart Intersection Center Software
- Camera Poles, Cables, Router etc. Connection equipments

Things to do to turn a signalized junction into a Smart junction are as follows

(Asya, 2019):

- If there is no fiber line to transfer the information at the intersection to the center, 4G data line should be taken for each intersection.
- At least 8 m for each direction. Height of the camera pole should be erected, 220 V energy cable should be drawn to each camera pole to provide energy to the cameras.
- CAT6 Ethernet cable should be drawn to each camera pole for data transfer.
- After the infrastructure and cabling works are completed, vehicle counting cameras, intersection monitoring camera and smart intersection management module should be installed.
- Commissioning should be completed with calibration and final checks.

2.5 DEVELOPMENT OF AN AUDIT FORM FOR ASSESSMENT OF NEEDS

For Turkish roads there is the need to develop road design and strategy. Therefore, an audit form should be prepared to include adaptation aspects. This audit form will speed up the adaptation period in road construction and repair. It will also make it easier to follow the same standards, requirements and operations. The forms which are produced in developed countries have been created according to the actions planned for future. A country such as Turkey which is at the beginning of the journey for the CAV, a set of criteria should be developed. To date, there are no published records of such an audit form created for Turkey. However, the criteria and evaluations examined have been applied as an adaptation of the values of the countries that have made pilot roads. Audit forms created in other countries are based on approximate values, although they are still not a precise criterion. The studies have been created mainly for physical and digital infrastructure. Digital infrastructure is categorized and evaluated according against similar countries with similarities in its advances in technology. As physical infrastructure, they have included criteria such as road surface, bridges, parking areas etc. In the audit form to be made, the necessary members for highway should be examined.

2.6 DEVELOPMENT OF A RESEARCH METHODOLOGY

Following conduct of work in Turkey to date and work in developed countries, the research method can be examined in three categories (Kumar, 2011);

2.6.1 APPLICATIONS METHOD

Application research method is examined in two categories. These are pure research and applied research. Required definitions for these issues are given below.

2.6.1.1 PURE RESEARCH

Pure research includes the creation and testing of ideas and concepts that are theoretically challenging to the researcher, but might or not have realistic relevance at

present or in the future. Therefore, such study also requires the testing of hypothesis that include very complex and technical principles.

2.6.1.2 APPLIED RESEARCH

Applied research is a form of study design that aims to solve a particular problem or to offer novel approaches to problems concerning people, communities or populations. It is often referred to as a scientific method of investigation or contract study because it requires the realistic application of scientific principles to daily problems (FormPlus, 2020).

2.6.2 OBJECTIVES METHOD

Objective research method is examined in four categories. These are descriptive, correlational, exploratory and explanatory research. Required definitions for these issues are given below.

2.6.2.1 DESCRIPTIVE RESEARCH

Descriptive study is a method of study that explains the population, circumstance or phenomena being studied. This reflects on how, when, where, and where to answer questions if there is a research question, rather than why (FormPlus, 2020).

2.6.2.2 CORRELATIONAL RESEARCH

Correlational study is a type of analysis approach that requires the measurement of two factors in order to create a statistically related relationship between them. The objective of correlational analysis is to classify factors that have some type of relationship to the degree that a difference in one creates a difference in another (FormPlus, 2020).

2.6.2.3 EXPLORATORY RESEARCH

Exploratory study is a method to explore a issue that has not been explored or extensively investigated in the past. The exploratory study is typically done in order to

achieve a deeper view of the current problem, but generally does not lead to a definitive outcome (FormPlus, 2020).

2.6.2.4 EXPLANATORY RESEARCH

Explanatory study is performed on a issue that has not been thoroughly studied before, demands for objectives, creates organizational concepts and produces an effectively-researched model. It is basically a form of research design that focuses on understanding the study aspects (Yousaf, 2017).

2.6.3 ENQUIRY MODES

Enquiry mode is examined in two categories. These are qualitative method and quantitative method. Required definitions for these issues are given below.

2.6.3.1 QUANTITATIVE

Quantitative analysis is more often than not correlated with hard evidence. Analysis is used to measure – that is, to attach numerical assignments to the results – the problem being studied such that the evidence can be converted into statistics. Knowing the concise statistics as outlined in this course would be important when performing quantitative analysis. Quantitative methodology is not related to mathematics. In fact, there are several different forms of quantitative analysis than most people expect. Mathematics and statistics are basically the method by which quantitative analysis finds. Opinions, perceptions and behaviours, while of a complicated nature, may be quantitatively measured in order to realize outcomes.

2.6.3.2 QUALITATIVE

Qualitative research is most commonly done to achieve a better understanding of the principles of the subject. Qualitative research relies on perceptions and motives. Qualitative research is used to provide perspective into the problem described in the research or paper. These may also help to establish theories or concepts at the beginning of quantitative method. In this case, it is done in order to help focus the

research itself. Qualitative analysis can help unravel patterns in culture, ideology or belief. It is a much more analytical study objective which therefore does not include concrete statistics such as statistical information. Alternatively, the aim is to get to the heart of the philosophy. It is the method of research most often used in the review of literature. It may be appropriate to read about the author and to be well informed in all his writing, or to participate in detailed research on a particular literary period. It may also be used for historical analysis, social and cultural analyses and personality study.



Figure 2.14 Types of Research

Source: (Kumar, 2011)

Data collection could be an organized method for collecting and analyzing specific data to provide alternatives to important queries and to evaluate results. It focuses on checking out all the material on a specific topic. Data is collected in order to be more subject to hypotheses that seek to specify developments.

Hypothesis eliminates assumptions while creating a proposal on the basis of the rationale. There are a variety of outcomes for data collectors that the information is collected. However, the key purpose of data collection is to place a scientist in an extremely good position to make predictions about future opportunities and trends.

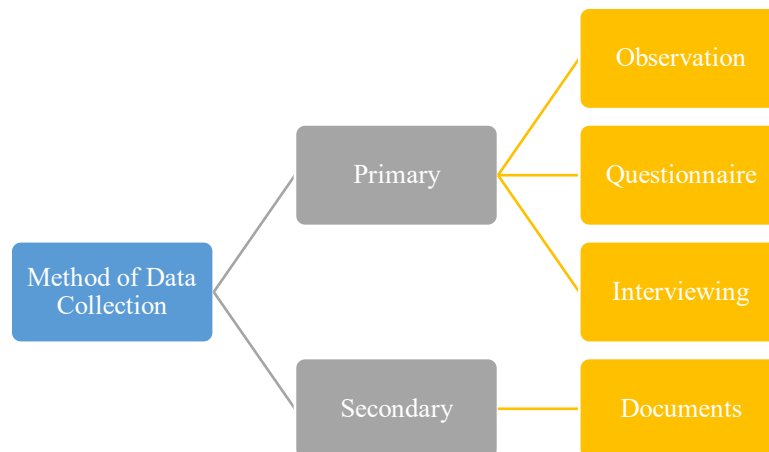


Figure 2.15 Method of Data Collection

Source: (Kumar, 2011)

Data collection method divides by primary data collection and secondary data collection. Primary data collection is that gathering of information collected at the supply. This method of collection the initial information collected by a scientist for a selected analysis purpose. Secondary data collection method is opposite hand of primary method. Because who is using those data, that is not the original or first user. The secondary method is collecting exist data like printed books, journals or online portals. (Formplus, 2020)

2.7 SUMMARY

The adoption of CAV based road specification and conditions shows significant variations from country to country. This is a result of different traffic regulations and sign information applied for each. Recognising these differences, but also the need for a common standard for CAV, the requirements will be different to some extent. By ensuring that the developed countries application of road audit application in Turkey, there will be a common ground to accelerate development of CAV based requirements for Turkish Road system in this juncture.

Thus, the audit form is prepared to identify key features to be applied. This will clearly demonstrate deficiencies and competencies which will be easily seen. The application

of this audit form will enable analysis of the road network and identify a road path for necessary action for Turkish Roads.

As a conclusion, Turkish road design needs to focus on digital infrastructure and more charging point. A design project should be carried out since the charging times of the existing cars cannot be reached for a long and sufficient distance. Even currently situation there is not enough parking spaces in case of Turkey's population that need to be developed on the future scenarios. An important issue to consider for the new design strategy is the charging stations that must be placed in the parking spaces and service areas. These charging stations will be shorten the waiting times and ease transportation. With GIS program, which is planned to be developed and implemented in Turkey, road conditions will be examined under control. With this system, the accuracy rate of maintenance and controls of road construction increases; emergency corrections can be made in the event of an error.

The operations in the ITS-Strategy Report, prepared by the Ministry of Turkish Transportation, Maritime and Communication, application part should be complete as soon as possible time and need to analyze other requirements. As a result of comparisons with other countries on the condition that Turkey is still lacking in some of that observed with the other criteria. Although there are some strong applications in Turkey but also there is deficiencies for adaptation as Network System, Geographic Information System (GIS), and Service Station etc.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

The need to develop a methodology is paramount for a structured study to be conducted. This chapter sets out the approach adopted through establishment of methods available for this study, selection of proposed method and justification, collection of data and geography, required data and reliability, and adopted method for analysis.

3.2 INTRODUCTION TO ANALYSIS

The existing highways should be designed for new cars according to those developing technology. The adoption of EVs and CAVs will require special planning and preparation to supply that the infrastructure is able to adapt to the changes that it will bring. Charging, road markings, speed cameras, automated diversion signals and parking are just a few of the aspects of physical and digital infrastructure that will need to be analysed in order to prepare highways for the future of transportation networks.

The Netherlands, UK, Finland and many other countries have created some pilot areas and road requirements have begun to be measured for in these areas. In this chapter shown how compatible is the Anatolian Highway in Turkey that these vehicles are examined. The aim of this research is the future vehicles of roads in relation to current situation in Turkey and the preparation stage work, and the need to determine what is the situation as infrastructure, design etc. The determined criteria have been prepared by influencing the projects that have been made. The analysis have been done with those criteria for each 10 km section of the highway (See below Figure 3.1).

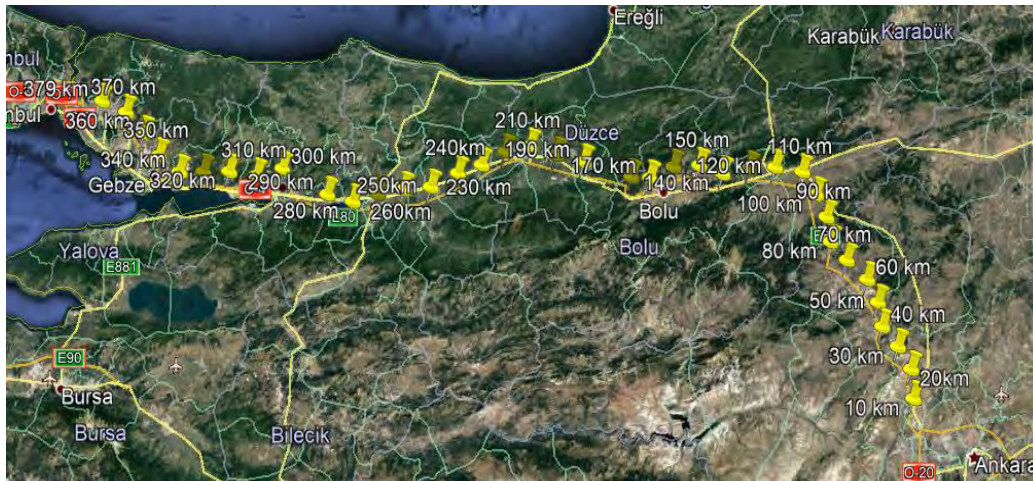


Figure 3.1 Analyzed Anatolian Highway

Source: Google Earth

3.3 AVAILABLE METHODS FOR STUDYING AND SELECTION OF PROPOSED METHOD

As a result of the examination of the research methods (See Chapter 2.6), the methods of the analysis to be performed were determined and the reasons were explained. The types of methods that can be applied are shown and explained in Figure 2.14.

From the Application category, this study is applied research. The questions about work will help determine the impact of future vehicles on roads and and how people will face problems about new vehicles, road condition, urgent situations etc. And it focused on the solution of these problems.

From the Objective category, this is exploratory research for the study. The reason for this is that this research method is suitable for discovering the relationships between the benchmarks and criteria. Exploratory research with a previously researched by adapting said Turkey is targeted to reach new data. A study realized in Turkey and this road is not yet available.

From the Mode of Enquiry category, the quantitative method for this study was applied to evaluate the criteria of the analyzes. At the same time, there is a need for a qualitative

method to collect the data on the map, to evaluate the analyzes statistically and to produce the results that will be prepared for the future.

3.4 COLLECTION OF DATA AND GEOGRAPHIC RESEARCH

In this section, data collection methods, how to analyze, how to reach secure data collection and geographic research of the region to be analyzed are mentioned.

3.4.1 COLLECTION OF DATA

The data used were examined geographically according to the distances determined on Google Map and Google Earth. In addition, some data related to infrastructure are based on projects carried out from GDH. Data such as traffic and transportation information, traffic volume maps, traffic signs standards and modern junction standards obtained from GDH, which have been examined and analyzed for this route. Traffic count systems are divided into two main groups as On-Road Systems and Roadside Systems. On-road systems such as magnetic loop systems, piezoelectric sensor systems are used for GDH. The most commonly used roadside system is video or sife-firing radar methods for classified volumetric counts. For intersection counts, which are made especially in order to determine the classied turning counts. In recent years, advances in traffic management applications within the scope of Intelligent Transportation Systems have led to the development of roadside counting systems using technologies such as video visual systems, passive and active infrared, ultrasonic, radar, laser, and microwave which can also be used for intersections. By using these systems, the communication network of the CAV and the infrastructure can be established. These systems, communicating with CAV, will enable safer, quicker route choices to be established.

The criteria to be examined during data collection are listed below;

- Traffic Management Measures;
- Road Design, Marking and Traffic Signs;

- Safe Harbor Area;
- Digital Communication and Service Station/ Rest Area;
- Road Surface;
- Crossing and Junction.

The six criteria determined should be examined in detail in the specified mapping programs. Data collection and evaluation took place within the scope of the information in the literature review. With the information obtained, these criteria has compared according to the requirements and regulations generally prepared. Since there are no regulations or rules for new cars and highways in the world, evaluations such as " good / moderate / poor or exist- N/A" have been applied. The countries involved at the highest level in this application should be made according to comparative, lacking qualifications and should be evaluated for Turkey. The determined criteria constitute the foundation of this adaptation process. Apart from this, it can be further developed. However, there is no defined basic structure for Turkey prior to this work.

3.4.2 GEOGRAPHIC RESEARCH

Turkey is at a geographical juncture of between Europe, Asia and the African continent, creating inter-continental links. Today, projects aiming at linking countries / regions with rich resources, where significant financial, commodity and information flows are concentrated, to production locations and market regions are gaining importance. Thus, it is aimed to facilitate transportation on highways and increase economic relations, trade and tourism by developing transportation connections.

In this context, Turkey is involved in many international projects and organizations aimed at providing regional and interregional road connections. International road transport and international projects in Turkey are listed below :

- International E - Roads Network
- ESCAP (United Nations/Economic and Social Commission for Asia and the Pacific)
- EATL (Euro-Asian Transport Linkages)
- TEM (Trans European North-South Motorway)
- TRACECA (Transport Corridor for Europe, Caucasus and Asia)
- BSE (Black Sea Economic Cooperation)
- ECO (Economic Cooperation Organization)
- TEN-T (Trans-European Core Road Network)



Figure 3.2 International Roads in Turkey

Source: (MTI, 2019)

Figure 3.2 above introduces Turkey's international connectivity. The routes of all the mentioned international projects include the Anatolian highway (Figure 3.2).

Therefore, working in this area will increase the quality of road condition standards. The highways network system of our country constitutes a requirement for its own national development, as well as for ensuring integrity and overall improvement in the region. The population is approximately 83 million and the total surface area is 783.562 km². Traffic flow is on the right (Wikipedia, Turkey, 2020).

The overall length of the highway under the management of the General Directorate of Highways is 67,119 km. It consists of three types of lane (KGM, 2019):

- State Highway
- Provincial Road
- Motorway

The below Table 3.1 introduces the road network in Turkey by surface types. This table, which was shared by GDH in 2018, has measurements on the basis of road surfaces and road categories in Turkey.

Table 3.1 Types of Surface in Turkish Road

ROAD NETWORK ACCORDING TO SURFACE TYPES (KM) / 01.01.2018							
	Asphaltic Concrete	Surface Treatment	Stone Block	Stabilized	Earth	Primitive	Total
Motorways	2 157	-	-	-	-	-	2 157
State Highways	16 991	13 691	66	36	-	282	31 066
Provincial Roads	3 802	26 492	248	632	520	2 202	33 896
Total	22 950	40 183	314	668	520	2 484	67 119

Source: (MTI, 2020)

Highway 4 (O-4), which are the largest cities in Turkey's capital city Ankara and İstanbul; is the most important highway linking the name. This highway is two-way and has six lanes, each way has three lanes (KGM, 2019). Total length is 379 km.

The below figure, Figure 3.3 shown the destination of the O-4 Highway (Anatolian Highway) between Ankara and İstanbul.

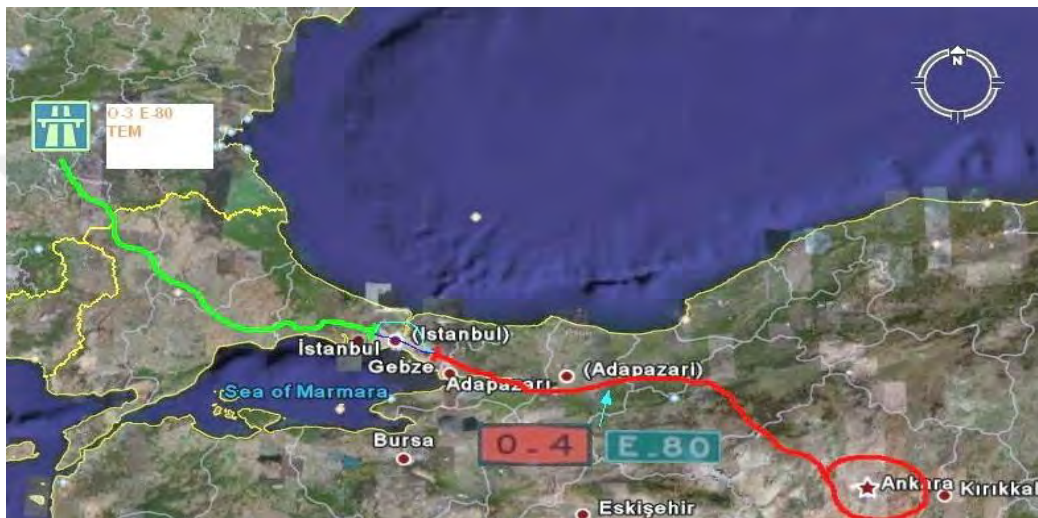


Figure 3.3 Anatolian Highway

Source: (KMO, 2019)

This highway designated Anatolian Motorway (Turkish: Anadolu Otoyolu) and shortened as O-4, is a road motorway leading the northwest of Marmara to the Central Anatolia Region of Turkey. The O-4 is a major highway in Turkey, since it connecting East İstanbul and the highly densely populated North East Sea coast of Marmara with the capital of the country, Ankara. O-4 is also part of the Regional E-road network E80 and E89, as well as the Asian Highway Network AH-1. The O-4 is Turkey's longest constructed motorway measuring 379 km (235 mi), just 14 km (8.7 mi) longer than the O-52. The partly extended O-5 is expected to reach the capacity of the O-4 when completed in 2019, with a cumulative capacity of 407 km (253 mi). Building work of the O-4 began in 1984 and was completed in 1992, with the exception of a small distance in the mountains west of Bolu. This hole was linked to the entrance of the

Mount Bolu Tunnel in 2006 (Wikipedia, 2020). Travel on this road passing through İzmit, Adapazarı, Düzce and Bolu is subject to a fee.

The following diagram introduces the major junctions and intersecting state roads on the Anatolian Highway.

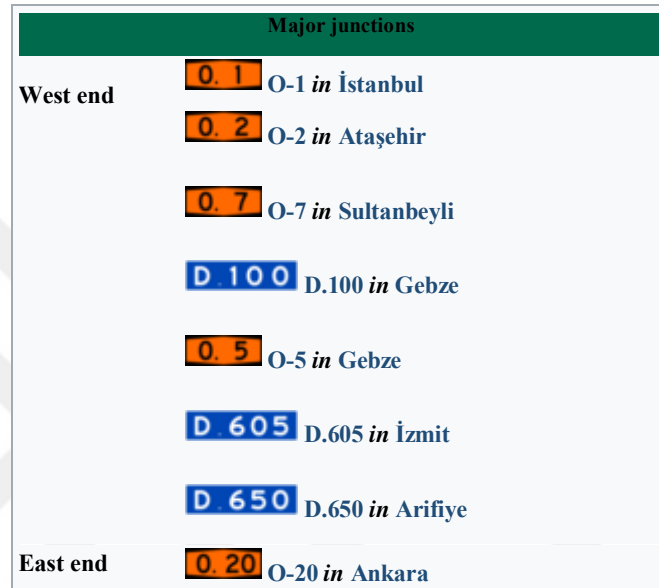


Figure 3.4 Major Junctions

Source: (Wikipedia, 2020)

3.5 REQUIRED DATA FOR ANALYSIS AND IMPORTANCE

In the analysis, which is shown in Table 3.2 (see below), what is needed for the new vehicles and the levels of these requirements are specified. The work to be done has been examined and evaluated based on these requirements. Those values will make reliable data analysis with the evaluation to be made in this study. Because the constructing of roads for EVs and CAVs includes these procedures. Since a specific regulation is not available, it will help to reach reliable result according to these criteria. This table was obtained by analyzing and adapting the criteria from Catapult-Transportation System.

Table 3.2 Required Data for Analysis

<p>Traffic Management Measures</p> <ul style="list-style-type: none"> ➤ Readability of markings, barriers, cones and general traffic control measures; existing digital infrastructures. ➤ Detailed information provide on road layout and expected vehicle behavior for traffic management measures (e.g. stop at traffic signal, merge in turn, use contra-flow lane etc.). ➤ Real-time updates to detail when traffic management measures are beginning and ending.
<p>Road Design, Marking and Traffic Signs</p> <ul style="list-style-type: none"> ➤ New roads and major junctions could be connected to electricity and fiber-optic/copper where practicable. ➤ Compliance of edge of road lanes and barriers to traffic management. ➤ Readability marking and traffic signs.
<p>Safe Harbor Area</p> <ul style="list-style-type: none"> ➤ Situations of these areas on the highway (Emergency Area or Shoulder). ➤ Well controlled in order to discourage their abuse.
<p>Digital Communication and Service Station/ Rest Area</p> <ul style="list-style-type: none"> ➤ Digital infrastructure include: sourcing, processing, quality control and information transmission, exist network, camera etc. ➤ Number of available charge station. ➤ The use of service stations as safe harbor zones for CAVs, and the necessary adaptations to achieve this and rest area.
<p>Road Surface;</p> <ul style="list-style-type: none"> ➤ Smooth surface prefer for determine to marking or edge of the road etc. (Currently)
<p>Crossing and Junction;</p> <ul style="list-style-type: none"> ➤ Smart Management System; signalized crossing and junction.

The following table introduces SWOT Analysis for Intelligent Transport System.

Table 3.3 SWOT Analysis in Turkey

STRENGTHS	WEAKNESSES	OPPORTUNITIES	THREATS
✓ An easy to adopt new technologies population structure	- Among the institutions and infrastructures that implement ITS lack of integration	➤ As a result of MTMC's partnership with ERTICO, opportunity to share knowledge and experience	* The high costs of ITS applications
✓ Concerned institution to implement ITS to be willing	- A common terminology on ITS and no standards	➤ Rapidly constructed double highway, viaduct, tunnel and bridges causing need for ITS	* External dependence on ITS technologies
✓ The existence of entrepreneurial capacity in ITS	- Institutional and individual awareness of ITS inadequate	- Continuous increase in urbanization and young population increasing demand for transportation	* Actively to international ITS platforms inability to participate
✓ The automotive industry is an important base in Turkey being	- Specialized in ITS implementing institutions lack of staff	➤ Increased mobility in business life	* Globalization and increasing international competition
✓ Widespread and modern communication infrastructure	- Lack of legislation on ITS	➤ Awareness of energy efficiency and environmental protection increasing tendency	
✓ Speed towards becoming Turkey's information society	- Lack of a national ITS union to gather ITS stakeholders under one roof	- Turkey is not yet advanced applications in ITS - Geographic proximity, neighborhood	
✓ Investments in the IT (Information Technology) sector	- Studies and incentives related to ITS not enough		
	- ITS related medium and long term planning the lack		
	- Among university-industry-institutions and organizations		
	- ITS in terms of software and hardware inadequate domestic production		

Source: (AUS, 2014)

The research methods developed are arranged according to Table 3.3. Strong and weak features can be seen easily for the research. With the SWOT Analysis, the results that can be obtained from the analysis of this research will be able to make necessary comparisons and assist in concentrating on the requirement.

3.6 SUMMARY

The route chosen in this analysis is that it connects the two cities where the traffic volume is high. At the same time, as mentioned in geographical research, Anadolu Highway is on the international road route. This is an important role in the selection of this road route. The aim of the research is to determine the requirements on this route urgently and to speed up the adaptation process.

The Anatolian Highway selected for this study is in the "toll-road" category. The first section from Sakarya to Istanbul and fourth section from Ankara to Düzce are the responsible of GHD for this corridor.

With the audit form planned to be made, the controls and results of the analysis will be more accurate. With this form, which should be made according to the categories applied on pilot counties, it is planned to help the highway regulations that need to be updated.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 INTRODUCTION

In this section, answers to the questions mentioned in the introduction are sought. The existing infrastructures are show proficiency on the state in Turkey for EVs and CAVs. The result is achieved by using data collection and criterion evaluation methods. The step-by-step examination of the set six criteria will reveal the level of compatibility of the essential elements required for road and traffic.

4.2 DATA COLLECTED AND RELIABILITY

Table 4.1 Information of Categorized System















Traffic Management Measures	Road Design, Marking and Traffic Signs	Safe Harbor Area	Digital Communication and Service Station/ Rest Area	Road Surface	Crossing and Junction
GOOD	GOOD	EXIST If exist= type	EXIST If exist= type	GOOD	EXIST If exist= type
MODERATE	MODERATE	N/A	N/A	MODERATE	N/A
POOR	POOR			POOR	

The Table 4.3 below is examined on the Anatolian Highway according to the determined criteria. These criteria are filled in good, moderate, poor; and exist - or which type, if available (Table 4.1). The audit form created was examined according to the requirements in Table 3.2. It is evaluated according to the condition of the six aspects determined on Anatolian Highway.

Table 4.2 includes sample figures that were examined and categorized for the Audit form. This examination was analyzed for each 10 km section of the highway in

Ankara- İstanbul and İstanbul- Ankara in two directions. A total of 758 km (departure and return) has been studied by examining online map. The data shown were determined by one-to-one measurements and evaluated under the leadership of other studies. Some sample fields related to this road are shown in Chapter 4.5.





Table 4.2 Categorized System









Crossing and Junction	EXIST If exist= Type 		NA 
Road Surface	GOOD 	MODERATE 	POOR 
Digital Communication and Service Station/ Rest Area	EXIST If exist= Type 		NA 
Safe Harbor Area	EXIST If exist= Type 		NA
Road Design, Marking and Traffic Signs	GOOD 	MODERATE 	POOR 
Traffic Management Measures	GOOD 	MODERATE 	POOR 

4.3 DATA ANALYSIS

The analysis was made by following the O-4 highway line on the map. Here it was examined according to the evaluation method in Table 4.1. It is aimed to make a more detailed observation and evaluation by separating the six pre-determined criteria.










Table 4.3 Audit Form

km	Traffic Management Measures	Road Design	Marking	Traffic Sign	Safe Harbor Area	Digital Communication	Service Station	Rest Area	Road Surface	Crossing	Junction	Location
0*10	Moderate	Moderate	Good	Good	Shoulder	Camera	N/A	N/A	Moderate	N/A		Yenimahalle/ ANKARA
10*20	Moderate	Moderate	Moderate	Good	Shoulder	Camera	N/A	N/A	Moderate	N/A		Susuz/ ANKARA
20*30	Moderate	Moderate	Moderate	Good	Shoulder	Camera	N/A	N/A	Moderate	N/A		Kahramankazan/ANKARA
30*40	Moderate	Moderate	Moderate	Good	Shoulder	N/A	N/A	Exist	Moderate	N/A		Kazan/ ANKARA
40*50	Moderate	Moderate	Good	Good	Shoulder	N/A	N/A	N/A	Moderate	N/A		Kızılcahamam/ANKARA
50*60	Moderate	Moderate	Good	Good	Shoulder	N/A	N/A	N/A	Moderate	N/A		Kızılcahamam/ANKARA
60*70	Moderate	Moderate	Good	Good	Shoulder	N/A	N/A	Exist	Moderate	N/A		Çamlidere/ ANKARA
70*80	Moderate	Moderate	Good	Good	Shoulder	N/A	N/A	N/A	Moderate	N/A		Çamlidere/ ANKARA
80*90	Moderate	Moderate	Good	Good	Shoulder	N/A	N/A	N/A	Moderate	N/A		Çamlidere/ ANKARA
90*100	Moderate	Moderate	Good	Good	Shoulder	N/A	N/A	N/A	Moderate	N/A		Çamlidere/ ANKARA

100*110	Moderate	Moderate	Good	Good	Shoulder	N/A	N/A	N/A	Moderate	N/A		Gerede/ BOLU
110*120	Moderate	Moderate	Good	Good	Shoulder	N/A	N/A	Exist	Moderate	N/A		Gerede/ BOLU
120*130	Moderate	Moderate	Moderate	Good	Shoulder	N/A	N/A	Exist	Moderate	N/A		Yeniçağa/ BOLU
130*140	Moderate	Moderate	Moderate	Good	Shoulder	N/A	N/A	Exist	Moderate	N/A		Yeniçağa/ BOLU
140*150	Moderate	Moderate	Moderate	Good	Shoulder	N/A	N/A	N/A	Moderate	N/A		Yeniçayduzt/BOLU
150*160	Moderate	Moderate	Moderate	Good	Shoulder	N/A	N/A	Exist	Moderate	N/A		Musluklar/ BOLU
160*170	Moderate	Moderate	Good	Good	Shoulder	N/A	N/A	Exist	Good	N/A		Ağaçcılar / BOLU
170*180	Moderate	Moderate	Good	Good	Shoulder	N/A	N/A	Exist	Moderate	N/A		Yumrukaya/BOLU
180*190	Moderate	Moderate	Good	Good	Shoulder	Camera	Charging	Exist	Good	N/A		Kaynaşlı/ DÜZCE
180*190	Moderate	Moderate	Moderate	Good	Shoulder	Camera	N/A	N/A	Poor	N/A		Bolu Mountain Tunnel
190*200	Moderate	Moderate	Good	Good	Shoulder	Camera	N/A	Exist	Good	N/A		Doğanlı/ DÜZCE
200*210	Moderate	Moderate	Moderate	Good	Shoulder	N/A	N/A	N/A	Moderate	N/A		Yenitaşköprü/DÜZCE
210*220	Moderate	Moderate	Moderate	Good	Shoulder	N/A	N/A	N/A	Moderate	N/A		Zekeriya köy/ DÜZCE
220*230	Moderate	Moderate	Moderate	Good	Shoulder	N/A	N/A	Exist	Moderate	N/A		Gümüşova/ DÜZCE
230*240	Moderate	Moderate	Moderate	Good	Shoulder	Camera	N/A	N/A	Moderate	N/A		Necatipaşa/SAKARYA
240*250	Moderate	Moderate	Good	Good	Shoulder	N/A	N/A	Exist	Moderate	N/A		Hendek/ SAKARYA

250*260	Moderate	Moderate	Good	Good	Shoulder	N/A	N/A	N/A	Moderate	N/A		Akyazı/ SAKARYA
260*270	Moderate	Moderate	Good	Good	Shoulder	N/A	Charging	N/A	Moderate	N/A		Arifiye/ SAKARYA
270*280	Moderate	Moderate	Good	Good	Shoulder	N/A	N/A	Exist	Moderate	N/A		Sapanca/ SAKARYA
280*290	Moderate	Moderate	Good	Good	Shoulder	N/A	Charging	Exist	Moderate	N/A		Kazakburun/ KOCAELİ
290*300	Moderate	Moderate	Moderate	Good	Shoulder	N/A	Charging	Exist	Moderate	N/A		İzmit/ KOCAELİ
290*300	Moderate	Moderate	Moderate	Good	Shoulder	Camera	N/A	N/A	Moderate	N/A		Gültepe Tunnel KOCAELİ
290*300	Moderate	Moderate	Moderate	Good	Shoulder	Camera	N/A	N/A	Moderate	N/A		Korutepe Tunnel / KOCAELİ
300*310	Moderate	Moderate	Moderate	Good	SOS Area	Camera	N/A	N/A	Moderate	N/A		Derince/ KOCAELİ
310*320	Moderate	Moderate	Moderate	Good	SOS Area	N/A	N/A	N/A	Moderate	N/A		Körfez/ KOCAELİ
310*320	Moderate	Moderate	Moderate	Good	Shoulder	Camera	N/A	N/A	Moderate	N/A		Hereke Tunnel/ KOCAELİ
320*330	Moderate	Moderate	Moderate	Good	SOS Area	Camera	N/A	N/A	Moderate	N/A		Kışladüzü/ KOCAELİ
330*340	Moderate	Moderate	Good	Good	SOS Area	Camera	N/A	N/A	Moderate	N/A		Dilovası/ KOCAELİ
330*340	Moderate	Moderate	Good	Good	Shoulder	Camera	N/A	N/A	Moderate	N/A		Dilderesi Tunnel/ KOCAELİ
340*350	Moderate	Moderate	Good	Good	Shoulder	Camera	Charging	N/A	Moderate	N/A		Gebze/ KOCAELİ
350*360	Moderate	Moderate	Moderate	Good	Shoulder	Camera	N/A	N/A	Moderate	N/A		Tuzla/ İSTANBUL
360*370	Moderate	Moderate	Moderate	Good	Shoulder	Camera	Charging	N/A	Poor	Overpass		Sultanbeyli/ İSTANBUL

370*379	Moderate	Moderate	Moderate	Good	Shoulder	Camera	Charging	N/A	Poor	Overpass		Ataşehir/ İSTANBUL
0*10	Moderate	Moderate	Moderate	Good	Shoulder	Camera	Charging	N/A	Poor	Overpass		Ataşehir/ İSTANBUL
10*20	Moderate	Moderate	Moderate	Good	Shoulder	Camera	Charging	Exist	Poor	Overpass		Sultanbeyli/ İSTANBUL
20*30	Moderate	Moderate	Moderate	Good	Shoulder	Camera	N/A	N/A	Moderate	N/A		Tuzla/ İSTANBUL
30*40	Moderate	Moderate	Moderate	Good	Shoulder	Camera	Charging	N/A	Poor	N/A		Gebze/ KOCAELİ
40*50	Moderate	Moderate	Moderate	Good	Shoulder	Camera	N/A	N/A	Moderate	N/A		Dilderesi Tunnel/ KOCAELİ
50*60	Moderate	Moderate	Moderate	Good	SOS Area	Camera	N/A	N/A	Moderate	N/A		Dilovası/ KOCAELİ
60*70	Moderate	Moderate	Moderate	Good	SOS Area	Camera	N/A	N/A	Moderate	N/A		Kışladüzü/ KOCAELİ
70*80	Moderate	Moderate	Moderate	Good	Shoulder	Camera	N/A	N/A	Moderate	N/A		Hereke Tunnel/ KOCAELİ
80*90	Moderate	Moderate	Moderate	Good	SOS Area	N/A	N/A	N/A	Moderate	N/A		Körfez/ KOCAELİ
90*100	Moderate	Moderate	Moderate	Good	SOS Area	Camera	N/A	Exist	Moderate	N/A		Derince/ KOCAELİ
100*110	Moderate	Moderate	Moderate	Good	Shoulder	Camera	N/A	N/A	Moderate	N/A		Korutepe Tunnel / KOCAELİ
110*120	Moderate	Moderate	Moderate	Good	Shoulder	Camera	N/A	N/A	Moderate	N/A		Gültepe Tunnel / KOCAELİ
120*130	Moderate	Moderate	Moderate	Good	Shoulder	N/A	Charging	N/A	Moderate	N/A		İzmit/ KOCAELİ
130*140	Moderate	Moderate	Moderate	Good	Shoulder	N/A	Charging	N/A	Poor	N/A		Kazakburun/ KOCAELİ
140*150	Moderate	Moderate	Moderate	Good	Shoulder	N/A	N/A	Exist	Poor	N/A		Sapanca/ SAKARYA

150*160	Moderate	Moderate	Moderate	Good	Shoulder	N/A	Charging	N/A	Poor	N/A		Arifiye/ SAKARYA
160*170	Moderate	Moderate	Moderate	Good	Shoulder	N/A	N/A	N/A	Moderate	N/A		Akyazı/ SAKARYA
170*180	Moderate	Moderate	Moderate	Good	Shoulder	N/A	N/A	N/A	Moderate	N/A		Hendek/ SAKARYA
180*190	Moderate	Moderate	Moderate	Good	Shoulder	N/A	N/A	N/A	Moderate	N/A		Necatipaşa/ SAKARYA
180*190	Moderate	Moderate	Moderate	Good	Shoulder	N/A	N/A	N/A	Moderate	N/A		Gümüşova/ DÜZCE
190*200	Moderate	Moderate	Moderate	Good	Shoulder	N/A	N/A	N/A	Moderate	N/A		Zekeriya köy/ DÜZCE
200*210	Moderate	Moderate	Moderate	Good	Shoulder	N/A	N/A	N/A	Moderate	N/A		Yeni taşköprü/ DÜZCE
210*220	Moderate	Moderate	Good	Good	Shoulder	Camera	N/A	Exist	Good	N/A		Doğanlı/ DÜZCE
220*230	Moderate	Moderate	Moderate	Good	Shoulder	Camera	N/A	N/A	Moderate	N/A		Bolu Mountain Tunnel
230*240	Moderate	Moderate	Good	Good	Shoulder	Camera	Charging	Exist	Good	N/A		Kaynaşlı/ DÜZCE
240*250	Moderate	Moderate	Moderate	Good	Shoulder	N/A	N/A	Exist	Moderate	N/A		Yumrukaya/ BOLU
250*260	Moderate	Moderate	Good	Good	Shoulder	N/A	N/A	Exist	Good	N/A		Ağaçcılar / BOLU
260*270	Moderate	Moderate	Moderate	Good	Shoulder	N/A	N/A	Exist	Moderate	N/A		Musluklar/ BOLU
270*280	Moderate	Moderate	Moderate	Good	Shoulder	N/A	N/A	N/A	Moderate	N/A		Yeniçaydurt/ BOLU
280*290	Moderate	Moderate	Moderate	Good	Shoulder	N/A	N/A	Exist	Moderate	N/A		Yeniçağa/ BOLU
290*300	Moderate	Moderate	Moderate	Good	Shoulder	N/A	N/A	Exist	Moderate	N/A		Yeniçağa/ BOLU

290*300	Moderate	Moderate	Moderate	Good	Shoulder	N/A	N/A	Exist	Moderate	N/A	✘	Gerede/ BOLU
290*300	Moderate	Moderate	Moderate	Good	Shoulder	N/A	N/A	Exist	Moderate	N/A		Gerede/ BOLU
300*310	Moderate	Moderate	Good	Good	Shoulder	N/A	N/A	N/A	Moderate	N/A	✘	Çamlidere/ ANKARA
310*320	Moderate	Moderate	Good	Good	Shoulder	N/A	N/A	N/A	Moderate	N/A		Çamlidere/ ANKARA
310*320	Moderate	Moderate	Good	Good	Shoulder	N/A	N/A	N/A	Moderate	N/A		Çamlidere/ ANKARA
320*330	Moderate	Moderate	Good	Good	Shoulder	N/A	N/A	Exist	Moderate	N/A	✔	Çamlidere/ ANKARA
330*340	Moderate	Moderate	Good	Good	Shoulder	N/A	N/A	N/A	Moderate	N/A		Kızılcahamam/ ANKARA
330*340	Moderate	Moderate	Good	Good	Shoulder	N/A	N/A	N/A	Moderate	N/A	✔	Kızılcahamam/ ANKARA
340*350	Moderate	Moderate	Moderate	Good	Shoulder	N/A	N/A	Exist	Moderate	N/A		Kazan/ ANKARA
350*360	Moderate	Moderate	Moderate	Good	Shoulder	Camera	N/A	N/A	Moderate	N/A	✔	Kahramankazan/ ANKARA
360*370	Moderate	Moderate	Moderate	Good	Shoulder	Camera	N/A	N/A	Moderate	N/A		Susuz/ ANKARA
370*379	Moderate	Moderate	Good	Good	Shoulder	Camera	N/A	N/A	Moderate	N/A	✘	Yenimahalle/ ANKARA

The analysis of the road data has been an extensive audit review of the corridor identified in Figure 3.1. Accordingly, the results are introduced below:

4.3.1 TRAFFIC MANAGEMENT MEASUREMENTS

Turkey is ready enough with management rules where the traffic flow in this region is understood the failure to create a problem. But technologically, this management

system needs to be changed and improved according to new vehicles. After the standards set for CAVs and EVs, various updates should be made in traffic regulations. The existing lighting system in the tunnels should be controlled to prevent danger of autonomous vehicles. Since there are no tunnels on the road types built in pilot countries, the requirements of autonomous vehicles cannot be determined. By constantly updating the network system, it will minimize such problems on roads and tunnels.

4.3.2 ROAD DESIGN, MARKING AND TRAFFIC SIGNS

The road design covers everything needed for traffic. Geometric design, traffic signs, barriers etc. The road design required for CAVs and EVs is not clear yet. This category can be changed according to future needs. Existing traffic signs on the road are clean and readable. The traffic sign meets the standards set by the pilot countries. Although these markers also varies between countries, it is adapted easily perceivable of autonomous vehicles in Turkey. Most marking renew is required. Some causes of abrasion on this road are due to traffic density, weather conditions etc. The selected road route acts as a bridge between the Central Anatolia Region and the Marmara Region. Climate conditions are a major factor in the deterioration of signs on the road surface. Another factor is the disappearance of these signs after the maintenance of the road surface. In Audit form, these regions are evaluated as "moderate".

4.3.3 SAFE HARBOR AREA

These areas, which are made in accordance with the road design, have dimensions that can be parked comfortably. Road surface and marking are not included in this analysis. One of the strategies that can be considered for the future should be the emergency aid stations (SOS- station) that should be located at the points to be determined. With Telecommunication systems, this need will be met and convenience will be provided for drivers and passengers for emergencies.

4.3.4 DIGITAL COMMUNICATION AND SERVICE STATION/ REST AREA

Infrastructure is a critical issue for connected autonomous vehicles. These cars need to interact with each other, infrastructure and others. Therefore, the network system must be well defined. According to the statistical result, there is a camera system in only 4.47% of the total road length. Existing cameras are available for security. Camera increase and camera function should be changed in this regard. Charging stations are very few on the route. It is available on about 1.84% of the total road length of charging stations. The rest areas on this road route provide sufficient opportunities for drivers and passengers. Rest areas are mostly in Type C category. Services such as parking area, fuel station, spare parts sales, rest, food and beverage sales are provided.

4.3.5 ROAD SURFACE

The category that is critically observed as the physical infrastructure on the Anatolian highway is the road surface. There are damages on this road surface that is considered to be "poor" around Sakarya and Istanbul. Similarly, these observations continue in the Bolu Tunnel. Although the lighting in the tunnel is sufficient for driving, there are difficulties in seeing the gaps on the road surface. These gaps in the driving of these connected autonomous vehicles will make it difficult to identify by the vehicle. These need to be managed and filled for all vehicles.

4.3.6 CROSSING AND JUNCTION

Traffic flow as management and design is moving towards junction points. It is necessary to work digitally for smart junction points. The lacks of the digital infrastructure are also observed in this category. Since the examined road route is highway, there is no need for pedestrian crossing here. The road generally passes through the city. The need for the rest areas on the Anatolian highway to serve both sides of the road route will be positive for the passengers and increase the preference

rate of this highway. The required efficiency should be achieved by adding pedestrian crossings to these areas in future strategy planning.

4.4 OUTCOME OF THE ANALYSIS AND RESULTS

This section includes the results obtained from the audit form. Analysis outcomes and necessary infrastructures are briefly explained. A summary for the six categories examined is available in Figure 4.1.



Figure 4.1 Outcome of Analysis

Table 4.1 shows the analysis of outcomes according to the specified criteria. Updating the regulations and identifying new strategic plan, although the lack of a critical benchmark for the biggest Turkey appears in the digital communication system. Therefore, these two criteria come first among the major works in which adaptation

should begin. In addition, it is clear that the physical infrastructure is good and some of the demolish regions need to repair. These processes will be easily achievable for Turkey. The criterion that requires maintenance is the road surface. The road surface, which has been worn for many reasons, poses a threat to current and future cars. With the maintenance of these criteria, road driving quality will increase.

4.5 SNAPSHOTS OF SURVEYS CONDUCTED

This section comparison of the best practical example with O-4 highway located in Turkey. According to this comparison, some deficiencies (digital infrastructure, network system, fiber-optic / copper, camera, wireless technology, road surface evaluation etc.) were found. Details of this analysis are shown in the figures below. In this section, it is aimed to exemplify the evaluation criteria on the Anatolian Highway. In order to better understand the investigation and evaluation of the research, the figures have been determined according to their location and current situation (These locations are according to in Table 4.2). Some of the examples examined in the regions shown in the figures are as follows; rest area, safe harbor area, road surface, traffic sign and marking, tunnel, existing camera, junction etc.



Figure 4.2 Example of Anatolian Highway

- This section is located in Dilovası / Kocaeli, the starting point is within 50-60 km from İstanbul.
- ✓ Road condition; 3-lane, lighting, barrier layout, road surface, marking.



Figure 4.3 Example of Anatolian Highway / Service Area

- This section is located in Kaynaşlı / Bolu, the starting point is within 180-190 km from İstanbul.
- ✓ Road condition; the service area serves a two-way routes. Fuel stations, rest areas, shopping stores, café etc.



Figure 4.4 Example of Anatolian Highway/ Traffic Sign

- This section is located in Kaynaşlı / Bolu, the starting point is 230-240 km from Ankara.
- ✓ Road condition; 3-lane, lighting, barrier layout, road surface, traffic sign.



Figure 4.5 Example of Anatolian Highway / Cameras

- This section is located in Kahramankazan / Ankara, the starting point is within 20-30 km from Ankara.
- ✓ Road condition; 3-lane, lighting, barrier layout, road surface, marking, traffic sign.



Figure 4.6 Example of Anatolian Highway/ OGS

- This section is located in Kazan / Ankara, the starting point is 30-40 km from Ankara.
- ✓ Road condition; Automatic Transition System = 3-lane, lighting, road surface (poor), marking (poor), traffic sign, speed limit, cameras.



Figure 4.7 Example of Anatolian Highway / Road Surface

- This part is in Doğanlı / Düzce location, starting point within 190-200 km from Ankara.
- ✓ Road condition; 3-lane, continuous shoulder, barrier layout, road surface, marking.



Figure 4.8 Example of Anatolian Highway/ Poor Road Surface

- This section is in Gebze / Kocaeli location, starting point within 30-40 km from İstanbul.
- ✓ Road condition; 3-lane, continuous shoulder, barrier layout, road surface (poor), marking (poor).



Figure 4.9 Example of Anatolian Highway / Junction


- This section is located in Yeniçaydurt / Bolu, the starting point is 140-215 km from Ankara.
- ✓ Road condition;  3-lane, lighting, barrier layout, road surface, traffic sign, marking.



Figure 4.10 Example of Anatolian Highway/ SOS Area

- This section is located in Derince / Kocaeli, the starting point is 90-100 km from İstanbul.
- ✓ Road condition; 3-lane, SOS area, barrier layout, road surface, marking, traffic sign.



Figure 4.11 Example of Anatolian Highway/ Tunnel

- This section is located in Dilderesi / Kocaeli, the starting point is within 40-50 km from Istanbul.
- ✓ Road condition; Tunnel = 3-lane, road surface, marking.

4.6 PILOT ROADS FOR THE INTELLIGENT TRANSPORTATION SYSTEM

Figure 4.12 and Figure 4.13 shown below describe some of the requirements for future roads. This project within the scope of "smart road - smart city" was realized in Honk Kong. Guidance on the highway to Turkey and comparison with the specified Figurine are targeted to be provided on the convenience. Figure 4.14 ta intelligent transportation system planned for Turkey are shown.



Figure 4.12 Pilot Road in Hong Kong #1

Source: (Tech, 2019)

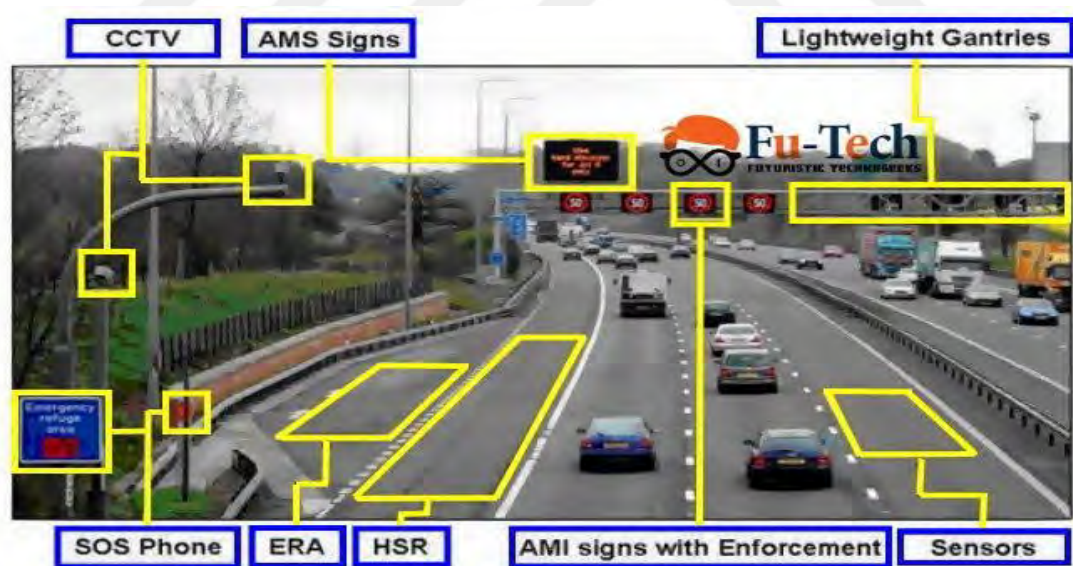


Figure 4.13 Pilot Road in Hong Kong #2

Source: (Tech, 2019)

In Figure 4.14, there is a sample map planned for Istanbul. Some of the elements expected to be made are; smart bus (path), fiber optic cables, wireless magnetic sensors, signalize pedestrian crossings etc.



Figure 4.14 Smart City in Turkey

Source: (Isbak, 2015)

4.7 SUMMARY OF DATA ANALYSIS

As seen in Table 4.4, the criteria that are determined need to be worked on in general. The results and requirements of the six criteria determined in the table are listed. Accordingly, the updating of the regulations have been analyzed according to the requirements of traffic regulations measurement, strategic planning arrangements should be made for deficiencies in the highway in Turkey. Although the applications made within ITS are working, adaptation is needed for other requirements. Although the current situation for road design provides safe traffic flow, it can be developed depending on the connected autonomous vehicles and electric vehicles. Traffic signs are the desired standards. There are damaged markings in some parts of the road route. These regions are shown in the audit form and need maintenance. Safe harbor areas are regular and functional. In addition to this section, SOS stations should be established and these areas should become more effective. There are critical requirements in category of Digital Communication and Service Station/ Rest Area. The biggest reason for this, lack of digital infrastructure and network systems. Network and cameras that are insufficient for the vehicle recognition system in connected autonomous vehicles; and a few number of charging stations in electric vehicles creates problems for the adaptation process. Although it requires critical maintenance on road surfaces in a few areas, generally smooth surfaces can be obtained with minor repairs. The last criteria was crossing and junctions. Pedestrian crossings have neglected because of road type which is highway. Digital infrastructure is required for the required smart junction system.

Table 4.4 Data Analysis

Aspects	Summary	Requirements
Traffic Management Measures	<p>MODERATE</p> <ul style="list-style-type: none"> - Digital Infrastructure - Mapping System for roads 	
Road Design, Marking and Traffic Signs	<p>MODERATE</p> <ul style="list-style-type: none"> - Adaptation of Road Design could work on for future (as requirement of CAVs and AVs) - Poor Road Markings need to repairing 	
Safe Harbor Areas	<p>MODERATE</p> <ul style="list-style-type: none"> - Controlling by systems (for discourage their abuse) 	
Digital Communication and Service Station/ Rest Area	<p>POOR</p> <ul style="list-style-type: none"> - The number of Charging Station must be increase (for charging duration) - All rest areas need charging stations (numbers could be calculate by traffic volume and other charging points) - Digital Infrastructure - Mapping System 	
Road Surface	<p>MODERATE</p> <ul style="list-style-type: none"> - Poor road surface need to repairing - Road surface needs to digital controlling system 	
Crossings and Junctions	<p>POOR</p> <ul style="list-style-type: none"> - Digital Infrastructure 	

CHAPTER 5

CONCLUSION

Vehicles and roads are starting to link and progressing towards fully autonomous vehicles and intelligent road infrastructure. The biggest majority of expected problems are related to technological developments. These problems need to be resolved in order for drivers to focus on them. In developed countries, the solution recommendations and application steps will be faster. World-wide smart road strategies need to be developed and adopted by governments. In addition, with road design, traffic designs and the application of related standards, it will be more easily adapted for AVs and CAVs. These cars developing all over the world aim not only to the comfort of the drivers, also to protect the ecology and sources.

5.1 OUTCOMES OF RESEARCH

Traffic management measure should be completed implementation of the ITS strategy plans for Turkey. Although the applications started are good on the highway, the deficiencies should be followed up. There is a green wave or camera system for traffic management, this system is installed for security. In addition to this, there is a need for network system to follow the road and provide connection with the infrastructure. In the absence of a digital infrastructure for traffic management, barriers, signs and traffic signs to be evaluated in general could be renewed and a deficiency could not be detected by their controls. The category of traffic management measure considered as moderate for Turkey.

The most important aspect of CAVs to identify the infrastructure (V2I) and provide safe drives. Without network system CAVs cannot drive safe. The analysis of the result identified that the biggest problem of all in Turkey is the lack of digital infrastructure. In relation to the physical infrastructure, there is some problems but they are not considered as major. These are related to the state of the road maintenance and they are considered to be minor issues which can be addressed through routine maintenance. The digital infrastructure (camera, mapping, internet connections, cables etc.) should

worked on the highways. Another important issue is that the charging stations are not sufficient. The road has 14 different charging stations. This issue shows that electric vehicles are inadequate when considered with their durations of charge. In normal fast charging stations, this time varies between 2 hours and 4 hours. Charging from a standard house can take a night or longer. Extra fast charging stations, which are planned to be prepared especially for the long road, are thought to provide up to 80% charge in a short time like 30 minutes. The traffic volume (light and heavy vehicle) of the Anatolian Highway in 2019 is approximately 100,000 vehicles per day. If all vehicles will be electrical, according to the current situation, minimum 7143 vehicles are proportioned to a charging station today. With the increase in charging stations, it is expected that the purchase rates of electric vehicles will increase. For summary this category considered as poor. This category is one of the major works to be done in this section.

Although there is no problem observed in road design, updates may be required. The modernity of the traffic signs is compatible with the standards and has a legible quality. Although road markings are poor, maintenance and repair is easily provided.

The layout and design in the safe harbor areas are at normal standards, the digital infrastructure that needs to be made in these areas and the control system should be developed and the abuse of these areas should be prevented. The road surface is included in the physical infrastructure type. Road surface on the road requires weakness as evaluation, but the work to be done is not so difficult. This category needs to moderate.

This studied, the fact that there is a few existing pedestrian crossing like overpass here ignores one of our general criteria. With the applications such as overpass in the rest areas, transportation comfort of the two-way route will be provided for the passengers. Since the strategy used in the design of intersections has normal signalized junction, the vehicles do not experience a problem due to use. That is green traffic time is calculated manually or semi-automatic. With the Wi-Fi communication system expected to be built, traffic volume can be easily calculated.

It is considered that if these improvements are made, the up-take of the CAV and EV would gain significant acceleration and acceptance by the public.

Most of the criteria determined according to the analysis results require “poor”. These infrastructure deficiencies will not take time because there is infrastructure and significant traffic management. Turkey - Anatolia Highway as part though is the strong negative impact of the digital requirements of this criteria. In this analysis, crossing can be neglected as pedestrian crossing is forbidden on the highway. Although there is no problem in traffic management and rules in the junctions, the lack of digital infrastructure does not comply with the planned junction system. It seems that the physical infrastructure does not cause serious problems on this highway. Since the digital infrastructure is only for security, the current roadway to these cars is insufficient. For the V2I level, the infrastructure system must be prepared and the geographical maps must be defined to the cars. In this way, a secure traffic network will emerge.

5.2 CONCLUSIONS

The quality of the adaptation of the planned road network in Turkey should be developed and should begin the transition process for ITS. The traffic rules and standards are different, but the selected road can easily adapt the changes to make it ready for a pilot study.

The change of road infrastructure located in Turkey and regeneration has high budget. According to the result, Turkey is ready for ITS applications but a serious investment is needed economically.

As demonstrated in this study. There is no Major deficiency in physical infrastructure. Following development of the digital infrastructure, Turkey will be able demonstrate readiness for these vehicles in terms of selected highway network.

There is some parameters are needed in highway design. This geometric and physical standards are available for the roads in Turkey. In addition, some categories should be

considered in the design of roads that require design and modification for the future. Road designs should be calculated according to the speed range of new vehicles and risk conditions (kerb, shoulder etc.) should be examined. As a result of examining the existing parameters for this study, it was evaluated as "moderate" in the audit form, since there was no major lack, but it would be necessary to modify it according to the new vehicles. These requirements are not yet finalized.

According to the data collection method and analysis applied, it has been observed that the highest requirement is in the Digital Communication and Service Station / Rest Area. This is because digital levels are important for CAVs. Apart from the communication within itself, the infrastructure should also contact the pedestrian and others. In this way, safe traffic flow can be observed. After determining that the basic need is digital infrastructure, traffic management should be arranged according to this digital infrastructure. Since there is a traffic management system in many countries, adaptations are required. In addition, other needs are listed in Figure 5.1, from high to low.

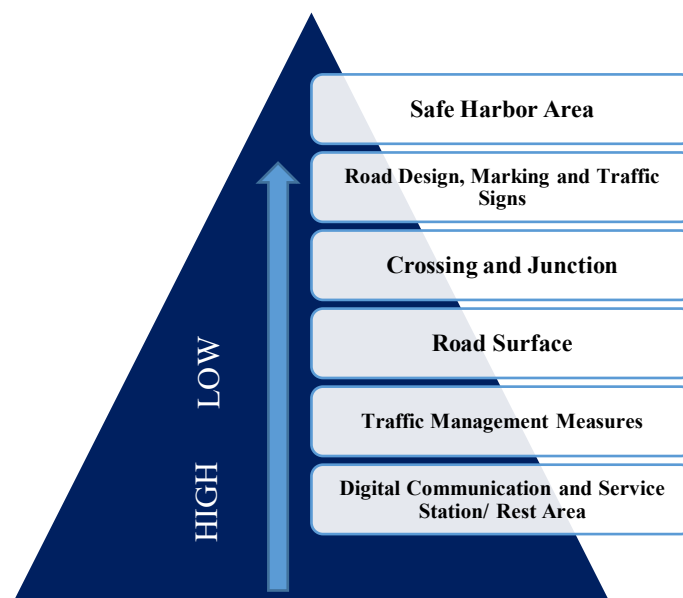


Figure 5.1 Degree of Requirements (Criteria)

5.3 RECOMMENDATION

This study is an object of research, starting from a section of the highway to Turkey to configure these cars and is one step closer to upgrade the road standards. In this study, an intercity highway was examined. As one of the recommendations, since there is no clear regulation worldwide for CAVs and EVs, the automotive industry and Turkish Directorate of Highway should prepare with a new regulation.

According to the study results, it is apparent that further digital infrastructure needs to be provided for roads in Turkey. Unless these infrastructures are provided, efficient AVs or CAVs driving should not be expected. If these vehicles do not work efficiently, for example, the vehicle's inability to detect the pit on the road surface (V2I) will cause the vehicle to automatically change direction which may result in safety compromised. The necessity of digital infrastructure to prevent this situation plays an important roleway in both traffic safety and traffic controls.

There is an inventory list that is needed to be generated for digital infrastructure. The status of existing highways should be audited through its entirety. A list for audit should be developed, based on best practice, and accommodating Turkish Road system conditions. These should include examples such as fiber-optic / copper, camera, wireless technology, plate recognition system should be given in detail in this document by location.

There is a need to adopt, modify and apply this audit mechanism as a governmental tool for classifying road readiness.

Similar work must be conducted for other rural and urban roads to identify priorities for Local Authorities (Belediye), GDH and private operators. As another recommendation, the next research topic should be the study and analysis of city centers. It has been observed that İstanbul Metropolitan Municipality has made more preparations for these vehicles on the highway. The impact of this for private operators must be examined and agreed for capital investment requirements.

The Turkish universities should encourage research on the subject of the highway and new vehicles. Combining the data to be collected will have a fast and fluid effect for the adaptation process.

Capital investment programme must be adopted for roads to be made ready.

New designed roads must have bear minimum requirements to support CAV and EV.

This report is first of its kind for Turkish Roads audit for EV and CAV. This is a fundamental requirement for the adoption the “New Eco-System” for developing technologies with new vehicle-road infrastructure.

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APPENDIX

APPENDIX A

KARAYOLU GEOMETRİK STANDARTLARI												KENT DIŐI İKİ ŐERİTLİ YOLLAR				S1			
PROJE ELEMANLARI				BİRİNCİ SINIF				İKİNCİ SINIF				ÜÇÜNCÜ SINIF							
Hizmet seviyesi		HS (A,B,C,D,E,F)		D	D	D	D	D	D	D	D	D	D	D	D	D	D		
Yüksek Ortalama Gulaik Trafik		12000		4000	4000	11000	5500	3000	8000	4500	2500								
Y.O.G.T		6500		400	400	1100	550	300	800	450	250								
Proje Saatiik Trafiki		1200		400	400	1100	550	300	800	450	250								
P.S.T		1200		400	400	1100	550	300	800	450	250								
Topografik Model		TM (Dz, D1, D2)		Düz	Dalgah	Dağılık	Düz	Dalgah	Dağılık	Düz	Dalgah	Dağılık							
Proje Hızı		Vp (km / saat)		100	80	70	60	70	80	70	60	40	60	40	70	60	50	30	
Minimum karp yarıçapı		R (m)		400	250	200	150	200	250	200	150	60	150	60	200	150	90	30	
Minimum klotoid parametresi		A (-)		160	130	120	100	120	130	120	100	60	120	60	120	100	70	30	
Maksimum boyuna eğim		m (%)		4	4	6	7	7	5	5	7	8	8	6	6	8	8	9	
Düşey karp		Karp Kırp Kk (-)		107-56	44-26	29-20	29-20	17-15	44-26	29-20	29-20	17-15	17-15	6-6	29-20	17-15	10-9	5-5	
İatsayısı		Ka (-)		51-35	30-23	22-19	22-19	16-15	20-23	22-19	22-19	16-15	16-15	8-8	22-19	16-15	12-11	7-7	
Maksimum Dever		n (%)		8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	
Emniyetli Duruş Uzaklığı		Ld (m)		155	110	110	90	70	110	90	70	40	90	70	40	90	55	25	
Emniyetli Geçiş Uzaklığı		Lg (m)		670	550	480	480	420	550	480	420	270	480	420	270	480	420	340	
Őerit Geniřliđi		L (m)		3,5	3,5	3,5	3,5	3,5	3,5	3,5	3,25	3,25	3,25	3,00	3,00	3,00	3,00		
Banket Geniřliđi ***		b (m)		2,5	2,5	2,0	2,0	2,0	1,5	1,5	1,5	1,5	1,5	1,0	1,0	1,0	1,0		
Platform Geniřliđi		PG (m)		12,0	12,0	11,0	11,0	11,0	10,0	10,0	9,5	9,5	9,5	8,0	8,0	8,0	8,0		
Köprü geniřliđi		Kısa köprüler (0-45 m) Wk		9,50				9,50				7,00							
Köprü proje yükü		Uzun köprüler (>45 m) Wu		8,50				8,50				7,00							
H:20 - S:16		h (m)		5,00	5,00	5,00	5,00	5,00	5,00	5,00	5,00	5,00	5,00	5,00	5,00	5,00	5,00		
Alt geçit (min h:5)		h (m)		5,00	5,00	5,00	5,00	5,00	5,00	5,00	5,00	5,00	5,00	5,00	5,00	5,00	5,00		
Gabari																			
Kamulařtırma Geniřliđi		Normal 60.00m ± projenin gerektirdiđi kadar				Normal 40.00m ± projenin gerektirdiđi kadar				Normal 15.00m ± projenin gerektirdiđi kadar									
Eksen uzaklığı L _e (m)		KS 23,00 ● 37,00 ● KS				KS 30,00 ● 30,00 ● KS				KS 7,50 ● 7,50 ● KS									

Figure A.1 GDH Geometric Standard