Intelligent Transportation Systems and Their Applications in Road Transportation Industry in Turkey

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***Abstract*— Urbanization has been evolved both in developed and emerging countries in the world. Increase of urban population, mobility, the usage of internet and computerized systems, environmental friendly applications are likely to lead dynamic changes in the community life and also life style. Increasing of the car usage and the need for carriage induce rapid growth of traffic intensity which cause some transportation problems especially in the road transportation industry in the world. Intelligent Transport Systems (ITS) have been developed to solve probable problems caused by the modern transportation environment through the adaption of innovative technologies recently. ITS are the advanced integration systems which plan, manage and control all the relations of passengers, drivers, vehicles, road operators, managers and the environment. Furthermore, the aims of these systems are to deal with traffic congestion, traffic and road status, pedestrians, vehicles, roads, traffic jam, pollution and accidents for efficient and safety transportation management by using computer, electronics and communication technologies in many countries.**

With the increased problems of the traffic congestion in the metropolitan cities in Turkey, the road transportation management has become a vital research topic to overcome its major problems immediately. By this reason, Intelligent Transport Systems are considered as new promising applications to solve these problems in Turkey. In line with this aim, the purpose of this paper is to shed light on the usage, benefits and importance of these systems with available applications in Turkey especially Turkish road transportation industry.

***Key words*— Information Technologies, Intelligent Transportation Systems, Road Transportation, Transportation.**

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I. Introduction

In today's global world, over half of the world population (54%) lives in urban areas. 30% of the world's population was urban in 1950 and by 2050, 66% of the world's population is estimated to be urban [1]. Similarly, with the rapid population increase and the further industrialization cause massive immigration from rural metropolitan areas, which have resulted in increasing urbanization rates in Turkey. The urbanization rate in Turkey was around 40% in 1980 and 65% in 2000, respectively. As of 2012, Turkey's urbanization rate has reached 77% [2]. Furthermore, the high urbanization (Table 1) the increase of suburbans, [3] and separation of working areas and housing zones has increased the growth of Road Motor Vehicles per thousand population (Table 2).

However, the higher increase of road vehicles leads high risk of accidents [4] As reported by Commission for Global Road Safety, 1.3 million people are killed and 50 million injured annually in road crashes worldwide and it is estimated about 2.4 million fatalities per year by 2030. Low and middle income countries account for 90% of global deaths from road crashes. About 48% of all fatalities are vehicle occupants and 46% vulnerable road users [5]

According to Turkish Statistical Institute, in the road network of Turkey 1 207 354 traffic accidents occurred in 2013 and among all those accidents the number of accidents involving death or injury is 161 306 [6]. It is obvious that without any changes the road transportation systems, these dreadful figures are likely to increase. There are some improvements on driver training, infrastructure and safety. Although they may contribute to reduce the number of accidents but their impact is not enough to combat this menace [7]

Thus countries have started to adopt information technologies to the transportation systems, now that is named as intelligent transportation systems (ITS).

Information technology (IT) has been used in many industries from education to heath care to government, and it is now in the early stages of transforming transportation systems [8]. Since 1960s, there has been many initiatives undertaken about ITS in Japan, USA and Germany. Also, both the research and applications are still continuing in the world. The aim of ITS is to provide more efficient and safer transportation system by increasing productivity, reducing time, costs and saving energy [9]. Therefore, by improving operational performance of the transportation network, ITS enhances driver mobility and convenience, delivers environmental benefits and boosts economic growth. For instance, ITS helped Japan to reduce CO_2 emissions by 31 million tons below 2001 levels in 2010 and with 11 million tons of savings came from effective use of vehicles [8]. The studies of Psaraki et.all, (2012), Muller and Usher (2014) also investigated the impact of ITS to the environment.

ITS developed various services, applications and systems for reducing aforementioned bad outcomes. These systems manage especially traffic and travel, public transportation, payment process, vehicle operations, information, emergency, maintenance and construction and also control drivers, passengers with these applications. Also these systems can help to manage vehicles, drivers, passengers, road operators and managers to reduce death, injury and accidents.

Intelligent transportation systems is divided into main two categories in the world [10] such as intelligent infrastructures and intelligent vehicles. Intelligent infrastructures are named as Data Collection for Proactive Traffic Management Infrastructure , Wireless Networks for Road-Vehicle and Vehicle-Vehicle Communication, Incident Detection, Monitoring (Roadside Camera Recognition), Congestion maps and travel time estimates, Public transport information and Accident Handling, intelligent vehicles such as Mobile Sensing, Probe Vehicles or Devices, Cruise Control (ACC), Lane Departure Warning (LDW), Pedestrian Detection Systems(PDS), Human Machine Interface (HMI), are the mostly used system in the world.

These systems are divided into seven categories according to Intelligent Transportation Systems Workshop 2012 (ITSW, 2012), in Turkey [11]. Passenger information systems; traffic management

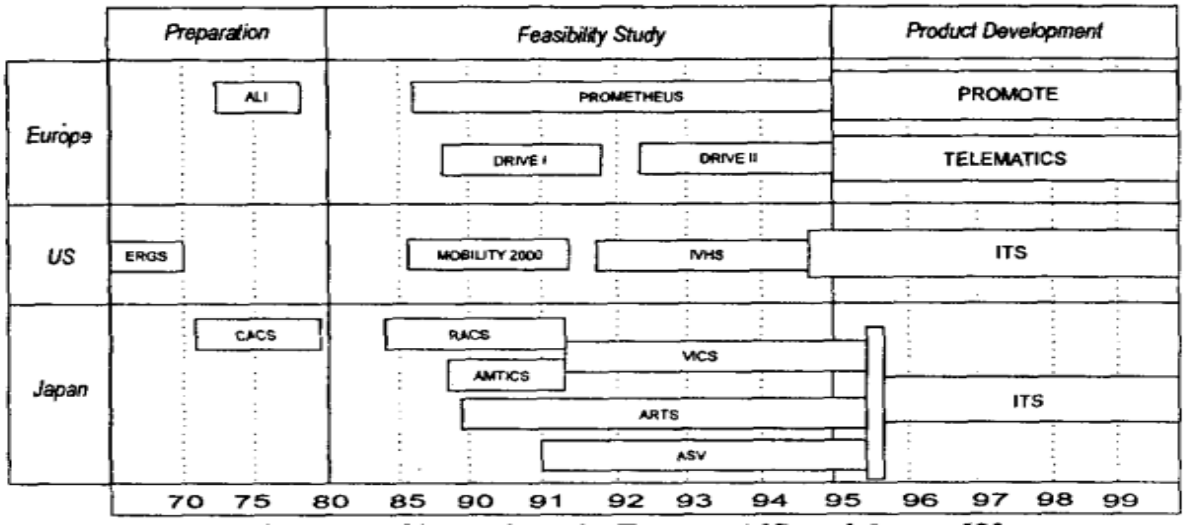
systems; public transport systems; electronic payment systems; freight and fleet systems; driver security and support systems and accident and emergency systems are mostly preferred in Turkey.

The aim of this study is to identify how the role of ITS has become vital in Turkey in line with the increase of urbanization usage of motor vehicles and also the high risk of traffic accidents as well as in the world.

II. Evolution of Intelligent Transportation Systems

Intelligent Transport Systems basically defined as the transportation solution towards alleviating the burden on human being about thinking and decision making.
The development of ITS is evaluated in three vital stages. First stage began with the ITS research in the 1960s and 1970s and the first research was Comprehensive Automobile Traffic Control System (CACS) in Japan. The aim of this system was to resolve the country's traffic congestion and other transportation problems. Furthermore, the Electronic Route Guidance System (ERGS) in the United States, and a similar system that is called ALI in Germany were developed in this stage. All of these initial systems were focused on route guidance and central processing systems with huge central computers and communications systems. These systems never resulted in practical application due to some limitations [12]. However, the first stage was considered as a data source for the next research and triggered the following stages [13]

Figure 1. The History of the ITS development



Source: [12]

The next stage comprises the period from 1980 through about 1995. Traffic congestion was a significant problem to be overcome in this period. Therefore, new research and development efforts directed at practical use got under way in developed countries. Road/Automobile Communication System (RACS) project, which formed the basis for the current car navigation system, began in 1984 in Japan. The U.S. Intelligent Vehicle-Highway Systems (IVHS) project was also progressing in this period. Also, ITS started to be used as a term in the early 1990s, with the adaptation of the IVHS by US Department for Transportation in this stage [14]. The aim of this project was to solve traffic related problems both by opening new roads and by making the existing transport infrastructure more efficient.

Although the birth of term ITS occurred in US, the integrated research projects, such as the PROMETHEUS (Program for a European Traffic System with Higher Efficiency and Unprecedented Safety), were launched firstly in Europe [15]. It was a project mainly focus on design and

implementation of driverless vehicles and autonomous driving algorithms, with the participation of auto manufacturers, universities and research centers from 19 European countries [16]. The European Community set up the Dedicated Road Infrastructure for Vehicle Safety (DRIVE I and DRIVE II) in Europe in 1980s and early 1990s aimed at promoting Road Transport Informatics and Advanced Transport Telematics. Some of the automobile companies such as BMW, Opel, Daimler Benz, Jaguar participated in these projects [17].

It is regarded that the period after 1995 is the third stage. In this stage, practical application of earlier programs has been recognized. Besides many systems such as smart pedestrian crossing systems, mobile traffic information system, lane change warning system, blind spot warning systems, satellite technologies, 3G, Wi-Fi has entered into application and many systems which before used are digitized.

The application of ITS system in Turkey firstly started at 1992 with an electronic toll collection system. This systems was developed to charge vehicles according to their vehicle grade and distance travelled. After that, with the increase of population and the car ownership, to reduce the traffic problem, avoid the loss of time in the traffic and to provide rapid transition, automatic switching system implemented in 1999 for Fatih Sultan Mehmet Bridge. Also, this system was accompanied by Card Pass System. Since 2012, Open Road Tolling (AutoPASS), which is the latest electronic toll collection system in Turkey has been using on toll roads. This system is a payment system that use passive RFID systems and enable cars to continue their roads without stopping [18]. Now, there has been a development and ITS is categorized into 7 parts as Passenger Information Systems; Traffic Management Systems; Public Transport Systems; Electronic Payment Systems; Freight and Fleet Systems; Driver Security and Support Systems and Accident and Emergency Systems in Turkey as mentioned before [11] (Intelligent Transportation Systems Workshop 2012).

III. The Need for the ITS

Urbanization has been developed not only in development countries but also in emerging countries since 1980s. Although the speed of urbanization has started to diminish, the rise of the rate of urban population to the total population is still continuing. The rise of this ratio is also much more higher in emerging countries Furthermore, the rate of urbanization in industrial countries such as England, Sweden and Japan is still growing. Therefore, when Turkey is compared with these countries, it is observed that this ratio will continue to grow [19].

Table 1: Ratio of Urban Population to the Total Population (%)

Country	2006	2007	2008	2009	2010	2011
ABD	81,01	81,29	81,57	81,86	82,14	82,38
Germany	73,44	73,53	73,63	73,72	73,81	73,94
Australia	66,71	66,90	67,08	67,27	67,45	67,66
France	82,28	83,02	83,75	84,49	85,22	85,74
South Korean	81,66	81,98	82,29	82,61	82,93	83,20
Holland	80,68	81,20	81,71	82,23	82,74	83,13
England	79,10	79,20	79,30	79,40	79,50	79,63
Sweden	84,46	84,61	84,76	84,90	85,05	85,20
Japan	86,89	87,80	88,71	89,62	90,54	91,13
Norway	77,81	78,13	78,45	78,77	79,10	79,37
Turkey	67,57	68,29	69,02	69,75	70,48	71,40
OECD	78,02	78,36	78,70	79,04	79,38	79,68
World	49,55	50,05	50,54	51,03	51,52	51,99

Source: [20]

The phenomenon of suburbanization which is a process of population redistribution away from central cities and into suburbs, [3] gained importance with the acceleration of urbanization. Hence, the rise of demand for the urban mobility has increased. Furthermore, this situation causes each city that has become the center of attraction encounter with a traffic chaos. Separation of working areas and housing zones force people to use motor vehicles between their home and work especially in big cities. The migration from city centers to silent suburbans increased the demand of personal vehicle use [19]. For this reason, the number of road motor vehicles is high and rising among countries. Table 2 shows the increase of road motor vehicle by years.

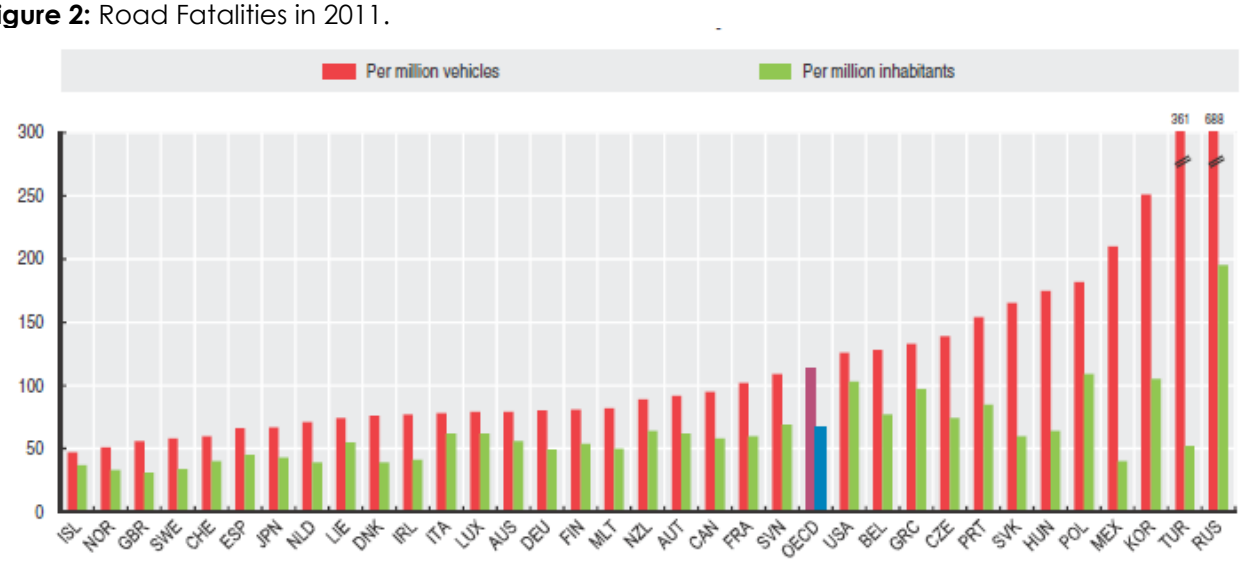
Table 2: Road Motor Vehicles per thousand population (2009)

Country	2003	2004	2005	2006	2007	2008	2009
ABD	796	810	816	818	820	815	802
German	576	537	543	549	553	556	564
Australia	595	599	549	553	557	561	569
France	594	595	596	598	598	598	598
South Korea	303	311	320	329	339	346	355
Holland	-	494	491	504	514	522	--
England	496	510	517	521	527	526	523
Sweden	-	508	513	517	523	521	519
Japan	581	587	592	594	592	592	589
Norway	525	535	546	558	572	575	578
Turkey	91	111	118	126	132	138	142

Source: [20]

Although the number of road freight vehicles are increasing, reducing road accident is a main concern for all governments. Figure 2 indicates the road fatalities which means any person killed immediately or dying within 30 days as a result of a road injury accident. In 2011, the best-performing countries are Iceland, Norway, United Kingdom, Sweden, Switzerland, Spain, respectively. Countries above the average of OECD are USA, Belgium, Greece, Check Republic, Portugal, Slovakia, Hungary, Poland, Mexico, Korea, Turkey and Russia.

Figure 2: Road Fatalities in 2011.



Source: [21]

*Suicides involving the use of a road motor vehicle are excluded.

As shown in table 2 and figure 2, parallel with rise of road motor vehicle, road accident is increasing. Reduction of accidents and assurance of road safety has become the main task for the governments. Thus, the need of a new traffic control system is obvious and ITSs are one of the measures that can reduce the impact of road traffic in the past, road traffic control systems were often used with the aim to provide one or two services that would function independently as different subsystems [4]. However, ITSs facilitate the management of transport flows by reducing the congestion, time spent in traffic jam and also assure the safety and convenience of drivers by using warning regarding dangerous situations caused by human or environmental factors now [22]. They help to monitor of road traffic conditions and supply of such information [4]. Furthermore, they also contribute to reduce energy consumption and environmental pollution [23]. All the benefits of ITSs may be grouped as below [8] (Ezell, 2010):

- increasing safety
- increasing traffic capacity and reducing the congestion
- increasing the mobility and convenience
- reducing environmental pollution
- boosting economy and increasing employment

As the given statistics and benefits reveal the need for the ITS. In the next part, firstly some of the example application of ITS in the world will be discussed and then the applications for Turkish Road Transportation will be examined.

IV. Application of Intelligent Transportation Systems in Turkish Road Transportation

Intelligent transportation systems can help manage road transportation with vehicles, roads, traffic lights, message signs, sensors, microchips, etc. [8]. These systems or vehicles collect the data/information about the traffic or road situation. Traffic information systems are transmitted the information with radio wave and infrared beacons [10]. These systems show information in three forms as text, simple graphics and maps.

There are great variety of ITS deployments and programs. Due to the wide range of intelligent transportation systems, it is useful to make a discussion of ITS applications with their specifications. In these part the most important and commonly applications of ITS both in the world and in Turkey are discussed. The most preferred intelligent transportation technologies are divided by mainly 2 categories as intelligent infrastructure and intelligent vehicles [24].

The key *Intelligent Infrastructures* are data collection for proactive traffic management infrastructure, traffic management infrastructure, wireless networks for road to vehicle (R2V) and vehicle to vehicle (V2V) communication, incident detection, monitoring (Roadside Camera Recognition), congestion maps and travel time estimates, public transport information and accident handling, *Intelligent Vehicles* such as Mobile Sensing, Probe Vehicles or Devices, Cruise Control (ACC), Lane Departure Warning (LDW), Pedestrian Detection Systems(PDS), Human Machine Interface (HMI), are the mostly used system in the world [24].

1. Intelligent Infrastructures

The types of intelligent infrastructures are below [24]:

Data Collection for Proactive Traffic Management Infrastructure: This information provides analyzing of crashing with using data from loop detectors.

Wireless Networks for Road to Vehicle and Vehicle to Vehicle Communication: Infrastructure for the management of traffic data comprises the first step towards wireless networks and global positioning systems (GPS). The aims of these systems are to provide location and time information in all weather conditions, anywhere on or near the earth where there is an unobstructed line of sight to four or more GPS satellites, routing, or route guidance systems that includes real traffic data and information [25].

Vehicle to Vehicle (V2V) communication systems for traffic management at intersections using fuzzy logic [26]. In addition some researchers combined V2V with R2V communication systems [27]. Also these systems are named as *Dedicated Short Range Communications (DSRC)*[8]. These systems provide active warning systems vehicles, pedestrian and also animals and on the roadside warn drivers furthermore it can help to reduce road fatalities. On the other hand these systems require large investments therefore it's difficult to adapt these systems countries' infrastructure easily.

Incident Detection: This system is important for specifying location of accidents or vehicle breakdowns to handle the emergency situation and respond to incidents quickly.

Monitoring (Roadside Camera Recognition): Monitoring people, ways and vehicles are important for quick response, safety transportation and control. Monitoring system is especially provided by roadside camera recognition that can be used for zone-based congestion charging systems or for charging on specific roads. Such systems use cameras placed on roadways where drivers enter and exit congestion zones [8].

Congestion maps and travel time estimates: These maps can help drivers to select home zones and to recognize rush hours. This map can help drivers to plan their route and these route's approximately travel/transit time. This application is essential for identifying rush hours and time saving with effective route planning.

Public transport information: This information system is vital for planning the transfer frequency and can help to reduce waiting time. Public transport information includes applications such as automatic vehicle location which enable transit vehicles, whether bus or rail, to report their current location, making it possible for traffic operations managers to construct a real-time view of the status of all assets in the public transportation system. These systems help to make public transport a more attractive option for passengers by giving them enhanced visibility into the arrival and departure status (and overall timeliness) of buses [8].

Accident Handling*:* This system provides emergency services after accidents.

2. Intelligent Vehicles

Intelligent vehicles are tolls that can help to reduce accidents, injuries and deaths. These vehicles can be listed as follows [10]:

Mobile Sensing Application**:** *Mobile sensing* application transmits information over standard third or fourth generation (3G or 4G) mobile phone networks. GPS is the one application used in mobile

phones. These systems provide quick and easy information about the roads. It can be used in the transportation vehicles for monitoring or tracking vehicles by mobile phones. It provides to get quick and right information coordinately.

***Probe Vehicles or Devices**:* These systems can help also monitor the products and process step by step by bluetooth or RFID, They can help to reduce losses and thefts.

Other intelligent vehicles can be listed as follows [24];

Cruise Control (ACC): It is a system that automatically controls the speed and a safe distance from the front vehicle.

Lane Departure Warning (LDW): This is a crash avoidance system alerting the driver if the vehicle moves out of its lane with a switched off turn signal. It works with cameras and sensors mounted on the vehicle able to detect the road markings [28].

Pedestrian Detection Systems (PDS): This system recognize human bodies from video segment and warns the driver about the danger of collisions with pedestrians. The main difficulties about this system are the ability to detect and track successfully human body or human figures from the other objects or images.

Human Machine Interface (HMI): This system warns drivers' distraction by system errors and unnecessary warnings or information [29]. This is the driver monitoring system that gives real information about the driver's mental state, driving style etc. [30].

According to Intelligent Transportation Systems Workshop 2012, Intelligent Transportation Systems divided into 7 categories in accordance with their usage in Turkey as [11]; Passenger Information Systems, Traffic Management Systems, Public Transport Systems, Electronic Payment Systems, Freight and Fleet Systems, Driver Security and Support Systems and Accident and Emergency Systems.

1. ***Passenger Information Systems***: It includes mobile and web traffic information systems, routing and mobile traffic applications. These systems can help passengers to plan, monitor and change their routes according to provided traffic information (heavy traffic, accident, road construction work). "Mobile Traffic" application of Istanbul Metropolitan Municipality in Turkey is a good example for this system. By using this application, it is possible to monitor the traffic situation in Istanbul and also density map service shows the live camera images in real time to the user's mobile phone. These systems are used in Izmir and Ankara too.

2. ***Traffic Management Systems:*** This system includes traffic cams, road sensors, and traffic density maps, green line systems to improve productivity, increase traffic service quality and reduce traffic density. These systems are used in all cities in Turkey.

3. ***Public Transport Systems:*** This system aims to increase usage of the public transportation to reduce traffic density. It includes smart bus stops, route planning, traffic density maps, bus routes passing and smart journey planner etc. Smart bus stops are capable of operating with solar energy and they shows when and which buses will come to the bus station. They are commonly used in the big and crowded cities like İstanbul, Ankara and İzmir in Turkey. Route planning provides information about the most appropriate route and alternatives, indoor and roads under construction, road structure, important places, weather condition

over the base maps from the Internet and satellite vector and provides information in video. Traffic density map; is generated via web for the purpose of directing the drivers and passengers to alternative routes for ensuring cost effective and comfortable travel. Bus routes passing provides information about specific station and stops near the passengers' address where they would like to go on the map. Also, it enables passengers to reach to the transportation schedule quickly. Finally, smart journey planner provides passengers to plan their travel from origin to destination with alternative transportation modes via bus, metro, train, plane etc. Also this system gives extra information about travel time, travel cost, etc. This system is commonly used in Izmir and Ankara.

4. ***Electronic Payment Systems***: This system includes open road tolling, electronic toll collection system, pass system with card and quick pass system. They are managed by RFID systems that can help the passengers to continue their road without stopping. And also it can help to reduce traffic jam and transit time.

   Automatic Pass System, (OGS in Turkish) is an electronic toll collection system used with radio-frequency identification (RFID) system. It is available on toll roads and toll bridges in Turkey. This system is also adopted to avoid traffic congestion at toll plazas.

   Another common electronic payment system is Electronic card. For example, "Akbil" (is the special name of the smart card) is used in the public transportation in İstanbul, Turkey. Also, "Kentkart" is used in İzmir with the same principle. These similar systems are used in Adana, Bursa, Kayseri and Gaziantep too.

5. ***Freight and Fleet Systems*:** Freight and fleet management systems are quality programs that can provide to optimize freight, monitor freight from point of destination to end user and aim to manage whole process from supplier to end user. This system is used by some logistics companies in Turkey.

6. ***Driver Security and Support Systems:*** This is the oldest control system dates back to 1970s. It comprises cruise control system, anti-lock braking system (ABS), emergency brake assist (EBA), emergency brake-force distribution (EBD), electronic stability control (ESC), advanced driver systems, parking sensors and different sensing systems like black spot tracing system, improper lane change preventer, night vision helper system, etc. The aim of these systems is to provide safety drive for drivers.

7. **Accident and Emergency Systems:** This system uses traffic incident management system for the monitor each stage of the process. Monitor system and automatic warning system are used for the heavy roads to solve accidents more quickly and efficiently. In this system firms especially prefer to use RFID, Transportation Management systems and GPS in the road transportation industry. 'e-call' is the new planned emergency system that will be used in the upcoming years in all cities of Turkey. This device will be mandatory for the vehicles and with this device, information will be sent to the emergency team in case of an accident.

Using of these systems can help to increase driver and pedestrian safety with online tracking and quick response systems; improve transportation performance and network with real time data and information, traffic lights and signs, etc. decrease congestion with road maps, online tracking systems, cameras, etc., develop personal mobility and convenience with navigation systems (GPS). These systems totally increase productivity and efficiency.

Among all the systems that are mentioned firms in the road transportation industry mostly prefer to use Transportation Management System (TMS), RFID and GPS for managing their road transportation activities in Turkey. These systems provide monitoring and tracking the process simultaneously for reducing damage, theft, loss, injury, etc. However the number of the IT usage is not at the desired level in the road transportation industry. According to statistics the usage of intelligent transportation systems is approximately 60% in Turkey [31].

V. Conclusion and Further Research

Intelligent transportation systems are fast growing discipline for the transportation systems. There are many types of applications in the world.

As mentioned above, the developed countries use these systems more efficiently and effectively. According to given statistics the number of death people in road accidents is lower in developed countries than Turkey. It shows that the level of development and usage of technology help to reduce accidents, deaths and losses. ITS are one of the technology that can reduce the accidents and such bad outcomes. In addition, these systems increase safety, traffic capacity, reduce the congestion, increase the mobility, convenience and also help to diminish environmental pollution. Furthermore, these systems support countries in terms of economic development and innovation. Regarding the fact that pecuniary loss and intangible damages that result from road fatalities, and injuries, Turkey need an urgent and effective implementation of ITS system. Although initiatives have been continuing since 1960s in the world, Turkey started to implement ITS technologies lately, in 1992 with electronic payment systems. While, many countries that implemented such technologies have been making contribution to their economic development, many problems about transportation haven't been solved in Turkey yet. For this reason, researching and making investment for these new ITS technologies is a main concern for Turkish road transportation. However, it should be noticed that these systems are costly and take long time to build the needed infrastructure.

For the further research, the ITS systems' financial benefits and effects on the country's development can be a topic to be taken up. Also this research can be applied comparatively on the emergent countries. Countries may use different analyzing tools for identifying essential intelligent applications or vehicles. SWOT (Strengths, Weaknesses, Opportunity, Threats) analysis which is one of the most preferred analyzing tool, may be used for these purposes. This analyzing tool can be a way of recognizing and solving such mentioned problems of big cities (metropolis) in Turkey. Furthermore, the role of incentives and investment of research and development activities (R&D) for ITS in Turkey can be an issue for the next research.

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