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A Comprehensive Study on Intelligent Transportation Systems

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***Abstract*- Transportation or transport sector is a legal source to take or carry things from one place to another. With the passage of time, transportation faces many issues like high accidents rate, traffic congestion, traffic & carbon emissions air pollution, etc. In some cases, transportation sector faced alleviating the brutality of crash related injuries in accident. Due to such complexity, researchers integrate virtual technologies with transportation which known as Intelligent Transport System. Intelligent Transport Systems (ITS) provide transport solutions by utilizing state-of-the-art information and telecommunications technologies. It is an integrated system of people, roads and vehicles, designed to significantly contribute to improve road safety, efficiency and comfort, as well as environmental conservation through realization of smoother traffic by relieving traffic congestion. This paper aims to elucidate various aspects of ITS - it's need, the various user applications, technologies utilized and concludes by emphasizing the case study of IBM ITS.**

***Keywords*-** Intelligent transportation system, Transportation Technologies, Applications, Strategies.

I. INTRODUCTION

Over the last several decades, the scale of highway transportation system has become larger than ever before. High- way Transportation System has become an indispensable part of human activities, it plays an important role in both eco- nomic and social development.

As the requirements for transportation capability rise annually, it is increasingly difficult for the highway system to provide high-quality travel services. At the same time, be- cause of the growing number of vehicle, the road is becoming saturated. As the situation worsen, more and more problems are exposed. Some problems are ancient, like congestion, while others are new like environmental impacts. Among the most notable transport problems are[1]:

- Traffic congestion
- Environmental impacts
- Energy consumption
- Accidents and safety
- High maintenance costs
- Land consumption

Besides, in the long run consideration, two more major motivations for considering the future of transportation are national productivity and international competitiveness, both closely link to the efficiency of transportation system [2].

Intelligent transportation system (ITS) is the application of sensing, analysis, control and communications technologies to ground transportation in order to improve safety, mobility and efficiency. ITS includes a wide range of applications that process and share information to ease congestion, improve traffic management, minimize environmental impact and increase the benefits of transportation to commercial users and the public in general. The focus on operations is enabled by a set of new technologies, especially Intelligent Transportation Systems (ITS) [3]. Moreover, it will also contribute to both mobility and sustain- able transportation.

Intelligent transport systems vary in technologies applied, from basic management systems such as car navigation; traffic signal control systems; container management systems; variable message signs; automatic number plate recognition or speed cameras to monitor applications, such as security CCTV systems; and to more advanced applications that integrate live data and feedback from a number of other sources, such as parking guidance and information systems; weather information; bridge de-icing (US deicing) systems; and the like [4].

Communication cooperation on the road includes car-to-car, car-to-infrastructure, and vice versa. Data available from vehicles are acquired and transmitted to a server for central fusion and processing. These data can be used to detect events such as rain (wiper activity) and congestion (frequent braking activities). The server processes a driving recommendation

dedicated to a single or a specific group of drivers and transmits it wirelessly to vehicles. The goal of cooperative systems is to use and plan communication and sensor infrastructure to increase road safety. ITS conduct research, development, and education activities to facilitate the adoption of information and communication technology to enable society to move more safely and efficiently.

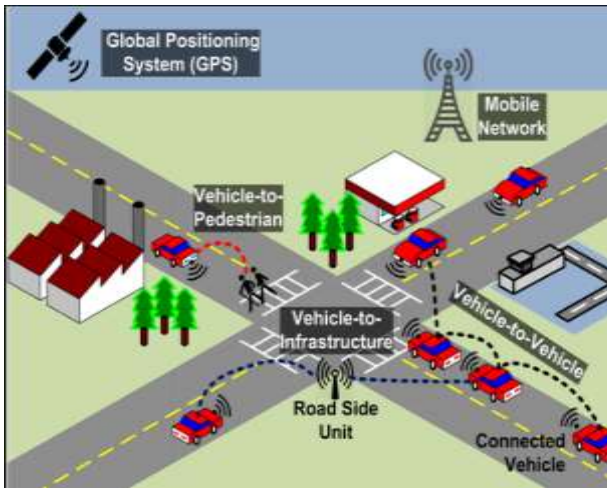

Figure 1: Intelligent Transport System

ITS, which is part of the Internet of Things, includes vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) technology and incorporates both wireless and wire line communications-based information and electronics technologies. Wireless technology is used to connect vehicle information and location to other vehicles, other transportation modes (such as pedestrians or bicyclists), local infrastructure and remote infrastructure in the cloud [5].

ITS is having a significant effect on transportation in applications such as electronic toll collection, ramp meters, traffic light cameras, traffic-signal coordination, transit signal priority and traveler-information systems. The adoption of ITS is expected to increase in applications such as fleet monitoring, tolling management, ticket management, transportation pricing, telematics and traffic monitoring. Key beneficiaries of ITS safety improvements as well as the availability of real-time information and analytics are travelers, businesses and transportation agencies. Data from ITS also has homeland security applications. ITS is not limited for highway traffic, it is also provide services and implement in navigation system, air transport system, water transport system and rail systems [6]. Day to day popularity of Intelligent Transportation System and increasing the demands and development in transportation systems intelligent transportation system divided into generations. Table 1 shows the generation of Intelligent Transportation System with period.

Table 1: Generations of Intelligent Transportation System (ITS) [7]

Generation	Period	Technology
First Generation (ITS1.0)	2000	One-way infrastructure based
Second Generation (ITS2.0)	2000-2003	Two-way communication technology
Third Generation (ITS3.0)	2004-2005	Automated vehicle operations and automated, interactive system operations and system management
Next Generation ITS	2006 Onwards	Multi-modal Incorporating personal mobile devices, vehicles, infrastructure and information networks for system operations as well as personal contextual mobility solutions. Green and Safety ITS.

II. NEED FOR ITS

Sustainable and efficient transport systems are requirements for economic well-being. However, there is a price to pay for good transportation. It is generally expensive to provide adequate transport infrastructure, and other undesirable side effects such as environmental impacts, land requirements and energy consumption are also noted. There is also a general trend to move away from just adding infrastructure as part of capital intensive transportation strategies - there is a trend towards more balanced and sustainable transportation solutions. ITS holds the promise of sustainability. It presents the opportunity for better management of existing resources and infrastructure, through the provision of information to travelers and transportation planning professionals and offers new control possibilities [8]-[10].

Worldwide we face numerous transport challenges. These include the need to:

- Improve road safety and security for all users.
- Combat rising congestion, which is increasing travel times and industry costs.
- Enhance the attractiveness of public transport.
- Reduce the environmental impacts of transport.
- Improve the competitiveness and performance of logistics systems.

- Ensure that populations worldwide have access to safe and affordable transport.

Sensible use of emerging technologies is essential to help meet these challenges. ITS provide sophisticated multimodal tools, which integrate advanced technologies and apply them to transportation to develop solutions that will improve the quality of life. ITS is about saving lives, time and money and improving the environment.

III. INTELLIGENT TRANSPORTATION APPLICATIONS

A. Emergency Vehicle Notification Systems

The in-vehicle eCall is generated either manually by the vehicle occupants or automatically via activation of in-vehicle sensors after an accident. When activated, the in-vehicle eCall device will establish an emergency call carrying both voice and data directly to the nearest emergency point or public safety answering point. The voice call enables the vehicle occupant to communicate with the trained eCall operator [11].

B. Automatic Road Enforcement

A traffic enforcement camera system, consisting of a camera and a vehicle-monitoring device, is used to detect and identify vehicles disobeying a speed limit or some other road legal requirement and automatically ticket offenders based on the license plate number. Some of the applications of road enforcement are discussed below [12]:

- Speed cameras that identify vehicles traveling over the legal speed limit.
- Red light cameras that detect vehicles that cross a stop line or designated stopping place while a red traffic light is showing.
- Bus lane cameras that identify vehicles traveling in lanes reserved for buses.
- Level crossing cameras that identify vehicles crossing railways at grade illegally.
- Double white line cameras that identify vehicles crossing these lines.
- High-occupancy vehicle lane cameras that identify vehicles violating HOV requirements.

C. Variable speed limits

Recently some jurisdictions have begun experimenting with variable speed limits that change with road congestion and other factors.

D. Dynamic traffic light sequence

Radio-frequency identification (RFID) technology with appropriate algorithm and database were applied to a multi-vehicle, multi-lane and multi-road junction area to provide an efficient time management scheme. A dynamic time schedule was worked out for the passage of each column. The simulation showed the dynamic sequence algorithm could adjust itself even with the presence of some extreme cases.

E. Collision avoidance systems

Sensors on the highways are installed to notify that there is stalled traffic ahead which helps in collision avoidance.

F. Electronic Toll Collection (ETC)

Electronic toll collection is a one of the most popular application of intelligent transportation system, which eliminates the delay and enhances the mechanism of collecting toll electronically in transportation sector. Electronic Toll Collection concept such as safety of travelers, increasing the performance of toll stations, safe time of travelers and also help in environmental problems and fuel consumption [13].

IV. WORKING OF ITS

Traffic Management Centre (TMC) is the vital unit of ITS. It is mainly a technical system administered by the transportation authority. Here all data is collected and analyzed for further operations and control management of the traffic in real time or information about local transportation vehicle [14]-[16].

Well-organized and proficient operations of Traffic Management Centre depends on automatized data collection with precise location information than analysis of that data to generate accurate information and then transmitting it back to travelers. Let's understand the entire process in a more detailed way [17].

A. Data collection

Strategic planning needs precise, extensive and prompt data collection with real-time observation. So the data here is collected via varied hardware devices that lay the base of further ITS functions. These devices are Automatic Vehicle Identifiers, GPS based automatic vehicle locators, sensors, camera etc. The hardware mainly records the data like traffic count, surveillance, travel speed and travel time, location, vehicle weight, delays etc. These hardware devices

are connected to the servers generally located at data collection centre which stores large amounts of data for further analysis.

B. Data Transmission

Rapid and real-time information communication is the Key to proficiency in ITS implementation so this aspect of ITS consists of the transmission of collected data from the field to TMC and then sending back that analyzed information from TMC to travelers. Traffic-related announcements are communicated to the travelers through internet, SMS or onboard units of Vehicle. Other methods of communications are dedicated short-range communications (DSRC) using radio and Continuous Air Interface Long and Medium Range (CAILM) using cellular connectivity and infra-red links.

C. Data Analysis

The data that has been collected and received at TMC is processed further in various steps. These steps are error rectification, data cleaning, data synthesis, and adaptive logical analysis. Inconsistencies in data are identified with specialized software and rectified. After that data is further altered and pooled for analysis. This mended collective data is analyzed further to predict traffic scenario which is available to deliver appropriate information to users.

D. Traveler Information

Travel Advisory Systems (TAS) is used to inform transportation updates to the traveling user. The system delivers real-time information like travel time, travel speed, delay, accidents on roads, change in route, diversions, work zone conditions etc. This information is delivered by a wide range of electronic devices like variable message signs, highway advisory radio, internet, SMS, automated cell.

With urbanization expanding with speedy stride, number of vehicles on road is also increasing. Combination of both in return puts enormous pressure on cities to maintain a better traffic system so that the city keeps on moving without any hassle. For the purpose application of Intelligent Transport System is the only solution. ITS is a win-win situation for both citizens and city administrators where it provides safety and comfort to citizens and easy maintenance and surveillance to city administrators.

V. TECHNOLOGIES IN ITS

Firstly we look the summary of enabling technologies in Intelligent Transportation System after that we discuss the enabling technologies areas in ITS.

Intelligent Transportation System integrates current and growing communication technologies. Due to emergence of many technologies, the transportation system is able to improve transportation conditions, safety and services [18]-[20].

A. Wireless Communications

Various forms of wireless communications technologies have been proposed for intelligent transportation systems. Radio modem communication on UHF and VHF frequencies are widely used for short and long range communication within ITS.

Short-range communications of 350 m can be accomplished using IEEE 802.11 protocols, specifically WAVE or the Dedicated Short Range Communications standard being promoted by the Intelligent Transportation Society of America and the United States Department of Transportation. Theoretically, the range of these protocols can be extended using Mobile ad hoc networks or Mesh networking.

Longer range communications have been proposed using infrastructure networks such as WiMAX (IEEE 802.16), Global System for Mobile Communications (GSM), or 3G. Long-range communications using these methods are well established, but, unlike the short-range protocols, these methods require extensive and very expensive infrastructure deployment. There is lack of consensus as to what business model should support this infrastructure.

B. Floating Cellular Data

GPS based methods: An increasing number of vehicles are equipped with in-vehicle satnav/GPS (satellite navigation) systems that have two-way communication with a traffic data provider. Position readings from these vehicles are used to compute vehicle speeds. Modern methods may not use dedicated hardware but instead Smartphone based solutions using so called Telematics 2.0 approaches.

Smartphone-based rich monitoring: Smartphones having various sensors can be used to track traffic speed and density. The accelerometer data from smartphones used by car drivers is monitored to find out traffic speed and road quality. Audio data and GPS tagging of smartphones enables identification of traffic density and possible traffic jams. This was

implemented in Bangalore, India as a part of a research experimental system Nericell.

Floating Cellular Data technology provides advantages over other methods of traffic measurement:

- Less expensive than sensors or cameras
- More coverage (potentially including all locations and streets)
- Faster to set up and less maintenance
- Works in all weather conditions, including heavy rain

C. Video Vehicle Detection

Traffic-flow measurement and automatic incident detection using video cameras is another form of vehicle detection. Since video detection systems such as those used in automatic number plate recognition do not involve installing any components directly into the road surface or roadbed, this type of system is known as a "non-intrusive" method of traffic detection. Video from cameras is fed into processors that analyse the changing characteristics of the video image as vehicles pass. The cameras are typically mounted on poles or structures above or adjacent to the roadway. Most video detection systems require some initial configuration to "teach" the processor the baseline background image. This usually involves inputting known measurements such as the distance between lane lines or the height of the camera above the roadway. A single video detection processor can detect traffic simultaneously from one to eight cameras, depending on the brand and model. The typical output from a video detection system is lane-by-lane vehicle speeds, counts, and lane occupancy readings. Some systems provide additional outputs including gap, headway, stopped-vehicle detection, and wrong-way vehicle alarms.

D. Sensing Technologies

Technological advances in telecommunications and information technology, coupled with ultramodern/state-of-the-art microchip, RFID (Radio Frequency Identification), and inexpensive intelligent beacon sensing technologies, have enhanced the technical capabilities that will facilitate motorist safety benefits for intelligent transportation systems globally. Sensing systems for ITS are vehicle- and infrastructure-based networked systems, i.e., Intelligent vehicle technologies. Infrastructure sensors are indestructible (such as in-road reflectors) devices that are installed or embedded in the road or surrounding the road (e.g., on buildings, posts, and signs), as required, and may be manually disseminated during preventive road construction maintenance or by sensor injection machinery for rapid deployment. Vehicle-sensing systems include deployment of infrastructure-to-vehicle and vehicle-to-infrastructure electronic beacons for identification communications and may also employ video automatic number plate recognition or vehicle magnetic signature detection technologies at desired intervals to increase sustained monitoring of vehicles operating in critical zones.

E. Inductive loop detection

Inductive loops can be placed in a roadbed to detect vehicles as they pass through the loop's magnetic field. The simplest detectors simply count the number of vehicles during a unit of time (typically 60 seconds in the United States) that pass over the loop, while more sophisticated sensors estimate the speed, length, and class of vehicles and the distance between them. Loops can be placed in a single lane or across multiple lanes, and they work with very slow or stopped vehicles as well as vehicles moving at high speed.

F. Bluetooth detection

Bluetooth is an accurate and inexpensive way to measure travel time and make origin and destination analysis. Bluetooth devices in passing vehicles are detected by sensing devices along the road. If these sensors are interconnected they are able to calculate travel time and provide data for origin and destination matrices. Compared to other traffic measurement technologies, Bluetooth measurement has some differences:

- Accurate measurement points with absolute confirmation to provide to the second travel times.
- Is non-intrusive, which can lead to lower-cost installations for both permanent and temporary sites.
- Is limited to how many Bluetooth devices are broadcasting in a vehicle so counting and other applications are limited.
- Systems are generally quick to set up with little to no calibration needed.

Since Bluetooth devices become more prevalent on board vehicles and with more portable electronics broadcasting, the amount of data collected over time becomes more accurate and valuable for travel time and estimation purposes.

It is also possible to measure traffic density on a road using the Audio signal that consists of the cumulative sound from tire noise, engine noise, engine-idling noise, honks and air turbulence noise. A roadside-installed microphone picks up the audio that comprises the various vehicle noise and Audio signal processing techniques can be used to estimate the traffic state.

VI. RESEARCH ON ITS

Governments are working with standards bodies and industry stakeholders to develop ITS that use telematics to allow for automatic communications among vehicles, infrastructure, and pedestrians to improve traffic safety and efficiency [18].

Vehicle-to-vehicle or Connected Vehicle systems are a key component of ITS, focusing on surface transportation. First-generation V2V systems involve the transmission of a basic safety message between vehicles so as to warn drivers of imminent collisions. Second-generation systems are expected to use vehicle sensors to trigger automatic safety-related actions [19].

In addition to the promise of improved road safety, V2V, and more broadly, ITS, is touted as easing traffic congestion and lowering overall carbon emissions. By directing drivers to less congested routes, helping to eliminate unnecessary stops, and providing drivers with real-time information on traffic, weather, and alternative transportation options, such systems are expected to reduce commute times, cut traffic emissions, and help people make greener and more efficient transportation choices. ITS had more opportunity to develop, especially in transport services for major international events [20].

A. ITS Canada

ITS Canada defines an application of advance and emerging technologies such as computers, sensors, control, communications, and electronic devices in transportation environment with ultimate focus on safer roads. The ITS Canada is moving forward toward fully integrated transportation management system, with improving efficiency and general mobility in transportation. ITS Canada has a complex collaboration with Europe, the United States, and Japan. These counterparts invest billions of dollars in ITS solutions to solve transportation difficulties. ITS Canada provides valuable contributions in exporting the latest innovation in ITS technologies abroad. ITS Canada has two more working groups in ISO TC 204.

B. ITS South Africa

SABS (South African Bureau of Standards)/TC204) was previously known as Sub Committee 71 H (SC71H), which is the South African ITS standardized organization. The SABS/TC204, imitates the scope of ISO/TC204 standards. The scope of SABS/TC204 standardization includes the information, communication, and control systems in the field of urban and rural surface transportation, traffic management, emergency services, commercial services, and so forth. SABS/TC204 which imitates the functionalities of ISO/TC 204 in the majority of its application, differs in a specific application that is ITS systems which are completely self-contained in the vehicle and do not interact with other vehicles or with the infrastructure; this includes the scope of ISO/TC 22/SC 3, respectively. There are five active working groups in operations as part of TC204, which is similar to the ISO/TC204 standards working group.

C. Global initiatives toward ITS

In order to initiate cooperative ITS, various processes are carried out all around the globe. In the European Union, ERTICO (European Road Transport Telematics Implementation Coordination Organization) focuses on this initiative. And in the United States, ITS America deals with the promotion of ITS and cooperative ITS development in that particular region. In Japan VERTIS (2) (Vehicle, Road, and Traffic Intelligence Society) took the initiative toward ITS deployment. The main objectives of VERTIS are to further enhance the research and development in the ITS-related arena and to establish communications with its counterparts in Europe and North America to create awareness globally.

D. ITS Korea

In 2001, Korea chose the establishment of ITS as one of the major plans of “Advanced Green City” and one of seventeen new growth engines of South Korea. In addition to that, through advanced IT technologies, the ITS makes great contributions to sharpening the Korea’s ITS. By 2020 ITS deployment rate would increase from 14% to 30%. Furthermore, installation of RSU, sensor hardware which are essential for ITS, would effectively increase. An analysis portrays that ITS deployment and installation would result in an increase of average travel speed by 20% and a decrease of traffic congestion by 30%.

E. ITS Australia

ITS Australia is an independent not-for-profit organization representing ITS suppliers, academia and transport businesses and the commuters. ITS Australia has various collaborations with leading ITS organizations all around the globe. ITS Australia classifies the application of vehicular communication, data handling and transmission technologies for in-vehicle, V2V, V2I, and mode-to-mode systems to increase transport efficiency, to provide safety, and to improve the performance of Australia's transportation networks.

F. ITS Taiwan

Taiwan's geography is complicated, which demands a diverse range of professionals and experts to ensure the successful deployment of intelligent vehicular network model. Furthermore, Taiwan's future economic growth depends on solid transportation infrastructures and management systems. Hence, in order to make advances in this area of ITS, the Intelligent Transportation Society of Taiwan was established in 1998 to bring together Taiwan's professionals and experts from industry, government sectors, research institutes, and academies committed to the development of ITS. Furthermore, ITS Taiwan has fruitful collaboration with various ITS organizations around the world such as ITS America, ERTICO in Europe and ITS-Japan. The members of ITS Asia Pacific, a regional society member, include China, Hong Kong, Indonesia, Malaysia, India, Thailand, and New Zealand. Apart from that, countries like the United Kingdom and Singapore actively participate in the deployment of ITS installation.

G. ITS India

Association For Intelligent Transport Systems (AITS), India is a registered not-for-profit organization working towards the development and deployment of ITS in India since 2001. AITS, India is a forum that brings Government, Academia and Industries together to focus on visions set- up by the Government and direct Research and Development for implementing visions in the field of ITS. Association For Intelligent Transport Systems, India is a registered not-for-profit organization working towards the development and deployment of ITS in India since 2001. AITS, India is a forum that brings Government, Academia and Industries together to focus on visions set- up by the Government and direct Research and Development for implementing visions in the field of ITS.

VII. IBM INTELLIGENT TRANSPORTATION: CASE STUDY

IBM Intelligent Transportation conforms to the National ITS Architecture, and follows the ITS common structure for the design of an ITS framework, as depicted in Fig. 2. The IBM Intelligent Transportation architectural design was developed around this framework. IBM Intelligent Transportation is tailored to meet the needs of the end user while maintaining the benefits of a common architecture. "Center" subsystems deal with the functions typically assigned to public or private administrative, management, or planning agencies. IBM Intelligent Transportation implements the center subsystems highlighted in Fig. 2, which include roadway information and reporting, traffic management, archived data management, and core services (such as administration, authentication, and authorization) [20].

A. Traffic Management

The traffic management subsystem consists of traffic surveillance and managing events or incidents.

B. Traffic Surveillance

Traffic surveillance processes traffic data and provides basic traffic and incident management services through roadside and other subsystems. All preprocessed data about vehicles passing through the surface street and freeway network are collected by processes. The data are then sent to processes that distribute it to other facilities and load it into the current and long-term data stores. The data in these stores, plus weather and incident data, are used by processes to produce an analysis. (In future releases, a predictive model of future traffic conditions will be produced.) The results of this process, and the data stored by processes, are available for display by traffic operations personnel and the media. The processes that make up the Provide Traffic Surveillance facility within the Manage Traffic function include storing and managing the processed traffic data, displaying and outputing traffic data, and exchanging data with other traffic centers to analyze, correlate, and report traffic data.

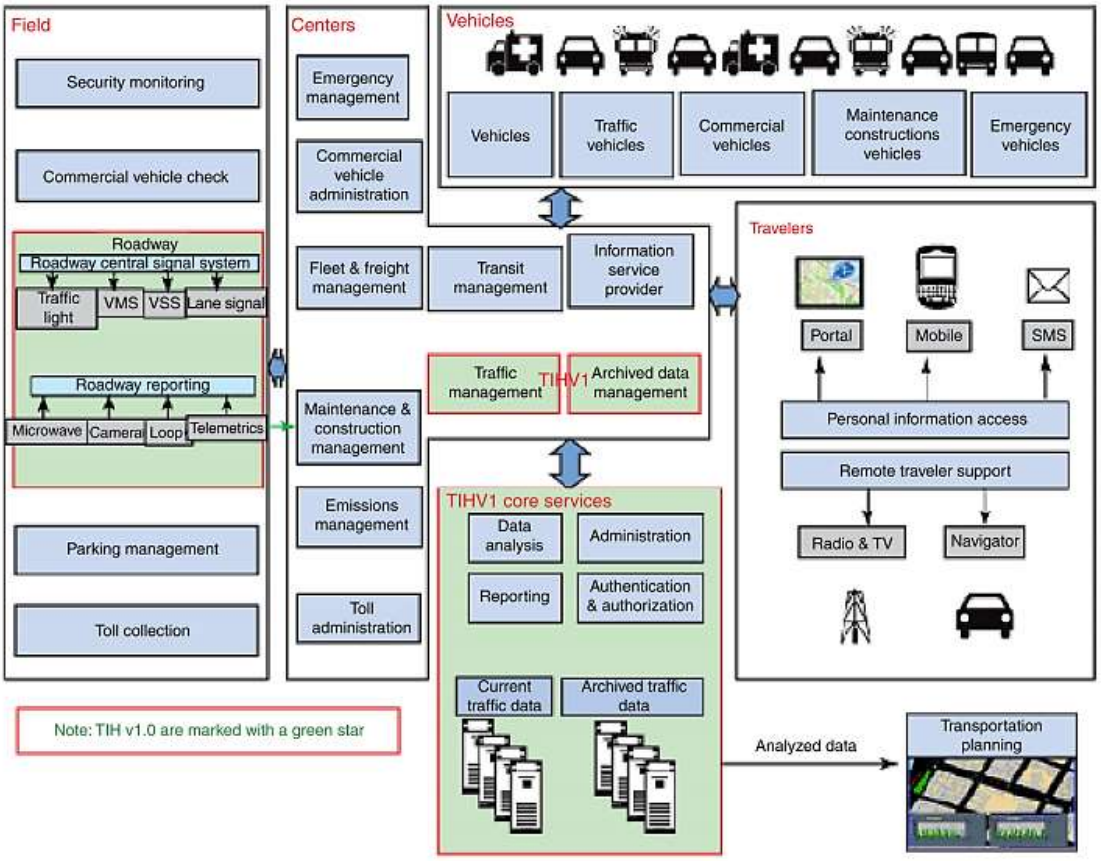

Figure 2: IBM Intelligent Transportation Systems

C. Manage Events/Incidents

ITS provides the processes that make up the manage incidents facility within the manage traffic function. These processes manage the classification of incidents and implement responses when they actually occur. The facility will store, manage, and categorize traffic events static data. It provides operator interfaces for events and it also provides traffic data analysis of traffic events and the major functionality is to review and manage events data. The event management processes divide events, or incidents, into three types: possible, predicted, and current data. For example, planned events could include special events, sports events, and maintenance and construction activities. Current incidents might include traffic accidents, natural disasters, and incidents caused by the effects of the weather.

D. Archived Data Management

The archived data management subsystem collects, archives, manages, and distributes data generated from ITS sources for use in: transportation administration, policy evaluation, safety, planning, performance monitoring, program assessment, operations, and research applications. Key services of the archived data management subsystem include managing the archive data administrator interface, managing the roadside data collection, acquiring archive data, storing and managing archive traffic data, analyzing archives, and finally preparing report inputs.

E. Application in Freight Management

Facing a world that emphasizes reliance on foreign goods, the experts have suggested that ITS be used to streamline and optimize shipping, ensuring an uninterrupted flow of goods into and across the nations. In these scenarios, ITS could expand into the realm of detection and tracking. The increase in imported goods necessitates an improvement in goods scanning and tracking to enhance freight system security. Such technologies would need to rapidly and efficiently scan for radiological, biological, and chemical threats, intentional or otherwise. To improve the efficiency of "sniffer" technologies, these devices could be applied while the freight is in transit. When a threat is detected, it could be reported to security personnel at the port along with information on the cargo vessel's location, its expected arrival time, and vessel schematics, which identify where the threat is

located. Such technologies could also alert emergency responders, ensuring the safety and efficiency of the freight system.

VIII. CONCLUSION

Many leading industrialized countries have embarked on major national ITS strategies to ensure that they integrate ITS successfully into modernizing their transport systems. Capturing the potential of ITS to facilitate social, safety, economic, environmental and commercial objectives is involving these countries in higher levels of co-operation, research and development and investment, across both the public and private sectors. So, Intelligent Transportation System is a broad field which covers many technologies and they plays a significant role in the technology era.

ITS deployments have the possible to offer the following benefits: improved safety, efficiency, mobility, accessibility, intermodal connections. Through the Intelligent transportation system, many areas take advantages. The beneficiaries' areas are arterial, freeway, freight, transit, incident, emergency, data collection, toll collection, environmental issue, traveler information and archived information management. This paper presents a wide-ranging area of intelligent transportation system and its applications and range of technologies. This paper enables researchers to understanding of Intelligent Transportation system overview and provides researchers with information on ITS areas in which further study may be needed.

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