# CHAPTER 2

# LITERATURE REVIEW

To know the present status of navigation system in transportation, the literature has been reviewed through reputed national and international journals, national and international conferences, books and internet etc. This chapter presents an overview of existing GPS based navigation system for transportation with their benefits and limitations and discusses some recently developed vehicle tracking systems. Alpine Claims created the first navigation system in 1981, which was used for transportation in early 1990s and become popular in the twenty-first century. Since then many companies are launching navigational products for transportation.

Rest of the chapter is organized as follows: - Navigation systems are explored in Section 2.1. Section 2.2 discusses the GPS and GSM based vehicle tracking system. The various worldwide transportation systems are explained in Section 2.3. Section 2.4 shows the research gaps. The summary of the chapter is explored in Section 2.5.

## 2.1 Navigation System

A modern navigation system determines the position of navigating vehicles using sensors and maps. Navigation system[75] is a collection of position and orientation sensors, computing devices, communication hardware and software also. It is the field of study, which focuses on the process of controlling and monitoring the movement of a vehicle. It is capable of containing maps, which are displayed as Graphical User Interface (GUI) in human readable format and provides direction to the vehicle or human using text or speech. The background of the navigation system is described below.

### 2.1.1 Background of Navigation System

The word Navigation is extracted from the Sanskrit word 'Navigraha', which means Navigaman in Hindi. Like human history, the history of navigation system is very old. Traditional navigation systems were limited to follow landmarks and memorize routes. The history of navigation systems is divided into following centuries 11$^{th}$ century, 15$^{th}$ century, 18$^{th}$ century, 1930s, 1940s and today. Some historians[76] stated

that more than 1,000 years ago, in the 11th century Chinese used simple compasses to pinpoint direction, based on the principle of magnet i.e. the opposite attracts. Magnetic compass system works on earth's magnetic field in which the north end of the magnet attracts the south pole of the earth. In 15th century Mariner's Astrolabe was used to find latitude while travelling far away from the sight of land. In 1533 Peter Apian's Geographia demonstrate the positioning in the "good old times", which was meant as measuring angle between two points. As shown in Figure 2.1 the angle between bright stars and the Moon is called as lunar distance.

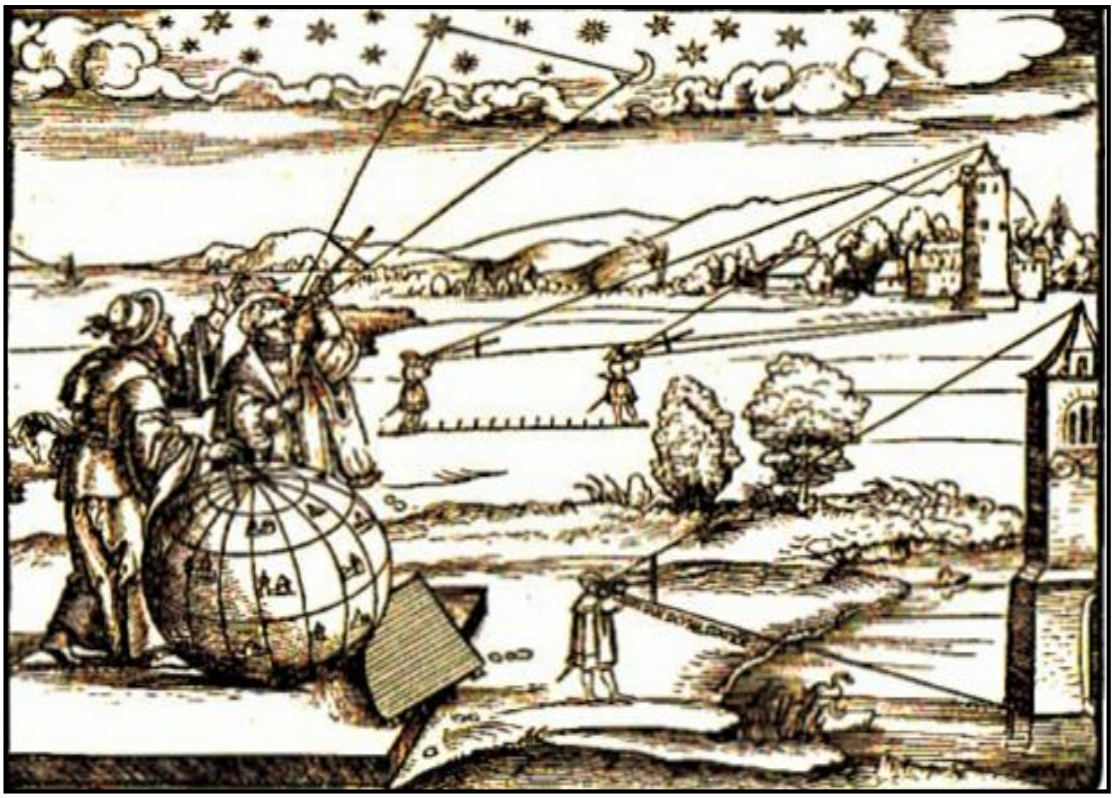

**Figure 2.1** Geographia by Peter Apian [Courtesy: Peter Apian, 1533]

In 18th century Marine Chronometer (looked like Astrolabe mariners) was used, it could navigate latitude, but could not find longitude. In 1915 German scientist[77]Alfred Wegener published the "The Origin of Continents and Oceans". Radio direction was begun in 1930s as the alternative to celestial navigation. Radar navigational tools were first used during 1930s and 1940s by several countries. An antenna was used to send signals through radio waves pulse and received by the antenna to calculate the distance of the object by computer. Nowadays GPS receivers are used for navigation to detect position very accurately.

Birds and animals also use navigational[78] system for migration. They use the several navigation cues like smell, vibrations, sound, site and temperature for navigation. According to some biologists there are four theories like use of the sun, the stars, the earth's magnetic field and visual landmarks, which are used by both animals and birds for navigation. Birds like humans use the sun, track the daily light-dark cycle whereas some birds use the shadow of sun to obtain location. They also use stars when the sun is not available as a guide at night. Most of the birds use earth's magnetic field for navigating thousands of miles. The idea of using visual landmarks by birds had long been a popular theory for navigation by using visual landmarks such as rivers, mountains and coastlines. Some biologists believe that birds use smell to navigate, but this theory is less accepted.

## 2.2 GPS and GSM Based Vehicle Tracking System

Several authors have developed various vehicle tracking systems based on GPS and GSM. Before GPS and GSM, various traditional techniques were used for vehicle tracking like vehicle cards, digital road maps, vehicle sensors etc. but they were not much efficient.

In 1989 Robert B. Weld described that communication[79] flows for vehicle navigation and information system like Infrared Proximity Systems, Low Power RF Beacons, Inductive Loop Systems, Sub-carrier Data Systems (RDS), Mobile Satellite Service (MSS), Trunked Radio Systems (SMRS), Cellular Radio Systems, and Data Radio Networks (DRN).

David M. Mark developed[80] a system in 1989 that had ability to perform five essential functions: location of vehicle, geographic database and its destination, instruction generation, route planning and vehicle control. Developed system also provides communication methods whereby commands and information may flow among these components. Then, these modules may be grouped and allotted to various people and devices involved in the Vehicle Navigation System (VNS). Dr. Alison Brown designed[81] a low cost GPS tracking system that provides more accurate service suitable for operation world-wide. A low cost vehicle sensor TIDGET$_{TM}$ developed by NAVSYS was used into this system. The system uses software product developed by NAVSYS that provides the transportation vehicle's

location to be computed even when only two minimum of two GPS satellites are in view.

Some authors used filtering techniques i.e. a centralized technique, in multi-sensor navigation systems for vehicles tracking, but the quality control has become a major concern in kinematic positioning, so federated filter, a special form of decentralized filtering has been evolved by Mohamed A. Abousalem *et al.* as a means of quality control[82] by constituting an integrated system in which sensors' performance is separated. The experimental result shows that these federated designs go well with with the requirements for system output and allows the use of preexisting software of the sensors in an integrated way without any modification.

According to J. B. Bullock *et al.* digital road maps[83] were widely used in vehicle navigation system throughout the world because of their more availability. The focus of five major digital road map suppliers was on producing database to support the functions of vehicle navigation.

The Intelligent Vehicle-Highway[84] Systems act was passed by congress in November 1991. The results of Max Cameron *et al.* research showed increased safety of traveler on highway and reduced response time in emergency. This research article also considered a project to show effective interaction between the public and the private sectors to achieve safety needs of public and transport.

The research of Eric Abbott *et al.* showed various applications for land vehicle along with the technical aspect of its navigation[85]. The primary goal of Dusan Teodorovic review was to presents the basic element of theory and application of Fuzzy Logic (FL) in traffic and transportation[86] engineering. Concept of fuzzy logic combines both subjective and objective knowledge. Fuzzy set theory represents mathematical approach to solve complex transportation and traffic problems that are characterized by subjectivity, ambiguity, and uncertainty and imprecision.

Alexander Fay proposed a flexible[87] and modular structure that is very helpful for the development of dispatching support system for various public transport systems and also useful in traffic performance, reliability and customer satisfaction.

An efficient fuzzy path tracking[88] algorithm was implemented by A. Rodriguez-Castano *et al.* in 2000 for path tracking and position estimation of vehicle using Differential Global Positioning System (DGPS).

An open architecture for tracking[89] and tracing in transport and logistics has been proposed by Kai Jakobs *et al.* The main criterion of this architecture was scaled extremely well. An additional server could be installed if needed, with no need to modify existing corporate IT infrastructure.

FL based steering control[90] system for an automated car was developed by Jose E. Naranjo *et al.* in 2003, using Real Time Kinematic Differential GPS (RTK DGPS) for high precision.

Jae Heon Ryu *et al.* gave an autonomous[91] system based on RTK-DGPS on a commercial vehicle for an unmanned transportation application. The limitation of this system was that the autonomous vehicle was operated in a limited area at low speed only.

GSM-Based mobile tele-monitoring[92] and the management system for inter-cities public transportations have been implemented by M. AL-Rousan *et al.* By using wireless technology, GPS and GSM system provides a powerful management of transportation engine, which allows tracking of the vehicle and gives updated information about the current trips.

S. Syed *et al.* presented a map[93] matching algorithm, using a High Sensitivity Global Positioning System (HSGPS) receiver in urban canyons at poor satellite visibility. This algorithm is well suitable for soft computational methods.

In 2004 Adrian Hiliuta designed a hybrid system[94] from the data of GPS and Inertial Navigation System (INS) to obtain correct navigation data of vehicle. In case of absence of GPS data, the system takes data from INS and performs its task.

A cost effective train tracking system[95] based on radio communication was developed by Antonio Jose Duarte Santos *et al.*, which locate the train on high precision in real time, both inside as well as outside the tunnel.

Ye Lei *et al.* developed a new methodology integrated[96] with GPS, General Packet Radio Service (GPRS) and Geographic Information System (GIS), which gives the possibility to solve questions about the Location Based Service (LBS), navigation and intelligent transportation.

Kalman filtering technique[97] was proposed by Han Baomin *et al.* which can give optimal estimation of moving vehicles when it is applied on Vehicle Navigation System (VNS) operated by GPS. In this technique, the navigation accuracy depends on reliable function model, stochastic model and proper estimation method so that it

provides the feature of good stability, strong adaptability and well elimination of gross errors.

The system developed by Stephen Teang Soo Thong *et al.* tracks[98] objects with higher accuracy in the areas where GPS signals are weak or unavailable by using the concept of concurrent GSM and GPS positioning system.

Bi Jun *et al.* gave an algorithm[99] for vehicle navigation system which takes the advantages of bidirectional search, projection, minimum angle and binary tree. This algorithm can reduce the searching space and increase the searching speed greatly and algorithm time complexity cannot exceed O(N).

A new wireless transport model[100] based on the combination of GPRS and bluetooth technology has been proposed by Song Jie *et al.*, which is fast, stable, secure and a new model of intelligent public transportation system that was established on the existing transportation model.

A hybrid GPS/GSM based positioning[101,102] system was designed by Hsin-Yuan Chen *et al.* and Tung-Yi Chou *et al.* to improve the accuracy with the help of FL.

An advance driving[103] information system of Vincenzo Di Lecce *et al.* receives the acceleration signature from the low cost sensors and a GPS receiver concludes the driving behavior. This architecture was robust and flexible.

An Automatic[104] Vehicle Location System (AVLS) is based on GPS and GSM technology. In some developing countries like Iran, wireless technologies like GPRS had not been developed well, so Ali Mousavi *et al.* decided to design a GSM based technology through which all data is provided to the user.

Khondker Shajadul Hasan *et al.* presented[105] an object tracking system based on GPS and GPRS which is cost effective (due to GPRS service) as compared to existing SMS based tracking system. This architecture reads the current location of the object using GPS and the data is sent via GPRS service. It is also helpful in car theft situations.

The results of N. Hernandez *et al.* research[106] showed that the uncertainty can be reduced by wifi localization system based on fuzzy logic. Traditional approaches[107] used Strong Tracking Unscented Kalman Filter (STUKF) for navigation which was the combination of Unscented Kalman Filter (UKF) and String Tracking Filter (STF). To remove the shortcoming of traditional approach, a new technique was

developed named Fuzzy Strong Tracking Unscented Kalman Filter (FSTUKF) by Dah-Jing Jwo *et al.*

The author Zhang Fei presented[108] the current situation and development situations of the ITS in china and introduced some ideas to promote development of technology for ITS. By using existing GSM network[109] technology authors Md. Zaved Parvez *et al.* designed a novel vehicle tracking system having advantage of low cost. It neither requires any modification in the existing system nor does it demand any additional hardware.

In the real environment[110] Received Signal Strength (RSS) technique had several limitations such as multipath, diffraction and reflection etc. Chih-Yung Chen *et al.* designed a new fuzzy approach called FL Indoor Positioning System (FLIPS) to avoid these limitations. Cell-ID based Vehicle Locator and Real-Time deactivator (VLRD) using GSM network is used for tracking vehicle and vehicle thieves.

Nilesh Dubey *et al.* designed[111] a system named VLRD to overcome the drawbacks of GPS and SMS based vehicle tracking systems, which is cost effective and highly reliable, works without using GPS technology. Iman M. Almomani *et al.* proposed a system[112] which is accessible at anytime, anywhere and allows system users to track down their vehicle position, speed, Stop, and movement. It also allows monitoring of the vehicle when other person is driving it. It prevents the vehicle theft by using vehicle alarm and displays the location of theft vehicle on Google map.

The major concern of Wen-hai Cai *et al.* was to promote[113] the usages of cloud computing in the field of transportation. This research also presented the procedure for making the cloud transportation system and an intelligent new generation transportation system which is based on cloud computing.

A hybrid GPS-GSM system was proposed[114,115] by Mohammad A. Al-Khedher and Montaser N. Ramadan *et al.* for tracking the vehicle using Google earth, it also increases the accuracy of measured location by using Kalman filter and displays the current location and status of the vehicle on Google earth. Intelligent anti-theft tracking system is very efficient and safe in emergency situation and engine failure.

Zhengzhong Li *et al.* designed[116] a Vehicle Tracking Data Recorder (VTDR) for recording vehicle speed, real time, mileage and other status information. The hardware and software architecture of this system includes Radio Frequency

Identification (RFID) authentication for driver, data collection, data storage, data printing, serial and USB communication and LCD display.

The main goal of Daniel K. Schrader *et al.* research was to design a more accurate and reliable system[117] using inexpensive GPS receivers only for vehicle tracking applications. A GPS, GIS, GPRS and RFID based bus monitoring system[118] was implemented in 2012. A new theoretical and rule based framework was designed for this system. This system was able to reduce man power which is required on monitoring center.

Muhammad Ridhwan Ahmad Fuad *et al.* also gave GPS, GSM and Goolge[119] earth based vehicle location tracking system. This system was used in many applications including vehicle security and fleet management. An integrated cost effective public vehicle tracking[120] system, which is combination of both technologies GPS and RFID is designed by Apurav Vasal *et al.* It provides public vehicle arrival information at predefined Stops and improves public vehicle occupancy.

A system integrated[121] with RFID, GPS and GPRS locates the accurate position of vehicle under complex environment. For better accuracy, LANDMARC algorithm was used by Y. Ning, W. Zhong-qin *et al.* In 2013 authors[122] Ibrahim Abdallah Hag Eltoum *et al.* designed a velocity based tracking system. The system developed by M. Behzad *et al*. allows users to track speed, water level, engine level[123] and location and also provides the scalability, integrity, portability, usability and security. Pradip et al. developed hardware prototype[124] and GUI application for monitoring the movement of vehicle using GPS, GSM and microcontroller. A GPS and GPRS based real time bus monitoring[125] system which provides the location and Estimated Time of Arrival (ETA) is designed by Jay Sarraf et al. Table 2.1 shows the year wise survey of GPS and GSM based vehicle tracking systems based on technology.

**Table 2.1** Year Wise Survey of GPS and GSM Based Vehicle Tracking Systems Based on Technology

| Year | Technology used | Description | Advantages |
|---|---|---|---|
| 1992 | TIDGET$_{TM}$ | Vehicle sensor system of Low cost developed by NAVSYS | • Highly accurate<br>• Inexpensive |

| | | | |
|---|---|---|---|
| 1993 | Federated filter | Special form of decentralized filtering used in transportation | • Uses existing softwares without any major modification<br>• Improves quality control |
| 1994 | Digital Road Map | It was used for vehicle navigation on road | • Inexpensive |
| 1999 | Fuzzy | Well suitable for both subjective and objective knowledge | • Solve complex transportation problem |
| 2000 | Fuzzy with DGPS | To get more accurate position DGPS was used | • Efficient<br>• Accurate |
| 2001 | GPS,GSM, GPRS and RFID | Hybrid architecture was designed with the help of GPS, GSM, GPRS and RFID technology | • Easy to install |
| 2003 | Real Time Kinematic Differential GPS (RTK-DGPS) | To enhance the precision of position data RTK_DGPS was used | • More accurate |
| 2004 | High Sensitivity GPS (HS GPS) with fuzzy | In indoor applications where GPS received signals were weak, HS GPS was used to integrate weak signal | • Well suitable for soft computational methods<br>• Provides accuracy at poor satellite availability |
| 2004 | Inertial Navigation System (INS) | INS was used with GPS. Fuzzy algorithm was used to correct INS and GPS data for accurate results | • It also works in the absence of GPS |
| 2006 | GPS+GPRS+GIS | Real time tracking and monitoring system was designed with these technologies | • Solve complex problem |
| 2006 | Kalman filter | Robust Kalman filter algorithm was used to | • Good estimation of gross errors. |

| | | | |
|---|---|---|---|
| | | eliminate errors | • Scalability<br>• Adaptability<br>• Robust |
| 2009 | Wifi Localization | Fuzzy based Wifi localization system was designed to obtain estimated position | • Robust |
| 2009 | Strong Tracking Unscented Kalman Filter (STUKF) | It provide the more accurate results as compare to traditional filtering technique | • Provides more accuracy |
| 2011 | Google Map | It was used to locate the received location from GPS on Google map | • View real time location on Googlemap |
| 2012 | GPS+GSM | An alert system was developed for commercial buses based on GPS + GSM technology | • Robbery alert<br>• Accidental alert<br>• On board location display |
| 2015 | GPS+GSM+ Microcontroller | Hardware prototype and GUI based application for displaying actual position of vehicle | • Efficient<br>• Compact<br>• Low cost<br>• Reliable |
| 2016 | GPS + GPRS | Provides real time location of buses and ETA. | • Efficient<br>• Complete location history |

A large number of route guidance systems, alternate route selection systems, optimum route selection and route diversion systems (Peter Bonsall *et al.*, Kim *et al.*, Mohamed Abdel-Aty *et al.*, Shou-Ren HU *et al.*, Hey Ran Kim *et al.*, Alexander Aved *et al.*, S.S. Keshkamat, Constantinos Antonioua *et al.*, Anastasia Spiliopoulou *et al.*, Xingang Li *et al.*) have been developed to select the optimum route. A limited technical literature for selecting optimal route to the best of our knowledge is presented here. Peter Bonsall designed a route guidance[126] and information system on route choice for urban networks. Advanced Traveller Information Systems (ATIS) provides alternate[127] routes to the driver using generalized estimating equations and binomial probit link function. Time taken to travel on diverted route is lesser as

compared to on normal route increases the probability of diversion. Real-Time Route Diversion Management System (RTRDS) was designed to create optimal[128] route diversions using available real-time and historical traffic information. A flexible and cost-effective systematic[129] framework based on traffic assignment models was designed to analyze the value of traffic information in route diversion control scheme. A dynamic route diversion model[130] was developed to capture travelers' route switching behavior in real-time, using on-line traffic management system. Adaptive Kalman Filtering technique was also used to present freeway O-D pattern prediction algorithm. The framework was presented by Constantinos Antonioua *et al.* in which he has discussed the impact of predictive guidance in decreasing mean travel time and travel time variability during incidents. The predictive Variable Message Signs (VMS) shifts[131] a considerable number of vehicles from the routes taking high travel time to the routes taking low travel time, showing more consequently reduction in delays and well-organized utilization of the network capacity. The contribution of onsite information[132] is to estimate the influence of information on drivers' route diversion decision and network performance accurately.

To avoid the recurrent motorway congestion, two route guidance policies[133] have been designed, which are triggered by a saturated off-ramp, but are not much efficient to resolve the spread out and motorway congestion problem. To resolve this, a second case was designed, based[134] on user-optimum considerations. Xingang Li *et al.* designed the diversion drivers' from expressway[135,136,137] to analyze the behaviour under different conditions of network and traffic. It is found from the above review of the literature that there is a need of existing and implementation of new systems, which will help the system users to select more precise optimal route among all the alternate routes and to choose optimal route on the basis of vehicle type.

Bashir Shalaik *et al.* designed a real[138] time bus tracking system which displays tracking information on mobile phones. Developed system provides the real time information about bus location, arrival and departure time of the next bus on particular bus Stops, on the platform of Google Android mobile devices. It shows the position of tracked vehicle on Google map without any interruption even during the time of switching pages and screen by users because of computer software technology 'Ajax'. The system was designed on Android based mobile phones.

Developed system uses the shelf GPS/GSM to send the current position at regular interval of 45 seconds when vehicle is in motion. It uses PHP, Java, 'Ajax', JavaScript, XML and MSQL programming languages. There are several advantages of this system as it provides better travelling choice for the users, saves waiting time at bus Stop and provides accurate information of bus tracking because location is transmitted at a regular interval (45 second approximately). There are several limitations of this system also. This system provides the location of vehicles on the Stop only. Suppose if the vehicle is in between any two Stop then this system is not able to provide the location of vehicle. Another limitation of this system is that it sends GPS data at regular time period of 45 seconds. So it increases the overhead for database and also increases the cost of system. As the system requires GPRS enable and android operating system based smart phones, it is not efficient in term of database complexity because if bus is damaged then also it send location information after every 45 seconds.

A. Al-Mazloum, E. Omer *et al.* designed child tracking[139] system based on GPS and SMS. An Android based child tracking system is designed for parents to track their children in real time. The system consists of two devices one for the parents and the other for the child. The duty of parent's device is to send the location request to child's mobile device and second, child device's main duty is to reply his/her location on parents' device. The architecture of the system is very simple. Child's device acts as client and parent's device acts as server. Child device must be GPS enabled. Parents send request for current location with their mobile phone and the child device will send current GPS coordinates to parents' device with the help of SMS. The advantages of the system are that there is no need of internet connectivity or GPRS, Server is not required for the system and the implementation of the system is easy. There is no need to maintain database. The intervention of children during the time of travelling is the disadvantage of this system. It is also not helpful in case of emergency.

Jattala I *et al.* introduced a Secure Automotive Telematics System (SATS) in which encrypted information[140] is transmitted between SATS and the tracking server. The security of TCP/IP socket (primary communication channel of SATS) is done by SSL/TLS protocol and of SMS (secondary or backup communication channel) is made by using AES-256 encryption algorithm. Constantinescu Z *et al.* presented a

system which provides[141] safety of drivers and passengers from accidents related to tracking system and intentional situations and events like criminal acts by other person, any malicious intention and deliberate causations. The core security technologies and mechanisms along[142] with detailed description of business models, vehicular applications relying on IT security was provided by Marko Wolf *et al.* in 2007.

An analysis of different attacks on navigation system was done by Becker G T *et al.* and authentication mechanism was discussed for vehicle tracking[143] systems, based on Timed Efficient Stream Loss-Tolerant Authentication (TESLA) algorithm. Kyusuk Han *et al.* purposed a three tired mechanism and architecture[144] to securely integrate external devices with the devices placed in vehicles. The architecture is divided into three modules: User devices, Electronic Control Units (ECUs) on vehicle network and gateway. Three tier architecture of this authentication protocol provides secure communication between in-vehicle network and external network.

A secure, safe and comfortable mobility system was designed by Akira Yano *et al.* to reduce[145] congestion by using smart phones, advance mobile communication and by connecting the vehicles to the internet. An intelligent transportation system was introduced to provide a secure, cost effective architecture[146] for vehicle tracking by using existing infrastructure. Chris Wullems *et al.* and Ishitaq Rouf *et al.* proposed authentication[147] schemes[148] which provide authenticity, integrity, privacy and security. The performance of this system is calculated by software simulation.

A trusted platform for inter-vehicle[149] communication was implemented by Schweppe *et al.* which was also used to securely store cryptographic material to perform cryptographic operations. TPM-based secure architecture[150] for Vehicular Ad hoc Network (VANET) is designed by Jadhav Shital Suresh *et al.* The deployment of base station is not required along the road, for this architecture. Chad C. Lamb *et al.* used System Level Diagnosis (SLD) to measure the diagnosability and the availability of the GNSS[151] is evaluated. The literature review specifies that researchers have designed various software based secure architecture to protect the communication between hardware devices and the server and the users, but none of them provided an architecture for information security with fault tolerance.

## 2.3 Transportation Systems

The first earth tracks[152] were formed by humans transporting goods and they frequently followed game trails. Several animals became elements in track creation like horses, oxen and donkeys. Later, the travois, a frame used to carry loads, was developed. In the 4th or 5th millennium BC animal-drawn wheeled vehicles were spread to Europe, in India they were developed in 4th millennium BC and in 1200 BC in China. John Loudon McAdam (1756–1836) designed the first modern highways, for the Industrial Revolution, using low cost material of soil and stone aggregate. In 1967, the first motorcycle was invented. In 1970, modern bicycle was invented, in 1871 first cable car was invented, in 1903 the wright brothers invented and flied the first engined airplane, in 1907 the very first helicopter - unsuccessful design and in 1964 bullet train transportation was invented. In 1662, Paris and France originated first omnibus for public transit system, although the provided service failed some days after its founder died; a famous transportation mode named omnibuses have appeared in 1826 in Nantes (France). In July 1829 these were introduced in London. The rail transport[153] was started in India in the mid-nineteenth century. There was no railway line in India till 1849 whereas in 1929, there were 66,100 km of railway lines serving most of the districts in the country. In 1966 when Haryana was separated from Punjab then a separate transport was needed, which would connect one part of the state with other parts effectively. So, Haryana Roadways Transportation[154] Limited (HRTL) was established with two Regional Transport Authorities (RTA) in 1966. Amabala, Hisar and Faridabad were the next three appointed RTAs in 1987 and other three new RTAs were formed at Rohtak, Karnal and Rewari in 1991. It has approximately thirty five hundred buses being operated by twenty depots, each manage by a General Manager, and seventeen sub-depots running under the depot concerned. HRTL provides its services for passenger transport intrastate as well as interstate. Approximately 1 million passengers travel in Haryana Roadways daily. To find out the research gaps various existing transportation systems are taken from India and worldwide for case studies, which are discussed below.

### 2.3.1 Rail Radar System

Rail Radar system used for tracking the train online was developed by Centre for

Railway Information System (CRIS) joined with Rail Yatri[155]. This application can be accessed by users from their desktop, laptop and mobile phones, via the devices' web browser. Around ten thousand trains running in country are operated by Indian Railways. By using this system, users can track timing of the train, routes, location and Stops. Also, there is no need to remember the train number or train name, by just entering any two stations (Delhi to Jaipur), users will get information about all available trains on that route. Besides this, the feature of zoom in and zoom out in this system helps the users to know the exact station where the train was stopped. It also provides information about the expected time to reach the particular station with departure time. Two colours (Red, Blue) code system is used in this system to show the tracking train status as shown in Figure 2.2.

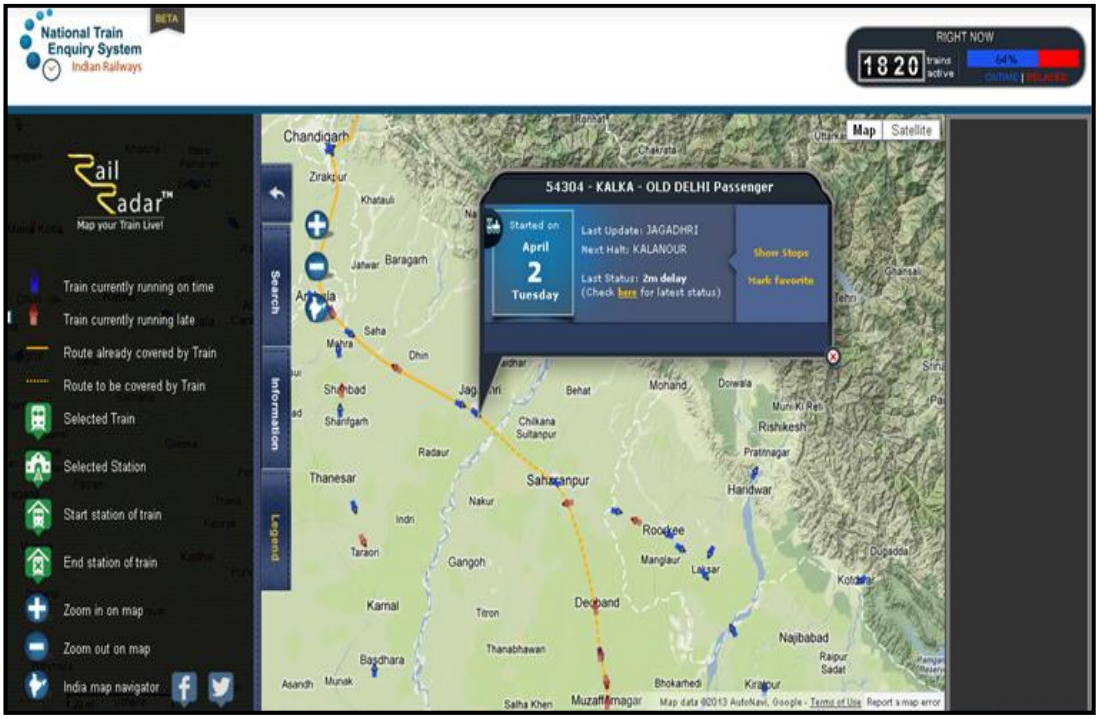


**Figure 2.2** Indian Rail Tracking System [Courtesy: Rail Radar, 2013]

After entering the necessary information about train, the train will be highlighted either Blue or Red. Blue indicator shows that the train is on time while Red shows that it is behind the scheduled time.

## Advantages

- GUI based application

- Save time
- Save money
- Passenger can watch the movement of trains running across all parts of the country
- Passengers can access the information at any time form any where
- highly reliable

### Disadvantages

- Security threats
- Slow speed due to heavy graphics
- Explanation of website is complex

### Gaps

- Most of the Indian transportation systems are not using the latest transportation models.
- Presented system demonstrate a total failure in case of emergencies
- Present transportation Model is a carrier oriented not goods oriented, exception is speed post.

## 2.3.2 Indian Postal Tracking System (Goods Oriented System)

Indian postal tracking system is online service for tracking the speed post as shown in Figure 2.3. The Government of India has proved[156] it free to all system users. Users can online track their articles that they send to valid address using speed post. A tracking number is issued to the users at the time of registering their speed post, a postal receipt is also given. By using this tracking number, users can access tracking information and confirmation of delivery of their items. Items like speed post, international EMS, Electronic Money Order, Express parcel, Registered mails, Electronic Value Payable parcel can be tracked with the help of this system.

### Advantages

- Fast checking of the status
- Tracking is free of cost
- User friendly interface
- Tracks National and International articles.

## Disadvantages

- Delay in complete updating
- No information during travelling of goods
- Email system is not working


**Figure 2.3** Indian Postal Tracking System [Courtesy: India Post, 2013]

## Gaps

- Tracking information is only for office location

### 2.3.3 Haryana Roadways

Haryana Roadways, a state government[157] approved transportation system, plays a significant role in passengers transport in the state as well as in major destinations in neighbouring states, it travels about 10 lakh kilometres every day and transports around 10 lakh passengers daily on one thousand intrastate and four hundred interstate routes. Haryana Roadways provides well coordinated, economic and safe journey to passengers. It has a fleet of thirty-four hundred buses which are operated by twenty depots and fifteen sub depots.

## Advantages

- Quick service
- Economic and safe journey
- Quality of service

## Disadvantages

- Lack of bus navigation information system
- Poor emergency hours service system
- Manual provision for route diversion

## Gaps

- Poor information system
- No emergency hours service system
- Poor route diversion system

### 2.3.4 NextBus

Nextbus is a system which predicts arrival information of navigating vehicles, updated at regular intervals and give reliable real time information[158] to the passengers as well as public transportation department. It was establish in 1996, is successfully providing its services with more than 135 installations in municipal, university, airport and corporate transportation systems till now. Nextbus uses GPS technology and proprietary algorithm along with historical travel data to predict the current position of vehicles, their proposed Stops, expected Stop, usual traffic patterns with high degree of accuracy. This information is updated frequently to keep the passengers on schedule when the vehicle is not. Nextbus arrival information can be obtained through internet to mobile devices e.g. tablets, smart phones, desktop and Light Emitting Diode (LED) signs installed at bus Stops.

## Advantages

- Improved customer's sevice
- Provides cost effective, robust and highly reliable real time information to passengers.
- Confident and accurate prediction

- It puts the passengers in control by providing information about the next vehicle arriving on that route.
- Use of high end technology
- Reducing uncertainty

## Disadvantages

- No provision for route diversion
- Carrier oriented only

### 2.3.5 WaitLess Bus Tracking System

The WaitLess bus tracking system is designed by four engineers; one of them is computer engineer and others are electrical engineer, of Georgia[159,160] Tech campus to display the real time location of buses. The hardware requirements of the system are the solar panel and the battery backup, Programmable System on Chip (PSoC) microprocessor, wireless module and a LED embedded map of bus transportation routes. The approximate location information of buses is depicted by LEDs when the tracking device connects to the internet to obtain GPS data and microprocessor parsed the data to enlighten tri-color LEDs which show the location of every bus. It helps pedestrians to take decision either they do wait for bus or walk. It requires 12 Volt (V) battery backup which is able to recharge by solar panel to make the system cost effective. Power supply, receiving data, processing data and output are the components of WaitLess bus tracking system. Sustained power supply regulated by solar controller provides enough current to the tracking devices as well as charges the battery at the same time. The core components of WaitLess bus tracking device requires 5V instead of 12V. Therefore a switching regulator is designed to step down the supplying voltage to 5V. The GPS data is received from the NextBus (another product) server with the help of embedded devices and internet, and send it to the processing unit. The programming team designed algorithms by utilizing the wiring programming languages based on C and C++ to process the data using ATmega168 microprocessor. After receiving the data from processing unit LED drivers instructs 42 RGB LEDs to blink displaying the location of buses on a map.

## Advantages

- Less power consumption

- Easy to install
- Cost effective

## Disadvantages

- More dependent on hardware
- Dependent on other server for data

### 2.3.6 Coach USA

Coach USA is running in North America[161] to operate scheduled routes of buses, charters, motor coach tours and city sightseeing tours. Around twenty local companies are managed and operated under this system to meet the specific needs of community. Coach USA is studied in three regions- North East region of United States, North central region and Canada.

North East region of U.S. covers NewYork, New Jersey and Pennsylvania provides services like commuters and local bus services, charter and contract services, Newark Airport express shuttle services. 'Gray line NewYork sightseeing" is also operated in this system to offer the Big Apple's premier hop on hop off Double Decker sightseeing bus tours.

Several major cities like Chicago, Milwaukee etc. in Northern Midwest are served in North central regions of U.S. with services including contract and charter services Chicago Airport bus services and school bus business in Milwaukee. 'Chicago-Trolley and Double Decker co.' is also operated in tours of Chicago double decker buses and classic trolleys.

Coach USA system serves Quebec and Ontaria in Canada region involving major centers like Toronto, Kingston, Niagara Montreal falls. Services provided by the system are charter and scheduled services, contracts services and different bus tours. Mega bus is also operated between major cities likes NewYork and Boston or Chicago and Minneapolis in the above mentioned three regions of U.S. Coach USA is becoming a 'Green Company' as it helps us to save environment by limiting the emission of buses to conserve energy.

### 2.3.7 Interstate Bus

After investigation of the feasibility of bus services, Interstate Bus system[162] was developed by Messrs Abel Erasmus and Fred Kinnear on 28 April 1975. Instead of

many complications and objections by railways and the BIC, Insterstate bus system was first applied on a small bus company of the late Jacob Mokgethi, who conducted only four buses in the hinterland of Thaba- Nachu on the assigned routes.

Nowadays, Interstate bus system is operated in a broad region of Mangaung Metropolitan municipal areas including daily services between Thaba Nchu, Botshabelo and Bloemfontein, Brandfort and regular weekend services from Bloemfontein to Welkom. It is also operated for organized hired groups. With time, Interstate Bus system underwent several transformations, as in 2004, through the Black Economy Empowerment process, 40% shares and management control of the company was under Blacks. Again in 2006, company underwent a Broad Based Black Economic Empowerment process and 'Itumele Bus' Line a new broad based company is established, trades as Interstate Bus Lines. The company was first known as Thaba-Nchu transport, later named Jakaranda transport.

### Advantages

- Operating among states
- Compatible with environment

### Disadvantages

- No provision for route diversion
- Carrier oriented

## 2.4 Research Gaps

As discussed the above literature we are able to find out various research gaps as shown below.

1. Same semantic of a Stop for small and long route
2. Manual method for classification of Stops and vehicles
3. On the spot observation for break/halt in journey
4. Either carrier oriented or goods oriented not both
5. No provision in navigational emergencies (e.g. accident or traffic congestion)
6. No provision for exploration of options for routes
7. High cost

## 2.5 Summary

A number of exiting GPS and GSM based navigational systems have been designed for public and private transportations. Most of the navigational systems are carrier oriented and costly (in terms of software and hardware). It is quite clear that the above discussed existing navigational systems provide little work on the use of fuzzy logic in navigational system and provision for route diversion. The aim and objectives is given in the next chapter.