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REVIEW

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A Systematic Review on Intelligent Transport Systems

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Abstract: Transportation is very important issue in everyone's life as the things need to be carried from one place to another. It plays a vital role to transport various health equipment's, groceries, and daily needs of the people from outside and inside the country. The intelligent transport system (ITS) is actually a system that uses the digital technologies to smoothen the transport system helping them to overcome the issue of accidents, reduce the pollution, reduce the traffic congestion on roads, and help them in delivering the services timely. Many researchers integrated various virtual technologies to propose the best ITS. In this work, the existing work on the ITS done in the last 20 years has been analyzed to address various issues and problems in the existing ITS models. The security aspects have also been addressed along with the various vulnerabilities and solutions to protect ITS. We provided a comprehensive study of existing literature on ITS, their highlights, merits, and demerits. The research papers focused on ITS have been analyzed and at last out of 80 research papers best 70 were included in this work for the study of ITS. The objectives of this study are to provide insights to the beginners of this research area and to analyze the existing solutions aiming to provide the ITS. The future research directions have also been proposed in this work.

Keywords: intelligent transport system (ITS), internet of things (IoT), machine learning (ML), security in ITS

1. Introduction

Intelligent transport system (ITS) is an emerging research area that involves the use of different areas like sensor networks, machine learning (ML), transport area from civil engineering, and many more. It is actually the combination of various research areas that focus specifically on the problem of road safety. ITSs are designed and implemented to tackle the traffic-related problems such as traffic management, accident prevention, tolling on roads, parking systems, and pollution control. ITS is concerned particularly to provide smart transport system to manage the huge number of vehicles on the road so that traffic congestions can be reduced and accidents can be avoided. ITSs strengthen the transport system using various technologies to empower the services related to traffic congestion, traffic management, and road accidents through informing the users about the real-time scenario of the road (Khorasani et al., 2013). ITS ensures the road safety and saves the life of people by prior informing them about road conditions, climatic conditions, and traffic conditions (Bělinová et al., 2010; Nguyen et al., 2018). This smoothens and makes the transport system efficient by enhancing the quality of transport networks.

As shown in Figure 1, it can be seen that the ITS works using information technology and wireless networks are involved to communicate the signals among various vehicles moving on the road. The moving vehicles in this way get to know about the status of traffic congestion on the roads and on that basis, they can prepare to handle the traffic. This scenario actually manages the traffic on the road as shown in figure, every vehicle moves on their own dedicated path. In this way, the ITS helps to make the transportation system to work in an efficient manner.

The quick rise in the population drastically effects the mobility of people on pavement. Vehicle traffic includes managing traffic in street organizations. It decreases congestion, lessens vehicle collisions, and improves vehicle flow on the road, particularly the normal utilization of pavement resources (Qureshik & Abdullah, 2013). The rules, signs, and lights for traffic and cops' traffic have added to introduce the foundation of guidelines for the traffic (Javed et al., 2019; Mfenjou et al., 2018). The system for transportation in growing countries faced problems with a few real factors due to the absence of street infrastructure: the vast majority of these growing countries lacks in adequate pavement frameworks. This implies that any kind of vehicle goes on single tracks. Moreover, some of the countries suffer from the telecommunication technologies due to which they are not able to tackle the problems of transport system. ITS is the integration of information and communication technology that helps them to tackle the problems generated due to traditional transport system. Transportation frameworks in agricultural nations are confronted with a few real factors. We have the absence of value street infrastructure: the greater part of these nations does not have great street infrastructures. The lack of telecom foundations is another issue in these nations. We additionally have the shortfall of an effective framework for observing exercises out and about connectivity. Additionally, there is a high pace of car crashes in these countries particularly on streets that connects urban cities (Mfenjou et al., 2018). Various technologies have been used for the implementation of ITS. The most popular technologies used these days are Internet of Things (IoT) and Internet of Vehicles

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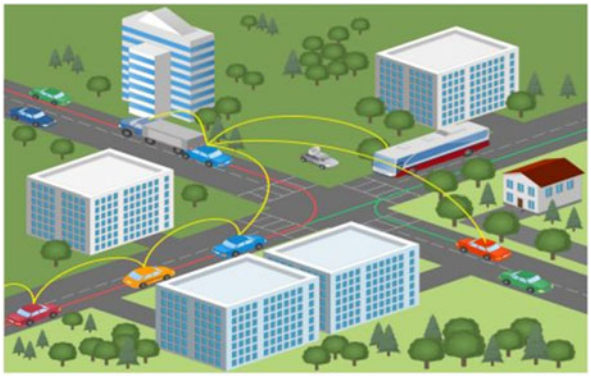
Figure 1
Intelligent transport system



(IoV) (Sherly & Somasundareswari, 2015). All the data that are required to provide information to the drivers will be collected through the sensors and after that that data will be analyzed using various data mining tools and technologies. ITS is the blend of technologies that operates together to provide the best transport management system. Vehicular ad hoc networks (VANETs) have variety of applications for smart transportation. VANETs help the drivers about constant traffic by sending notice and data messages just as by creating alarms for hazards. The primary point of VANETs is to give traffic security and proficiency as far as decreasing time, cost, and emission of pollution. IoT is an arising technology that connects the digital and actual world (Javed et al., 2016). The idea of IoT has prompted the development of the more brilliant and insightful planet by enabling communication among items and human (Kunwar, 2014; Mfenjou et al., 2018). The various application areas for ITS have been represented in Figure 2.

1.1. Motivation of systematic review

The key points that motivated to do this work are:

- ITS is the need of today's modern world. As continuously, there is rapid rise in the count of vehicles on the road due to which the people try to violate the traffic rules and policies to reach their destination as early as possible. This results in increase of the accidents day by day. So, to save the people lives, it is a very important area to be investigated to smoothen the transport system.
- The existing research carried out by various people consists of various approaches to propose the best solution for providing efficient transport system, but still there are many aspects which they have not considered and ignored but are very important to explore. Exploring more in this area of ITS is the significant motivation for this systematic study.

Figure 2
Application areas of ITS

- This systematic study will definitely help the beginners to do research on the unexplored areas of smart transport system.

1.2. Contribution of review

The major aspects that are contributed by this systematic study are:

1. The need of ITSs, its significance and requirements, its pros and cons, and various issues related to its implementation has also been discussed in this work.
2. The major application areas where ITS is widely used are presented in this review.
3. The various problems that are faced while implementation of ITS and solutions to tackle those problems along with the security issues and challenges have also been described in this work.
4. The existing literature in which different ITS proposed by them and their drawbacks has also been highlighted. Future research areas to implement ITS have also been discussed.

The work carried out in this paper is organized as follows: Section 2 describes the background of ITSs; in Section 3, the methodology used for systematic review of the existing literature and various research questions that arises has been discussed. Section 4 describes the ITS technologies and applications of IoT and IoV in ITS. In Section 5, various issues related to ITS security have been discussed. ML-based security mechanism has also been discussed in this section. Then further in Section 6, brief discussion about the existing ITS approaches and issues proposed by various researchers has been done. Finally, in Section 7, the conclusion of this systematic study along with future directions in this area has been described.

2. Background

Transportation is the most concerned issue as everybody needs to go from one place to another to earn their living or there can be number of reasons. The traffic on the roads is increasing day by day that is threatening the human life. Smart strategies need to be implemented to smoothen the transport system to prevent the accidents (Mahmood, 2020; Zhang, 2019). Different strategies using different technologies have been proposed by different researchers and they have been discussed in Section 3. Among all these approaches, this paper focused on particularly the problems and solutions for them proposed by existing work carried out for ITS.

2.1. Timeline evolution

The ITS implementation actually began in 1970s. Initially, in year 2000 (Verhoeff et al., 2000) an ITS proposed as "VEHIL: A full-scale test methodology for intelligent transport systems vehicles and subsystems" in the form of a hardware that was deployed on vehicle and tested and named as intelligent vehicle system (Yang et al., 2017). It used the concept of platooning and this approach was totally hardware based and testing was done for full vehicle system. Due to its complex implementation, it was not so much successful. Then a traffic simulator tool was constructed (Im et al., 2000) to evaluate the performance of ITS. That simulation tool combined the characteristics of vehicle, driver, and environmental factors, and performance of ITS was evaluated for curved road. The interaction among different vehicles on the road was done using the brake simulation. The survey of all the existing applications of intelligent vehicle systems has been done in the research carried out by Bishop (2000) in year 2000. The distributed computers that shared memory telematics environment (DIME) for intelligent transportation

systems were implemented by the "SIM group at The Nottingham Trent University, UK" in year 2001 (Bargiela & Peytchev, 2001). The proposed DIME system combined the approach of diverse traffic and travel information system. This system was particularly designed for collection of the data messages by the transport system for the city Nottingham, but its performance was not as expected. In Shimura et al. (2003), an autonomous model was proposed for group management in which every node independently investigates and find out with which node it has to work and then dynamically combines and make a group to complete the requested job. This model was implemented for the moving systems that consists of moving terminals and base stations. Information to the vehicles moving on the road was communicated through the base stations, and it was tested specifically for areas of Japan and finally a base station model was designed for the ITS. In year 2003, ITS was proposed dedicated for the cities that involved use of cybernetic transportation system called as CTS. It worked only for the vehicles on the road that were incorporated with the features of automated vehicles, so not applicable for other vehicles (Parent & Gallais, 2002). The proposed approach was experimented only for the European cities. Dailey et al. (2002) proposed self-describing data model for ITS applications in which a framework was proposed to create, encode, and decode the data stream that helps to develop the ITS. "Push to Talk Service" was proposed for ITS (Gan & Lin, 2007) in which at one time only one person is allowed to speak and other persons on the road in their vehicles will listen to him. This approach was actually to provide the interaction between the persons driving their vehicle on the road to inform others about the road scenario using walkie talkies. To avoid interference, only one person was permitted to speak at a time. From year 2010 onwards, various approaches were proposed for the evaluation of ITS using various ML mechanisms (Khorasani et al., 2013). A number of data analytic techniques were reviewed to evaluate the best data analytic method for ITS (Javed et al., 2019). The development of cooperative ITS (C-ITS) using IoT and IoV has also been elaborated by various researchers (Mfenjou et al., 2018).

2.2. Advantages of ITS

ITS uses the information technology and various other advanced technologies that are not used by traditional ITS. ITS provides benefits in two areas: first is to reduce the traffic congestion and to reduce the number of accidents and second to transform the conventional ITS into intelligent one to improve its efficiency and to provide ease to drivers. The below described are the advantages of using ITS (Khorasani et al., 2013):

1. **Mobility:** As transportation is very important factor in people's life, economy of the nation and people depend upon ITS. Due to which they need to move from one place to another and similarly goods and services also need transportation to serve the people's needs. ITS helps in providing the path for the travelers to move from one place to another by prior informing them about the road traffic conditions. In this way, ITS plays a vital role in mobility of people and products throughout the world.
2. **Traffic congestion:** ITS is generally used for avoiding the traffic congestion by providing the information about the road conditions, climate conditions, and other factors like traffic lights and many more and guides people with most suitable route to avoid the problem of traffic congestion and in this way, it smoothens the traffic system.
3. **Pollution control:** The traffic on the road increases day by day due to several reasons due to increase in vehicles; the emission of pollutants from the vehicles is also increasing which then harms the environment. Pollution can be of any kind like emission of harmful smoke from vehicles that causes air pollution and loud horns of vehicles cause noise pollution. So, implementation of ITS can guide people and vehicles to not emit the pollutants by providing timely guidance to them for their vehicle maintenance.
4. **Accident prevention:** The increase in traffic on the road also raises the number of accidents that actually threaten the lives. ITS implementation can prevent the accidents and can save the lives of people by providing them proper directions while driving.
5. **Improvement in reliability of time to travel:** Implementation of ITS reduces the time required to reach to the destination by providing best optimized route for traveling (Newman-Askins et al., 2003).

2.3. Disadvantages of ITS

The ITS has many benefits but nothing is always perfect. ITS has negative impacts also that are discussed in this section:

1. **Dependency:** The implementation of ITS totally depends on the internet connectivity. That means it cannot work in the areas that do not have internet connection and the area where internet connectivity is very poor. The ITS implementation requires use of variety of latest technology which may or may not be familiar to the people using it so it is not much successful currently. It is an emerging technology that still needs a lot of work to be carried out. Moreover, many of the vehicles are not incorporated with the latest technologies on which ITS can be implemented. ITS is beneficial for only those vehicles having inbuilt latest technologies and components.
2. **High cost**: Due to the use of number of components in the implementation of ITS, the entire ITS system becomes very expensive so it is not feasible to implement it for everyone. It needs a lot of advancements so that it could be made cheaper and everyone can easily afford to purchase the required components so that their vehicles can be connected with ITS. Moreover, the maintenance cost is very high.
3. **Lack of awareness**: As ITS is an emerging technology, many people are still not aware about this technology so they are not aware about the benefits of this system. To make ITS successful, awareness among the people is required.
4. **Lack of resources**: ITS cannot become successful until all the required resources are made available. The variety of resources are required to implement ITS that can be technology related, manpower related, and rules and policies need to be adopted that are very difficult to collaborate.

2.4. IoT and IoV in ITSs

IoT is the emerging and extensively used technology these days. IoT is used in every area of the technological oriented modern world. IoT is widely used in the applications of transport like managing the traffic, controlling the traffic lights, implementing the smart parking system, providing best routes for transportation, and identifying the road conditions and climatic conditions based on which traffic on the road can be judged and accordingly, the person can travel (Eswaraprasad & Raja, 2017; Murad & Hidayanto, 2018).

2.4.1. IoT applications

IoT devices are deployed in various regions of an area and mostly it is used in the prevention of traffic congestion on the roads, telematics frameworks inside vehicles, security, and

surveillance systems. IoT is used in the transportation by deploying the various components like sensors, actuators, and other devices. They collect the data and analyze that data using ML approaches to extract useful information for prediction of the road conditions to provide the ITS. The inclusion of IoT in transportation sector completely transformed the scenario of transport system in the world. The various applications of IoT in transportation includes public transport management, real-time vehicle tracking, connection of vehicles using RADAR, global positioning system (GPS) and cameras, distance traveled, and fuel consumption identification and many more (Azimian, 2011). The applications of IoT in various areas are represented through the diagram (Figure 3).

2.4.2. IoV applications

IoV is being widely used these days in implementing ITS to optimize the performance of transport system through integration with IoT. There were several drawbacks of IoV in transport system like change in topology which changes the entire network of vehicles due to their motion, lack of reliability due to poor internet connectivity, increase in number of vehicles day by day, and its compatibility with the devices (Ashokkumar et al., 2015; Sharma & Kaushik, 2019; Wang et al., 2017). Due to which they had to integrate with IoT and security is the major concern while using IoV. They use the concept of VANETs to provide applications for ITS. IoV is the combination of IoT and VANETs that is an emerging research area in the field of ITS (Newman-Askins et al., 2003). IoV comprises of five types of communication: a) vehicle-to-vehicle (V2V), b) vehicle-to-roadside units, c) vehicle-to-personal devices, d) vehicle-to-sensors, and e) vehicle-to-infrastructure of cellular networks as shown in Figure 4.

3. Review Methodology

The research done on implementing ITS from year 2000 onward till date has been systematically reviewed and summarized in this work. The existing literature review methods have been also analyzed and refereed to do the systematic study of existing approaches for ITS.

3.1. Review plan

This systematic study starts by considering last 20 years work done on implementing the ITS. All the existing literature has been analyzed carefully to evaluate the quality of the work done for ITS. A number of review papers that discussed the ITS have also been taken to identify the best review methodology. All the research done previously has identified to extract only the relevant information and finally unified. The protocol of systematic review has been carefully examined and then concluded after appropriate discussion is followed to carry out this systematic study. The number of the articles reviewed in this systematic study is summarized as below.

3.2. Research questions

This systematic study on ITS is primarily focused on the review of existing approaches proposed by various researchers to implement ITS. The research questions that arise with this systematic study are summarized in Table 2.

3.3. Search criteria

The proper insight is required to do the systematic review. The existing work has identified based on the keyword ITS. The related

Figure 3
Applications of IoT in various areas

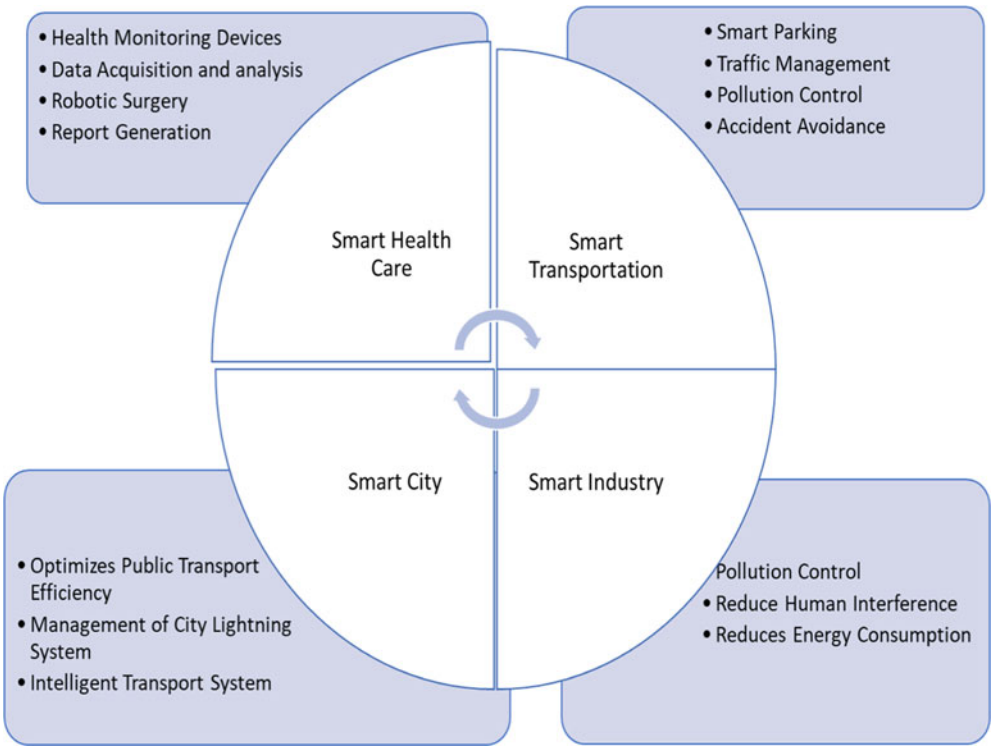
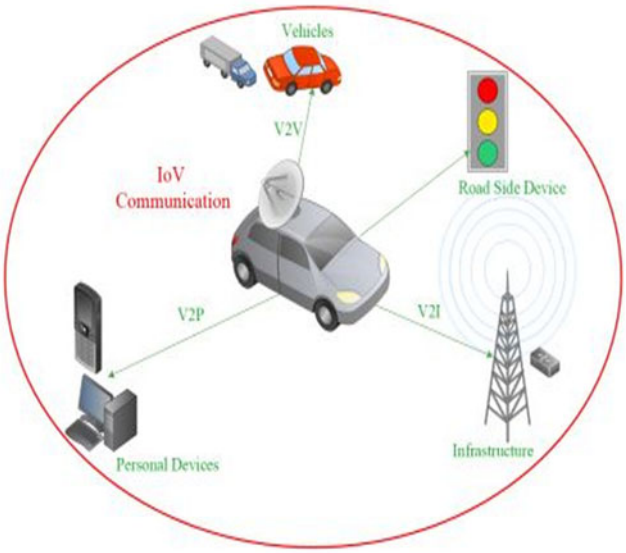


Figure 4
Communication in Internet of Vehicles



work that consists of the implementation of ITS has been considered for carrying out this systematic review. The work that has been done from the last 20 years on ITS has been searched to be included in this systematic study. The manual research technique has been used to identify the papers consisting of ITS keywords and the papers specifically focusing on ITS implementation, and review of ITS systems has been considered for this detailed study.

3.4. Inclusion and exclusion

ITS implementation is an emerging technology that needs a lot of exploration. The search for the keyword "Intelligent Transport System" results in exploring irrelevant papers also that are not related to this study of ITS. The methodology of selection of relevant papers for this systematic study was a very difficult task. The papers related to the two areas: implementation of ITS and review or surveys on ITS have been specifically chosen for this systematic review of ITS as mentioned in Table 1 below: Inclusion and exclusion criteria for choosing best papers related to this study have been shown in figure below. This criterion involves four stages. first is searching all the papers related to ITS, second is to identify the papers related to the approaches used for implementing ITS and review papers were also analyzed. At last, at third stage, filtration

Table 1
Comparison of existing surveys on intelligent transport systems

Author	Year	Contribution	Limitation
Qureshik & Abdullah (2013)	2013	Application areas of ITS	Has not considered existing literature
Tian et al. (2016)	2015	Video-based surveillance of ITS	Surveillance system only
Seredynski and Viti (2016)	2016	Cooperative ITS for public transport	Focused only on public transport system
Zear et al. (2016)	2016	Issues and solutions to ITS problems	Did not consider technologies such as IoV and agent-based computing
Vaishali and Jeyapriya (2017)	2017	Main concern was collision avoidance of automobiles	Confined to traffic at peak hours
Ghosh et al. (2017)	2018	Based on importance of GPS and GSM system in ITS	Not considered all aspects of ITS, limited to GPS and GSM
Mfenjou et al. (2018)	2018	Implementation of ITS in developing countries: Sub-Saharan Africa	Main focus was on urban systems only
Galea et al. (2020)	2020	Object detection models in night	Limited for simpler systems in local environment
Harvey and Kumar (2020)	2020	ITS security challenges and solutions	Not considered cyber threats and biometric system security
Lamssaggad et al. (2021)	2021	Current and future trends in ITS	Focus was on security aspects only

Table 2
Research questions with significance

Q1.	What is ITS and its need?	To find out the importance of ITS
Q2.	What are its positive impacts?	To aware people of this technology
Q3.	What are the reasons for its failure?	To overcome the issues related to the failure of ITS
Q4.	What are the approaches to implement ITS?	To categorize the pros and cons of the available solutions to implement ITS
Q5.	What are the requirements to implement ITS?	To help the people to collaborate resources required and budget assessment to implement ITS
Q6.	What are the parameters to be considered for evaluation performance of ITS?	To analyze the relevant parameters that actually impact the performance of ITS
Q7.	Discuss pros and cons of existing approaches	To open the new research directions
Q8.	What are the different application areas of ITS?	To help the beginners to choose the required area of ITS to work upon

Figure 5
Summary of related work

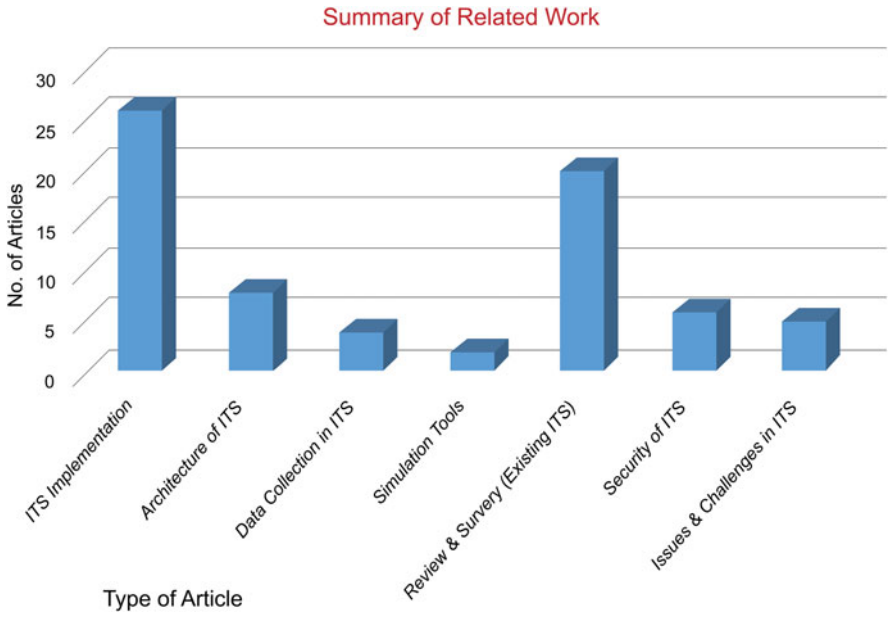


Figure 6
Data conversion process

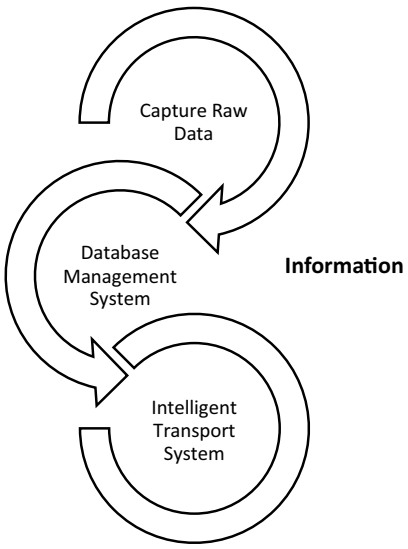


Table 3
Quality screening questions

Q1.	Does the research papers include the ITS?	Yes
	The papers and articles that do not contain the keyword ITS have been excluded from the literature review	No
Q2.	Do the title, abstract, and text of research papers include the approaches to implement ITS?	Yes
Q3.	Have the titles on particular application area of ITS like smart parking, accident avoidance (not included)	No
Q4.	Do the titles involve the keywords ITS along with the systematic review, survey, and study?	Yes

has been carried out to include only relevant papers for this systematic review, and rest are excluded as mentioned in Figure 5.

3.5. Quality assessment

In this stage, the quality of the research papers gathered has been analyzed for the quality assessment. The screening questions for the assessment of quality have been discussed in Table 3, and quality publications from various authenticated and authorized resources have been included for systematic study to provide quality work.

4. ITS Technologies

ITS uses various technologies for its implementation. Some of the major technologies used by ITS are as discussed below in Table 4 (Balasubramaniam et al., 2017; Prabha & Kabadi, 2016; Zear et al., 2016).

4.1. Data collection technologies

ITS needs to use data collection techniques so that it can communicate with different moving vehicles on the road. Data collection techniques are very as mentioned in Table 6 important as it collects the information related to physical location of the devices along with various aspects that are very important to consider for the working of ITS. They are mainly categorized into two categories as described in the figure above. Infrastructure-based technologies comprise of sensors, CCTVs, while vehicle-based technology involves use of GPS systems.

4.2. Communication technologies

The vehicles on the roads need to communicate with each other to get information about the current status of the road that helps them to provide prior information to prevent the vehicle collisions and traffic congestion avoidance. The communication technologies that are commonly used are as shown in the figure above in Table 5. VANETs are very popular and used widely in ITS applications (Zear et al., 2016).

Table 4
Data collection technologies for ITS

Sr. no.	Type of technology	Name of technology	Medium	Description
1.	Site based	Video graphic	Infrared traffic	Capable to represent large amount of data but not suitable for large distant objects
2.	Site based	Infrared	Infrared traffic logger	Higher accuracy of collected data but less area coverage
3.	Floating cellular data	Triangulation method	Antennas	Used for estimating the traveling time based on distance between antennas
4.	Floating cellular data	Vehicle re-identification	Sensors	Used for vehicle detection
5.	Floating cellular data	GPS based	Satellite navigation	Detects the speed and location of vehicle, works in every climatic condition even in heavy rainfall

Table 5
Communication technologies for ITS

Sr. no.	Name of technology	Description
1.	GSM	Provides two-way communication and provides services like paging, SMS
2.	GPRS	Reliable and packet-oriented data transmission service
3.	MOBITEX and TETRA	Provides large area coverage

Table 6
Database technologies for ITS

Sr. no.	Name of technology	Description
1.	Big Data	Advanced technology that provides various tools to handle huge amount of data based on five Vs of Big Data
2.	Cloud Services	Allows to manage and store data without requirement of any infrastructure and allows the movement of data globally across the world
3.	Data Fusion	Allows fusion of data from different sources like GPS, phone tracking, moving vehicles and converts them into manageable form

4.3. Database management

The data collected by various wireless devices need to be analyzed and data need to be stored in proper structured format. The way of data conversion is shown in Figure 6 management system that stores the data related and helps the ITS to analyze the data. It helps in analyzing the traffic-related data and provides the required information (Hong et al., 2015).

5. ITS Security Concerns

Now-a-days, a lot of research is being carried out to design the autonomous vehicles that can also be considered as ITS. It is the need of hour to implement such systems to avoid traffic congestion, prevent vehicle collisions, avoid the accidents, and ensure the safety of people. These systems automate the driving process, but use of technology is not always beneficial. Every technology has its limitations; similarly, these systems also have some problems that could not be overlooked. These problems and issues related to autonomous vehicles should be taken into consideration and solutions must be provided to solve these issues (Anandakumar et al., 2019). The use of autonomous vehicles has both advantages and disadvantages; in this review, the positive impacts of autonomous vehicles that comes under one of the ITS have already been discussed. Now here, the negative impacts of autonomous vehicles have been discussed:

Table 7
Common ITS attacks and its consequences

Sr. no.	Name of attack	Consequences
1.	DoS attack	Makes the server unavailable to users
2.	Vehicular ad hoc network attacks	Misleads the vehicles by providing wrong information
3.	Wired network attacks	Jamming of signals
4.	Physical attacks	Compromise of services
5.	Wireless network attacks	Snooping, eavesdropping, and man-in-the-middle attack

1. **Safety issues:** The autonomous vehicles have various drawbacks in terms of security like sometimes the vehicles could not be controlled in emergency situations or while moving at very high speed, they become uncontrollable. Moreover, the sensors inside the autonomous vehicles often fail to sense the objects that suddenly come in front of the vehicles on the road. Due to these safety issues, the autonomous vehicles create the problems in the field of ITS. The sensors are sometimes unable to detect the obstacles on the road due to low visibility in heavy rain, thunderstorm, and other climatic conditions.
2. **ML issues:** Most of the autonomous vehicles use ML techniques like applying brakes, object detection, and automatically stop of the vehicle in case of an emergency but that can sometimes pose problems for them. These ML algorithms cannot ensure that these vehicles are safe and accident free. We cannot force the companies to use the standardized dataset for training, validation, and testing.

So, these ML-based autonomous vehicles still suffer from the problems that need to be solved.

3. **Traffic congestion and vehicle collision**: These vehicles are incorporated with number of technologies and these are driver less vehicles due to which sometimes the components of the vehicle can fail. Due to wrong understanding of the commands issued by the person sitting in the car, these vehicles can generate problems and get stuck on the road which could give rise to traffic congestion on the roads and vehicles can collide with each other.
4. **Social acceptance:** There was a serious incident reported of increase in number of accidents by the automated cars manufactured by Tesla. Social acceptability is a very important issue to be followed by the people moving on the road as well as for the people using these automated vehicles. The people should be made aware about the features and facilities provided by these autonomous vehicles. Proper training should be given to them to operate these types of vehicles so that challenges and issues resolved with them can be resolved.
5. **Quality of service (QoS) design issues:** While designing ITS, the most important concern is the QoSs provided by it as shown in Figure 7. The design of ITS must ensure the best quality of the services. QoS impacts the availability, performance, and scalability of the ITS.

The ITS involves the concept of mobile vehicles so the network arrangement is dynamic, and it keeps on changing all the time due to which the performance of ITS degrades over time. The number of devices is connected on the road side in ITS that communicates with each other. The communication among these components should ensure reliable and stable connectivity among the vehicles in the network. ITS needs to deal with real-time constraints especially in the scenario of safety of the vehicles (Khan, 2017). The latency is the important requirement for measuring the performance of ITS. Moreover, ITS involves the use of variety of vehicles that communicates in different ways. So, the protocol stack of ITS should be efficient to adapt itself to these changes.

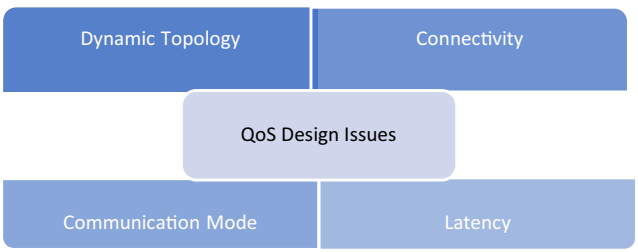
6. **Communication technology issues:** There are number of issues that arises when communication technologies are used in ITSs. These issues need to be tackled for the successful implementation of ITS (Maimaris & Papageorgiou, 2016):

   (a) Distance: This is the most important issue that impacts the performance of ITS. As the distance between the vehicles on the road increases over a communication network, the performance of ITS gradually decreases. It uses single hop and multi-hop communication. Bandwidth: It is related to the amount of the information that can be sent between source and destination. Media Access Control (MAC) protocol is used to prevent the collision between the information packets and detects the communication if unsuccessful. The amount of bandwidth required depends upon the type of information to be communicated. Generally, VANETs require high bandwidth for communication of large amount of information.

   (b) Privacy and security: The ITS uses wireless communication and these type of communication technologies are more vulnerable to the security threats. There are many chances for the loss of privacy and confidentiality due to connection-less communication. The number of malicious nodes can interfere between the communication that takes place between the source and the destination. The security mechanisms such as digital signatures, authentication, and many more can be used to prevent the compromise of ITS to maintain the integrity of the system.

   (c) Timeliness: The information between the source and destination needs to be communicated when required. No delay is permitted here. This is an important issue to be considered by the technology that is responsible for the communication between the different components of ITS, otherwise the ITS is of no use, if it fails to deliver the information timely.

Figure 7
QoS design issues



5.1. ITS security challenges

The trend of ITS is increasing at very high rate. ITS involves the use of wireless devices like sensors, actuators, data processing units, etc. The vehicles on the road communicate through these wireless devices connected to one base station (Ali et al., 1964). The challenges that are faced by an ITS are very important to address to provide reliable and effective ITS. The ITS involves the communication of information between different vehicles on the road that can compromise their integrity, authenticity, privacy, and confidentiality, so these issues need to be solved to overcome the security challenges of ITS (Zear et al., 2016). A variety of technologies like RADAR, IR, and LIDAR are used for providing prior information to the drivers about the situation of roads and vehicles to avoid various problems on the road. As ITS totally involves the utilization of wireless components, it is vulnerable to security threats due to which actual information can be modified by the attackers and it may mislead the drivers that creates problems for them. The various issues related to security have been addressed here along with the possible solutions to overcome these issues (Harvey & Kumar, 2020). The threats for ITS should be identified. The infrastructure of ITS should be protected from vulnerabilities as it can be compromised with other nations during any bad situations like war between the nations. Cyberterrorists usually attack ITS to know about the route information so that they can plan the attack in emergency situations. Most of the attacks are due to money. The motivation behind the attacks on ITS is to steal the confidential data and to gain the access of the system. Denial of service (DoS) attack can take place to cause the problem of traffic jam on the road and create a scenario of difficult situation for the emergency vehicles particularly. This can also be done to confuse the people and to disturb the protests going on the road. This can threat the life of the people in emergency situations and can also lead to financial loss. Map hacking can also be done by the terrorists to get access of all the tracks of the road. As discussed earlier, ITS components communicate through wireless devices, so these wireless networks are more vulnerable to security threats as compared to physical attacks on ITS. These attacks as mentioned in Table 7 generally occur to delay and slow down the ITS services, to crash the ITS 18 server, and to get the access of the confidential information stored in database. ITS is based on internet so spoofing can be done by the attackers to monitor the communication going on over the network.

5.1.1. ITS attacks

Vehicles are more vulnerable to security threats as it can compromise the safety of vehicles. Sybil attack is very harmful

Figure 8
ITS attacks

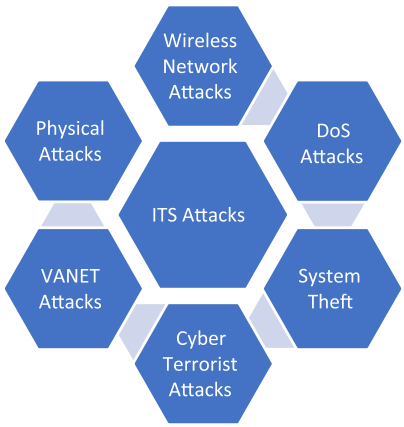
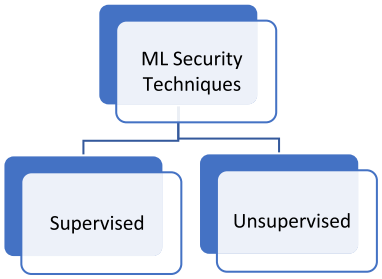


Figure 9
ML security techniques



and difficult to identify in the vehicular networks. The various attack categories for ITS are shown in Figure 8.

5.2. ML-based security solutions

As the network and complexity keep on growing in ITS, it is becoming very difficult to handle the network. So, manually analyzing the network and data on it is a challenging task. ML is a field of artificial intelligence based on learning algorithms that helps to analyze the data in easiest way in very short duration. ML algorithms as mentioned in Figure 9 when applied to ITS help to detect the security vulnerabilities in an effective manner. They can easily mitigate the consequences of security attacks. ML algorithms help to detect the intrusions very easily in ITS (Lamssaggad et al., 2021).

Supervised ML techniques help to identify and detect the already known attacks and based on the dataset, they can easily prevent the attackers to enter into the system. Intrusion detection system (IDS) is used to detect these intrusion activities; IDS uses some attributes to classify the network data into attacks or normal. ML model when applied on the data classifies it into normal traffic or abnormal traffic. In this way, supervised learning model is based on detection of attacks based on some pre-assigned labels in the dataset. These ML techniques also help to detect the known attacks more effectively and with higher accuracy. To detect the unknown attacks is very difficult as no labels are assigned to them prior. So, anomaly-based IDS is the concerned issue that needs to be considered while detection of malicious activity in ITS. These anomaly-based approaches help to overcome the drawback of signature-based IDSs. In this approach, the network traffic is examined and if the system behavior deviates from its normal behavior that means it is an intrusion activity. In this way, unsupervised learning model helps in detection of attacks. Usually, distributed DoS (DDoS) attacks are identified through these ML algorithms.

6. Discussion

Traffic congestion is the serious issue across the world that needs to be addressed. It is the problem that is growing at very fast rate in developing countries due to increase of urbanization and increase in number of vehicles on the road. The traffic congestion is responsible for various problems like: delays, threatening of lives, and causes problem of pollution (An et al., 2011). ITS can help to mitigate all these problems by suggesting optimal routes and prior informing the travelers about the road and traffic conditions by responding to them without causing any delay (Javed et al., 2019; Khorasani et al., 2013). C-ITS that primarily focused on predicting traffic management on the road is based on historical data. C-ITS is mainly concerned with optimizing road safety, provides comfort to the driver of the vehicle, and helps in the management of the traffic. C-ITS is concerned with handling of large amount of data as it works on the basis of data collected by various wireless sensor devices (Autili et al., 2021; Javed et al., 2019; Shobha & Deepu, 2018; Seredynski & Viti, 2016). The data need to be analyzed to extract useful results which can further be used for prediction of traffic on the road in future so there is need of techniques to analyze huge amount of data collected. The two approaches for implementing the ITS have been discussed that were represented using ITS framework of Europe that was called as FRAME and other was the architecture of ITS implemented in USA. Both ITSs were totally different on the basis of the methodology used by them as they vary from state to state.

The main focus was to compare these two ITS approaches and current scenario of ITS in Europe (Bělinová et al., 2010). The issues and challenges that need to be tackled during the implementation of distributed architecture for ITS while considering public transport have been discussed briefly. The reliability and scalability issues were also addressed in this paper (Nasim & Kassler, 2012; Levina et al., 2017). The communication needs to be done between the vehicles, passengers, driver, and other components in case of public transport systems. These components are very important to be identified and the phenomena through which all these components actually interact should be considered to implement ITS (Šimunović et al., 2009). The new architecture for testing based on VISSIM platform worked well for public transport system (Ghariani et al., 2014). IoT has been widely used in deployment of ITS. It is responsible for connecting the components of transport system. It actually provides the real scenario of the roads by deploying sensor nodes at different points on the road (Vaishali & Jeyapriya, 2017). Infrared and ultrasonic sensors have been deployed to examine the current status of the road (Šimunović et al., 2009). The traffic signal has been analyzed and a buzzer is produced if anyone violates the rules of traffic signals. ITS is the component of smart cities concept. The detailed analysis of existing literature involving various proposed approaches for ITS has been summarized in Table 8.

Chavhan et al. (2021) proposed an approach to provide optimal path based on some algorithms to choose shortest path to help the travelers to reach their destination on time. The ITS proposed was only for the metropolitan region. They considered that the GPS does not update the travelers about the sudden incidents that occur on the roads which can mislead them about the current scenario of the road due to which they may have to face problems of getting delayed while traveling. There is problem with Google maps that

Table 8
Summary of existing approaches for ITS

Author(s)	Year	Proposed approach	Limitation
Sarrab et al. (2020)	2020	Real-time ITS for traffic monitoring and used Wi-Fi for communication between moving vehicles	Suitable only for single lane roads, lacks in energy efficiency
Bali et al. (2020)	2020	Used IoT and RFID and proposed green corridor technology for emergency vehicles	Suitable only for emergency vehicles
Elbery et al. (2021)	2021	Proposed two systems, TTSON and VDC, to avoid traffic congestion	Slow speed in eliminating traffic congestion and increase in traffic density
Arshad et al. (2020)	2020	Proposed an energy efficient approach to improve traffic conditions by optimizing street lights	Not applicable to detect the animals sitting near poles on the roads
Jacob (2020)	2020	IoT-based smart traffic management approach to detect the traffic violations and report to higher authorities	Not able to detect the traffic due to road conditions
Lei et al. (2018)	2018	Microcontroller-based ITS to detect the road surface conditions	Not able to analyze real-time traffics
Uddin et al. (2021)	2021	Implemented ITS using NVIDIA Jetson Nano	Best in performance but limited services
Faldu et al. (2019)	2019	Hybrid approach to calculate time using IoT, sensors, and camera	No such limitations
Janahan et al. (2018)	2018	Clustering algorithm based on KNN model to count the number of vehicles to minimize the waiting time at traffic lights to avoid traffic congestion	Not able to detect the exact vehicle count
Eswaraprasad and Raja (2017)	2017	Used neural networks to manage the traffic based on IoT	Not suitable for decision Taking
Baskar et al. (2007)	2007	Implemented existing architectures to propose a hierarchical approach to manage traffic	Could not provide the suitable model for traffic prediction
Gan and Lin (2007)	2007	Walkie Talkie approach to detect the vehicle location on the road	Limited features and outdated approach
Dailey et al. (2002)	2002	Data-oriented approach for ITS	Loss of data may occur
Zaheer et al. (2019)	2019	Vehicular network-based approach using various dynamic route-finding algorithms	Suitable only for metropolitan areas
Siddiqi et al. (2016)	2016	Visible light communication approach to detect vehicles on the road	Not suitable to work in scenarios except V2V
Ejaz et al. (2020)	2020	Internet of Vehicles-based infrastructure for ITS	Completely dependent on charging which is not available all the time
Levina et al. (2017)	2017	Service-oriented enterprise architecture designed for Saint Petersburg specifically	Limited for enterprise use only
Binjammaz et al. (2013)	2013	Global positioning system to collect tolls and pay as you go to avoid road congestion	Not efficient
Nasim and Kassler (2012)	2013	Distributed architecture for ITS based on SOA, grid computing, and cloud computing	Not scalable and reliable
Mao et al. (2021)	2021	Machine learning and genetic algorithm to optimize the traffic control mechanism	Performed best for only one parameter that is travel time
Rao et al. (2011)	2011	Statistical techniques to analyze the traffic particularly for Delhi city	Based on survey so lacks in accuracy

they do not always provide the accurate information about the routing paths which could be problematic for the people traveling (Bishop, 2000) on the roads. Now-a-days, almost on all the roads cameras have been deployed to examine the traffic conditions of the road and to identify the people who breaks the rules of the traffic. The objective of video recording is to extract the required data if required in an emergency situation from huge amount of data (Kavitha & Chandrappa, 2017; Shobha & Deepu, 2018). The techniques for implementation of ITS which gradually decrease the emission of harmful pollutants and the techniques that reduce the consumption of fuels have been analyzed (Nasir et al., 2014). Various technologies have been integrated to implement ITS. GPS, GIS, GPRS, and RFID technologies have been used to design the ITS (Jin et al., 2020). ITS used the internet technology to permit the communication between the various vehicles on the road. GPSs cannot provide the accurate information to ITS due to uncertainties in environmental factors (Binjammaz et al., 2013). This is the reason for integrity requirement for GPS to get exact information about the traffic. The GPS Doppler has been used to optimize the matching process. Nkoro and Vershinin (2014) described the current and future scenario of ITS particularly for cars and infrastructure. The existing challenges of ITS have been reviewed. The existing research that has been carried out to predict the traffic scenario to avoid vehicle collisions and accidents has been described in detail. The feature selection techniques have been discussed which is very important. Siddiqi et al. (2016) implemented an ITS based on communication between V2V using visible light. This approach used photodiodes and LEDs to detect the visible light for communication between vehicles. This approach was successful to detect the brakes if applied by any one on the road from a distance of 20 m and gives warning to other vehicles moving on the road so that accidents can be avoided (Suhas et al., 2017). IoV technology is a combination of vehicular and IoT (Gawade & Meeankshi, 2017). In this paper, an infrastructure for charging of moving vehicles has been proposed having constraint of charging them at the same time. The discussed problem was based on integer programming and a solution was proposed to solve that problem using branch and bound algorithm. Finally, an IoV-based scheme was proposed for charging the electric vehicles that resulted in reduction of cost for charging (Ejaz et al., 2020; Zaheer et al., 2019). Federici et al. (2011) discussed the problems faced during the research related to the implementation of ITS methodologies.

They described that while designing ITS, the security concerns have not taken into consideration which can threat these systems to various vulnerabilities. The concept of visible light has been introduced to evaluate the performance of vehicular communication. The research was focused on Visible Light Communication (VLC) technology that involved the use of light emitting diodes that worked as transmitter and photodiodes have also been used that worked as a receiver (Dahri et al., 2019). Various regression models have been trained to predict the travel time for the traffic network considered for experiments (Mao et al., 2021). In Ambak et al. (2009), ITS specifically for safety of bikes has been proposed, and various issues faced have been discussed in detail. The ITS is capable of providing safety to the vehicles. Various ITS techniques have been proposed that ensures the safety of the vehicles and gradually reduces the number of accidents. The scenario of ITS in the Wuhan City of China has been described in Yan et al. (2012) and Janusova and Cicmancova (2015).

ITS has already been implemented there 10 years ago, but still they feel need of ITS to enhance the transportation system in a better way. Wuhan University of Technology has also proposed one ITS that aimed to provide road safety, to reduce the pollution caused by vehicles, and to save energy consumption by road and water transportation system. At last, the five research areas have been proposed in the field of ITS. The vehicles on the road are connected to the traffic control systems using wireless devices due to which they are vulnerable to security threats. These vulnerabilities can impact the reliability of the ITS. Moreover, it can also degrade the quality and effectiveness of ITS that can result in poor QoS. So, the various design issues and QoS challenges need to be tackled while designing ITS (Javed et al., 2018). ITS using GIS has been developed to provide Advanced Traveler Information System specifically for Hyderabad city (Kumar et al., 2003). The proposed system was user friendly and was capable of providing the complete information about the roads of the city, tourist places within the city, hospitals, public, and private offices. The system was efficient to provide the shortest path so that traveler can reach their destination on time. They concluded that the aged person and drivers did not follow the rules of parking which leads to traffic congestion on the roads, so people of different age groups need to make aware about the parking rules so that the problem of traffic congestions can be reduced (Rao et al., 2011). Im et al. (2000) proposed a tool for the simulation of traffic to evaluate the performance of designed ITS before its implementation. The proposed simulation tool was capable to combine the attributes of driver, vehicles, roads, and climatic factors which actually effects the performance of ITS. The special focus was on public transport system and special vehicles used for specific purposes like for carrying heavy weight and for import and export of products inside and outside the country (Bishop, 2000). “VEHIL” was a methodology for testing the ITS, vehicles, and the subsystems. It was particularly focused on the safety of the roads and people. Hardware-based approach was proposed to increase the speed of testing an ITS. Due to the use of hardware components, it was a very complex model. Moreover, only longitudinal behavior of vehicles have been considered which was the limitation of this proposed approach (Verhoeff et al., 2000). The nodes that are a part of an ITS decide whether to work with other nodes in the network or not depending on the nature of the task to be performed (Shimura et al., 2003). This model was specifically designed for the moving systems that consist of mobile nodes and base stations. The performance requirement is very high as the vehicles on the road can be moving at very high speed, so the proposed model was applied to Smart Gateway that is the one of the popular ITS proposed by Transportation Association of Japan. Base station has been developed and implemented on roads to evaluate the performance of ITS (Dailey et al., 2002). The technologies to be used in ITS and its efficiency have very important role in implementing ITS (Jarašūniene, 2007). The need of man power in ITS is very important issue. ITS is a combination of various technologies. The two cost analysis methods have been proposed to analyze the socio-economic impact of ITS for convoy driving systems (Juan et al., 2006). The various frameworks available for managing and controlling traffic have been discussed and compared (Baskar et al., 2007).

7. Conclusion and Future Scope

The implementation of ITS is a very important issue as it resolves number of problems related to transportation system. Designing ITS is very important to save the lives of people and on the other hand, it improves the road infrastructure system also. The systematic study of the existing ITS has been discussed in detail in this work. The articles related to ITS in different

perspectives have been considered and analyzed to conclude the pros and cons of ITS. Initially, the review plan has been discussed. Then the research questions that arise from this work have been presented and discussed (Bargiela & Peytchev, 2001). The related work has then discussed along with their problems and solutions they proposed. The various issues associated with ITS related to its security aspects, designing aspects, and challenges have been elaborated. A lot of review papers have been published in the context of ITS, but none of them has discussed all the aspects related to ITS. This paper has covered almost every aspect of ITS beginning from its need and ending up in challenges and issues if implemented. In future, a lot of work needs to be done in this research area. The open research issues in this research of ITS include identification of important metrics that impact the performance of ITS. The more work needs to be done in the field of providing solutions to the security aspects of ITS to make it secure.

To sum up, there is a great relationship between Western rhetoric and English writing, rhetoric is not only the use of rhetoric. However, the use of figures of speech can provide some very useful writing skills for English writing. Rhetoric, as a whole, is an art of persuasion. In the process of using various rhetorical devices to write, English writers should pay attention to strengthening their understanding of rhetoric itself and the knowledge covered within it, and combine the rhetorical perspective to improve their ability to use rhetorical devices such as contrastive and exaggeration.

Conflicts of Interest

The authors declare that they have no conflicts of interest to this work.

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