Digitization and intelligent management systems in transport: an overview of problems and solutions

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Abstract. **The implementation of intelligent transport systems /ITS - Intelligent Transport/ in the transport sector is one of the first tasks in the development of information and communication technologies /Information and Communication Technologies - ICT/. In essence, it is an actual task and means creating and processing the information flows and data in real time to locate and manage the vehicles, infrastructure and traffic in order to improve the mobility and the quality of the transport services offered. This article aims to give a modern view of digitalization of technological and business processes, as well as the development of ITS in the field of the transport sector. Special emphasis is given to modern problems and solutions in the digitization and implementation of these information systems. with a view to their effective and safe use, traffic and mobility management, improving the efficiency and quality of the service, as well as the impact on the ecology, etc.**

Keywords: Digitalization, Management, Technology, Transport, Intelligent Systems, Information and Communication Technologies.

I. INTRODUCTION

Transport services occupy an important place in human existence and especially in today's digital era in which the world is changing very dynamically. Transport plays a vital role in transporting various goods, services and people. Moreover, the requirements for it are constantly increasing and are associated with an increase in the speed of delivery, safety, security and comfort of transport. All this requires the use of so-called intelligent transport systems (ITS), which systems use digital technologies to manage the transport system. This aims to tackle the problem of accidents, reduce pollution, traffic congestion and deliver goods in a timely manner. In this regard, transport has always been a leader in integrating the latest technologies.

Building a good ITS involves the use of various areas such as sensor networks, machine learning (ML), transport area of civil engineering, etc. In this regard, various research areas dealing with these problems focus specifically on the problem of road safety. ITS is designed so that they can overcome problems related to traffic control and management, accident prevention, road charging, parking, noise and pollution control, etc. The present analysis is based on the systematized in [1], [2], [3], [4] and the study is aimed at refactoring the problems and solutions of the use of these systems in transport.

ITS provides intelligent management of the growing number of vehicles on the road in order to reduce congestion and avoid accidents Various technologies are also used to empower congestion, traffic management and road accident services by informing users about the road scenario in real time [5].

ITS ensures road safety and participants are informed about traffic conditions, climate, etc. All this makes the transport system efficient, and the quality of transport networks is increasing [6], [7].

ITS works using information technology and most often wireless networks. Signals are transmitted between different vehicles, as are infrastructure equipment. On this basis, moving vehicles become familiar with and handle traffic, and ITS helps the transport system to operate in an efficient way [4].

Different technologies are used to implement ITS, nowadays these are the Internet of Things (IoT) and the Internet of Vehicles (IoV) [8]. ITS are a combination of technologies working together to provide the best transport management system. Automotive networks (VANETs) have a variety of intelligent transport applications. These networks help drivers by sending notification and data messages by setting up hazard alarms. VANETs give security and skills to traffic, with the aim of reducing travel

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time, costs and pollution emissions. IoT is a technology that connects the digitalization of the real world [9], [10].

Existing research is based on different approaches to offer the best solution to ensure an efficient transport system. There are many aspects that have not been considered thoroughly enough, and technologies are developing very quickly, which requires constant refactoring of IT solutions for the construction of these systems.

The study aims to consider:

- The need for ITS, importance and requirements, pros and cons, as well as issues related to their implementation.
- The main application areas of ITS.
- The various problems we face in implementing ITS, as well as the solutions to address these problems, along with security issues and challenges.
- Future research areas for ITS implementation are also discussed.

II. Materials and Methods

A. Intelligent Transportation Systems

Modern ITS are designed to improve the efficiency and safety of transport systems. They aim to optimize transport costs, energy and fuel consumption, and to preserve the environment. ITS are an integral part of larger projects for building smart cities and regions using modern IT methods and infrastructure for transport management, data processing and analysis, maintenance and automation of logistics, decision-making systems, etc. In this way, modern ITS opens new opportunities for IT services for drivers, passengers and providers of infrastructure and e-services provided in cloud computing, etc. That is, ITS is rather a general term for many models, systems and applications that are developed and implemented, not just strictly IT [4].

From the point of view of the development of transport infrastructure and services, the application of ITS is in the following areas shown in Fig. 1:

Fig. 1. Application areas of ITS.

As road traffic is constantly increasing, it is necessary to implement intelligent transport system management strategies to prevent accidents [11], [12], [13]. There are many strategies on this issue by using different technologies that are implemented in ITS. An important place is also the management of projects in the construction and modernization of transport sites and systems [14], [15], [16].

As early as 2000 year [17] ITS proposed as "VEHIL: a full-scale test methodology for intelligent transport systems, vehicles and subsystems" in the form of hardware, which was implemented on a vehicle and tested and called an Intelligent Vehicle System [18]. The concept of the hardware-based grouping was used, and testing was done for the complete vehicle system, but due to its complex implementation it was not so successful. A traffic simulator tool for ITS performance evaluation was then constructed [19]. This simulation tool combines the characteristics of the vehicle, the driver and the environmental factors, and the ITS efficiency.

In the following years there are also developments, but from 2010 onwards different approaches are proposed to assess ITS using different mechanisms for Machine Learning /ML/ [5], [20]. Several data analysis techniques are proposed to evaluate the best method of ITS data analysis [21]. The development of cooperative ITS (CITS) using IoT and IoV has also been developed by various researchers [10].

As early as the 1990s, the U.S. Department of Transportation adopted a national ITS standard. In this model, the traffic management subsystem maintains monitoring and controlling road traffic by exchanging data with the road infrastructure subsystem. On this basis, the following two criteria for the classification of ITS systems can be considered:

- intelligent infrastructure and
- intelligent vehicles.

Now the Architecture Reference for Cooperative & Intelligent Transportation (ARC-IT) provides a framework for planning, programming, and implementing intelligent transportation systems [22].

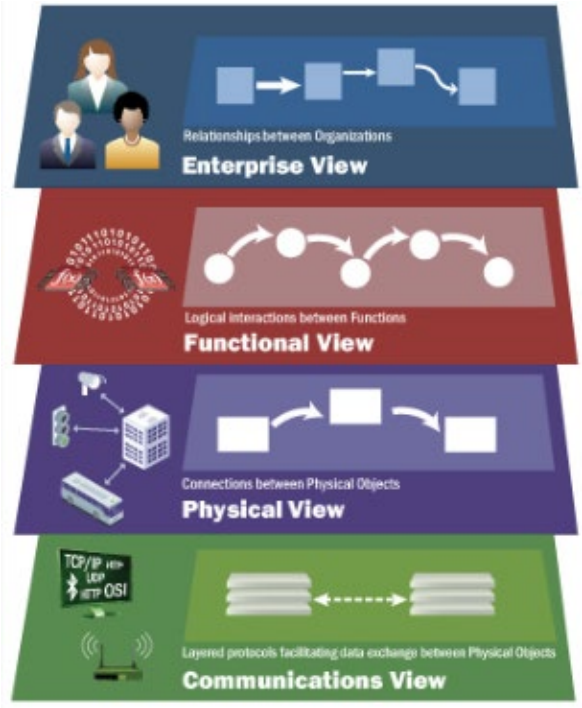

Fig. 2. Architecture Reference for Cooperative & Intelligent Transportation (ARC-IT).

ARC-IT has shown on Fig. 2 is comprised of 4 Views:

- *Enterprise* - Describes the relationships between organizations and the roles these organizations play in the connected vehicle environment.
- *Functional* - Describes abstract functional processes (elements) and their logical interactions (data flows) that meet system requirements.
- *Physical* - Describes physical objects (systems and devices) and their functional objects, as well as the high-level interfaces between these physical objects.
- *Communications* - Describes layers and protocols that are required to support communications between physical objects involved in the connected vehicle environment.

a) Advantages of ITS

ITS use information technology as well as other advanced technologies to support the organization of transport work. The benefits are mainly expressed in two areas: *First* - to reduce congestion and the number of accidents, and *Second*, to transform conventional transport systems into intelligent ones in order to improve their efficiency. Below are the advantages of using ITS [5]:

- *Mobility:* Through ITS, road users are informed in advance about road traffic conditions. In this way, ITS plays a vital role in the mobility of people and goods and services worldwide.
- *Congestion:* ITS is commonly used to avoid congestion by providing information on road conditions, climatic conditions and other factors such as traffic lights and many others and directs drivers to the most appropriate route to avoid the problem of congestion and thus smooths out the traffic system.
- *Pollution control:* Road traffic is increasing day by day due to several reasons: the increase in vehicles and the emission of pollutants from vehicles which is also increasing, and this harms the environment. Pollution can be of any kind, such as the emission of harmful smoke from vehicles, which causes air pollution, as well as noise pollution, etc. By implementing ITS, this can guide people in vehicles not to emit pollutants by providing them with timely guidance on vehicle maintenance.
- *Accident prevention:* Increasing traffic on the roads also increases the number of accidents that threaten human life. Implementing ITS can prevent accidents and save people's life by providing them with proper instructions while driving.
- *Improving reliability of travel time:* The application of ITS reduces the time needed to reach the destination by providing the best optimized journey route [23].

b) Disadvantages of ITS

ITS also have several disadvantages and negative impacts, which can be formulated as follows:

- *Dependency:* The deployment of ITS depends on the built infrastructure and Internet connectivity. The implementation of ITS requires the use of various latest technologies that may not be familiar to the people who will use them. Many of the vehicles are not equipped with these latest technologies to allow the deployment of ITS, i.e. the benefit is only for these vehicles, which have the latest technology and components built in.
- *High cost:* Due to the use of a number of components in the implementation of ITS, this system has become very expensive and it is not possible to apply it to everyone. Maintenance costs are also very high.
- *Lack of awareness:* Since ITS are based on emerging technologies, many people are not aware of this, so they are respectively not aware of the benefits of this system, i.e. successful ITS is the one with which people are informed.
- *Lack of resources:* ITS cannot become successful until all the necessary resources for their construction and deployment have been made available. The diversity of resources is necessary to implement ITS, which can be related to both technology and manpower, etc.

B. *IoT and IoV in ITS*

IoT (Internet of Things) is used in every area of the technologically oriented modern world. IoT and IoV (Internet of Vehicles) is widely used in transport as traffic management, controlling traffic lights, implementing an intelligent parking system, providing the best transport routes, and identifying road and weather conditions on the basis of which road traffic can be judged and the person can travel [24], [25].

a) IoT Applications

IoT devices are in different regions of an area and are mostly used to prevent road congestion, telematics frameworks in vehicles, security, and surveillance systems. IoT is used in transportation by deploying various components such as sensors, actuators, and other devices. They collect the data and analyze these data using ML approaches to extract useful information for predicting road conditions to provide ITS. The inclusion of IoT in the transport sector completely transforms the transport system scenario in the world. Various IoT applications in transportation include public transport management, real-time vehicle tracking, connecting vehicles using a global positioning system (GPS) and cameras, distance traveled and fuel consumption identification, and much more [26]. IoT applications in different areas are represented by the diagram (Fig. 3).

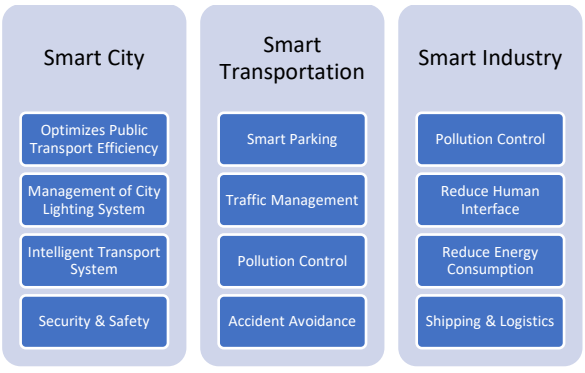

Fig. 3. Applications of IoT in various areas.

b) IoV applications

IoV is widely used these days in the implementation of ITS to optimize the performance of the transport system through integration with IoT [27], [28], [29]. IoV integrates with IoT, and security is the main concern when using IoV. They use the concept of VANETs to provide ITS applications [23]. IoV is a combination of IoT and VANETs, which is an emerging ITS research area. IoV performs five types of communication:

1-from vehicles to vehicles (V2V),

2-roadside devices,

3-personal devices,

4-from vehicles to sensors and

5-from vehicle to infrastructure of cellular networks, as shown in Fig. 4.

Fig. 4. Communication in Internet of Vehicles.

C. ITS technologies

ITS applications use different technologies. Some of the main technologies used by ITS are discussed below in Table 1 [30], [31], [32].

TABLE 1 DATA COLLECTION TECHNOLOGIES FOR ITS

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

Vehicles communicate with each other to obtain information about the current state of the road, traffic, as well as to avoid traffic jams and accidents. The communication technologies shown in Table 2 are VANETs and are widely used in ITS applications [32].

TABLE 2 COMMUNICATION TECHNOLOGIES FOR ITS

№	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

ITS must use data collection techniques so that it can communicate with different moving vehicles on the road. Data collection techniques are very important, as indicated in Table 2, as they collect the information related to the physical location of devices together with various aspects which are very important for ITS operation.

There are two categories: infrastructure-based technologies include video surveillance sensors, and vehicle-based technologies involve the use of GPS systems.

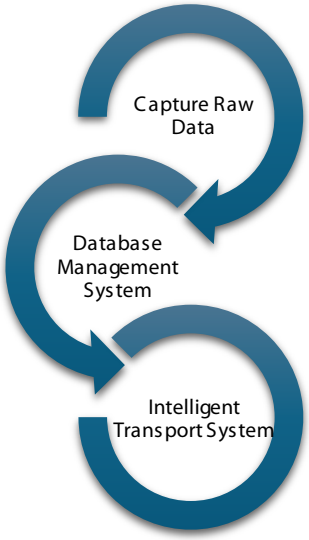

Fig. 5. Data conversion process.

Data collected from different wireless devices must be analyzed and must be stored in an appropriately structured format. Data conversion is displayed in Fig.5 a management system that stores the linked data and helps ITS analyze it. Analysis of traffic-related data helps to extract the necessary information from the technologies used shown on Table 3 [33].

TABLE 3 DATABASE TECHNOLOGIES FOR ITS

№	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 infra-structure 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

The issue of ITS security is also very important, both for infrastructure and vehicle components. The general attacks on ITS and their consequences are shown in Table 4.

TABLE 4 COMMON ITS ATTACKS AND ITS CONSEQUENCES

№	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

A lot of research is underway to design autonomous vehicles that can also be considered ITS. The need to implement such systems is to themselves avoid traffic jams, yes themselves prevent accidents and accidents. Problems and issues related to autonomous vehicles need to be considered and reliable solutions must be provided [34]. The use of such autonomous vehicles has advantages and disadvantages. The negative impacts of autonomous vehicles are as follows:

-*Safety issues:* Autonomous vehicles have various security flaws, with sometimes vehicles not being able to be controlled in emergency situations or while driving at very high speeds and they become uncontrollable. In addition, sensors in autonomous vehicles often fail to sense the objects that suddenly come in front of vehicles on the road. Because of these safety issues, autonomous vehicles are causing problems in the field of ITS. Sensors can sometimes not detect obstacles on the road due to low visibility in heavy rain, thunderstorm and other weather conditions.

-*ML problems:* Most autonomous vehicles use ML techniques such as applying brakes, detecting objects and automatically stopping the car in the event of an emergency, but this can sometimes create problems for them. These ML algorithms cannot guarantee that these vehicles are safe and accident-free. We cannot force companies to use the standardized data set for training, validation and testing.

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

-*Congestion and collision of vehicles:* These vehicles are included with a number of technologies and these are driverless vehicles, which is why sometimes the components of the vehicle can become damaged. Due to a misunderstanding of the commands issued by the person sitting in the car, these vehicles can generate problems and collide on the road, which can lead to traffic jams on the roads and vehicles can collide with each other.

-*Social acceptance:* A serious accident has been reported with an increase in the number of accidents from automated cars manufactured by Tesla. Social acceptability is a very important issue to be followed by people driving on the road as well as people using these automated vehicles. People need to be informed about the features and facilities provided by these autonomous vehicles. They should be given appropriate training to work with these types of vehicles so that the challenges and problems solved with them can be solved.

-*Quality of Service (QoS) Design Problems:* When designing ITS, the most important concern is the QoS's provided by it, as shown in Fig. 6. ITS design should ensure the best quality of service. QoS has an impact on the availability, performance and scalability of ITS.

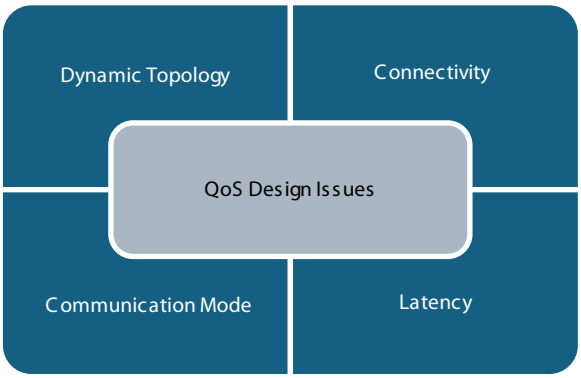

Fig. 6. QoS Design Issues.

ITS are based on the concept of mobile vehicles, i.e. their location is constantly changing. ITS must deal with real-time constraints, especially in the vehicle safety scenario [35]. Latency is the important requirement to measure ITS performance, different vehicles communicate in different ways, leading also to:

-*Problems with communication technologies:* There are several problems that arise when communication technologies are used in ITS These issues need to be addressed for the successful implementation of ITS [36], which also raises the issues of vehicle spacing, confidentiality and security of information and timeliness for information exchange.

Vehicles are more vulnerable to security threats as this can compromise their safety. For example, Sybil Attack [37] is very harmful and difficult to identify in vehicle networks. The different attack categories for ITS are shown in Fig. 7.

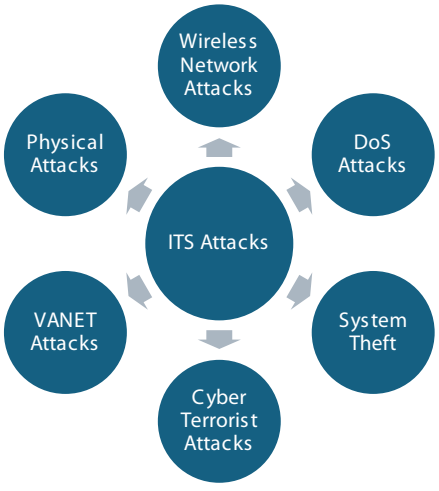

Fig. 7. ITS Attacks.

ITS involves the communication of information between different vehicles on the road that may compromise their integrity, authenticity, privacy and confidentiality, so these issues need to be addressed to address security challenges [32]. The various security issues are addressed together with possible solutions to overcome these problems [38]. Wireless networks are more vulnerable to security threats than physical attacks on ITS. As indicated in Table 4, these attacks aim to slow down and block ITS services, crash the ITS server, and gain access to confidential information from the database.

ML-based security solutions involve the use of artificial intelligence and help analyze data in the easiest way in a very short time. ML algorithms (Fig. 8) are applied to ITS, help to effectively detect security vulnerabilities (security systems). They can reduce the consequences of security attacks and help detect intrusions very easily in ITS [39].

The Intrusion Detection System (IDS) is used to detect these intrusion activities. IDS uses some attributes to classify network data into attacks or normal. ML techniques also help to detect known attacks more efficiently and with higher accuracy. Detecting unknown attacks is very difficult, as they are not previously assigned labels. So, IDS based on anomalies is the issue addressed to consider when detecting malicious activity in ITS. These anomaly-based approaches help to overcome the disadvantage of IDS. In this approach, network traffic is investigated, and if the behavior of the system deviates from its normal behavior, it means that it is an intrusion activity. Thus, the unsupervised learning model helps in detecting attacks.

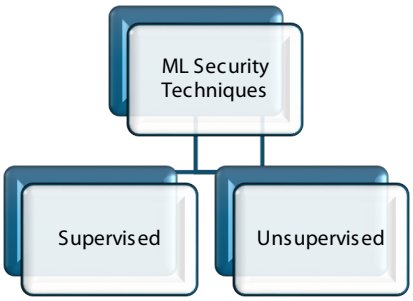

Fig. 8. ML Security Techniques.

Typically, distributed DoS (DDoS) attacks are identified by these ML algorithms.

D. Traffic monitoring system

Some existing models offer a distributed system that guarantees flexibility and autonomy in the proposed modules [10]. In these modules the problems are solved with some optimization schemes. The solution of these optimization problems related to the intelligent transport system imposes autonomous computing, which is an emerging concept in computing. A quadruple paradigm is proposed: self-configuration, self-healing, self-optimization, and self-defense. This is operational in the proposal of four large modules as it includes: control point self-management, interference detection and propagation, dynamic route planning and section monitoring (Fig. 9).

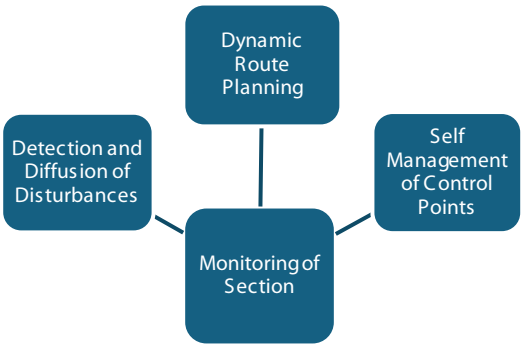

Fig. 9. Scheme of the structure of inter urban road network monitoring system.

The establishment of such an ITS project in countries lacking a well-developed infrastructure contributes to the infrastructural development of transport systems. Economically, it offers several openings in terms of sus-trainable. Building, installing and administering checkpoints requires a lot of work, which opens up a large infrastructure project horizon. The idea here is to define a modular system in which each module solves part of the problem and if possible, based on optimization models and according to performance criteria. This makes the system easier to understand, administer and improve.

E. AI in ITS Project Management

The use of artificial intelligence in the management of transport projects gives more accurate information about the time of completion of the project, more accurate reports, more accurate identification of risks [40]. This makes the management process more efficient and leads to project success [41], [42].

In the management of transport projects, large amounts of textual data are generated. The analysis of this data can improve management processes, reduce costs, increase efficiency, and more. This analysis is shown in Fig. 10 and includes a four-step process:

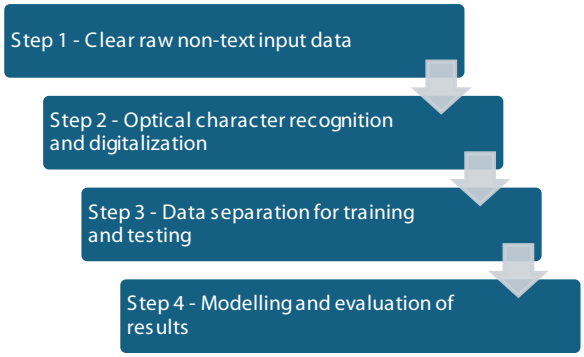

Fig. 10. Four-step model for text analysis in project management in transport.

- *The first step* aims to clear raw input data by removing data that is not textual.
- *The second step* (Engineering) is the stage in which with special methods the text is digitized. The importance of engineering for the final results is extremely great, as the information from the second step is fed to the algorithm and the correct digitization is the basis of the decisions made.

- In *the third step*, the data is divided into training data and testing data. This is a mandatory step for performing machine learning.
- In the last *fourth step* "Modelling and Evaluation" different methods and algorithms are used to obtain results from the textual data.

This is a new area of application of AI, as many projects contain a large amount of documentation and their multiplication allows errors and inaccuracies.

III. Results and discussion

The results of the work on the study can be classified into two aspects for the emergence and development of ITS: Transport related issues and Techniques involved in solving these issues. This raises a discussion about:

A. Transport issues

Due to population growth, traffic and transport are increasing, which also raises several topical issues such as traffic control, air pollution, crime control, disaster management, congestion control through appropriate navigation systems.

Various issues that have been focused on the literature review are summarized. Based on the study, it can be concluded that the main challenges in most of the work of ITS are related to traffic and congestion control, as well as disaster and accident management. Air pollution, efficient navigation and resource management are also important, although less focused on research.

B. Techniques involved in solving these issues

The specificity of the transport process is that different problems require to be solved in real time based on the dynamic information received to solve them. Technological solutions are diverse, often technologies of different generations, which reliably and securely need to communicate with each other. As an example, the use of various CCTV cameras can be used, as well as sensors that are used to provide real-time information. GPS technology is combined with different image processing techniques for more advanced navigation systems.

The use of advanced technologies such as VANETs, cloud computing, agent-based computing are being introduced to make the transport system more efficient and intelligent. Up to now sensors of VANETs, techniques for vehicle cloud computing are agent based. This is currently the best solution, and improvements due to technological advances are expected in the future, using GPS, intelligent infrastructure such as traffic lights, RFID readers, etc.

IV. Conclusion

Explosive growth separately in traffic and population density raised various issues such as air pollution, congestion and accidents which have become an important area for research.

The implementation of ITS is a very important issue, as it solves several problems related to the transport system. The design of ITS is very important for security and safety, and on the other hand it improves the road infrastructure system. ITS can therefore be used to address these transport-related issues. ITS combines various technologies such as data collection, communication, machine learning and data mining to provide transportation and related services. These services include traffic control, navigation systems, driver assistance systems and fault detection systems. In addition to this, ITS also decides on transport related to issues such as disaster management, congestion control and air pollution. Further improvement of ITS includes the addition of new techniques such as IoV, cloud computing for vehicles, agent-based computing which includes the introduction of artificial intelligence into transport systems. By combining these techniques, ITS can be more effective in solving transport-related problems.

The systematic study of existing ITS examines them from different perspectives, the pros and cons of ITS on various issues related to security aspects and design challenges are taken into account. Many review articles have been published in the context of ITS, but none of them have discussed all aspects related to ITS. Much work needs to be done in the future in this research area. Open research questions in this ITS research include the identification of important indicators that impact on the effectiveness of ITS. This has to be done in the area of providing solutions for the dependability and security aspects of ITS.

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