Internet of Things

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Intelligent Cyber-Physical Systems for Autonomous Transportation

Springer

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ISSN 2199-1073 ISSN 2199-1081 (electronic)
Internet of Things
ISBN 978-3-030-92053-1 ISBN 978-3-030-92054-8 (eBook)
https://doi.org/10.1007/978-3-030-92054-8

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Foreword

The advent of autonomous transportation systems (ATSs) has drawn greater attention to deal with the challenges faced by traditional transportation systems such as traffic congestion, energy utilisation, security, and parking. The concept of ATSs is not new in the market; it has undergone numerous laboratory and field testing to work successfully in real-life applications. However, the introduction of artificial intelligence (AI) in the ATSs is what attracts researchers the most. The advancement in technological research and development in the area of AI has proven to give promising solutions to the challenges faced by modern society, such as rise in population, climate variability and spike in energy needs. Therefore, AI, along with the use of data-collection and smart technologies, drives the research on ATSs to unrivalled heights.

Cyber physical systems (CPSs) have revolutionised further the autonomous transportation systems by achieving greater efficiency and reliability as compared to the traditional transportation systems. The CPS technology is based on integration of physical systems (sensors, actuators etc.) along with the data-driven cyber systems (software). It employs the use of IoT-based technology to design driverless vehicles that enables more safety and security and is a boon to the hustled human lives. The CPS for autonomous transportation is not dependent on human control and thereby delivers efficient results in areas where humans fail (such as construction sites, agriculture, and mining).

This book comprises a number of chapters that focus on the theoretical and practical concepts regarding the need for intelligent cyber-physical systems for autonomous transportation. Apart from covering the topics ranging from CPS to AI, it also sheds light on different use cases and security issues in intelligent transportation systems. It is a very good incubation for those who are novice to the area and at the same time helps to provide useful insights for researchers who wish to dig deep into the concepts of CPS utilising the intelligent algorithms. The "Intelligent Transportation" highlighted in this book employs the collaborative use of artificial intelligence technology and real-time data collection from the physical systems along with data analytics.

It is fascinating to mention here that the editors and authors of this book represent distinct regions in the world, thereby covering different aspects of ATS in those regions. Irrefutably, this geographic fusion of technical minds would provide a more comprehensive view in this emerging field.

Durham University, UK Anish Jindal
July 2021

Preface

Cyber-physical system (CPS) is referred to as an engineered mechanism wherein the physical processes are controlled through computations and computer-based algorithms. CPS intertwines the software and physical elements (depicting different and discrete behavioral characteristics) working at spatial as well as temporal scales to interact with each other based on the context. Among others (smart grid, smart cities, health systems), one of the most challenging examples of CPS is the transportation system (including vehicles and drones). The orchestration of computing, things, and vehicles in a complex urban transportation ecosystem ends up in a complex environment. In such a scenario, the characterization of individual systems may provide a deep insight into the potential methods to interact with the surroundings. Due to these reasons, the future CPS will have limited dependence (or reliance) on human control and will focus on embedded intelligence in the form of artificial-intelligence (AI)-based processors and control. Such systems will operate vehicles and transportation key elements as a prevalent landscape of future transportation systems. Nowadays, the adoption of AI and machine learning (ML) to solve the problem of uncertainty along with the usage of probabilistic models and algorithms to handle predictive analytical problems is prevalent in a wide range of environments. On similar lines, the intelligent CPS also relies on AI and learning algorithms for approximation and employs statistical training and probabilistic algorithms running at the intelligence edge devices embedded with inference engines.

Although the automobile manufacturers are pushing hard towards the growth of this future intelligent CPS for the transportation sector, several challenges are new and increasingly complicated. The stringent need for coordination, amalgamation, and unification among the virtual (including the computational elements) and the physical worlds is essential for the success of intelligent CPS for smart transportation. The expanding smart cities require an instrumented transportation infrastructure and intelligent CPS to control and coordinate the same. The advent of connected and autonomous vehicles adds situational awareness in vehicles using the networked infrastructure of smart cities. For this reason, there are several latest technologies (edge intelligence, deep learning, generative adversary network,

software-defined networks, intent-based networks, and context-aware computing) that are trying to act as enablers for future smart transportation. The main reason for the confluence of these smart technologies, adaptive systems, and runtime models is because of the increasingly instrumented world enabled through pervasive sensing and actuating capabilities, adaptive real-time and networked control, analytical and cognitive capabilities, intelligent edge-fog osmosis, and compute and storage clouds. The availability of cognitive intelligent assistants in the vehicles human-out-of-the-loop CPSs is proliferating in smart transportation. Hence, the enabling technologies and intelligent applications emerging from the integration of the CPS and embedded intelligence have a potential for innovation and incubation engine for a broad range of research, academia, and industrial ventures.

This book provides a comprehensive discussion on some key topics related to the usage or deployment of AI in urban transportation systems. It presents intelligent solutions to overcome the challenges of static approaches in the transportation sector to make them intelligent, adaptive, agile, and flexible. This book showcases different AI-deployment models, algorithms, and implementations related to the intelligent CPS along with the pros and cons of the same. Even more, this book provides deep insights into the CPS, specifically about the layered architecture and different planes, interfaces, and programmable network operations. The deployment models for AI-based CPS are also a part of this book with an aim towards the design of interoperable and intelligent CPS architectures. Uniquely, the readers will find practical implementations, deployment scenarios, and use cases related to vehicular, traffic management, underwater transportation, and many more.

The current and future application of AI lies in the CPS-based urban transportation use cases like traffic lights, emergency vehicles, traffic management, underwater transportation, signal processing, high-speed trains, subway track vibration, complex data analysis, vehicle safety, secure information transmission, and mobile crowdsensing. These applications cover almost every domain related to transportation where computational decision making and networking is partially or fully required, and so the future of this area is bright. The current level of research and literature in this area of focus is limited to specific and smaller segments; therefore, this book will make us understand the applicability of AI-based CPS in a wide range of transportation applications that drive life's routine. The current advances in smart cities require intelligent control and management of urban transportation infrastructure with the vision of autonomous cars to provide global visibility. As intelligence empowers the connected vehicles and transportation infrastructure and everything, AI-based CPS architecture will open various bottlenecks encountered by the connected transportation sector.

This book is divided into five parts. The first part provides an overview of transportation systems and future transportation systems. This part discusses the historic evolution of transportation systems alongside presenting the key challenges and applications. The second part focuses on AI and its need and application in transportation systems. This part also covers the application deployment of AI in transportation systems. The third part covers the historic evolution of CPS and its role in future transportation systems. The fourth part provides application use cases

of autonomous transportation systems in traffic lighting, underwater transportation, advanced signal processing, high-speed train induced subway track vibrations, complex data analysis, and vehicle safety systems. The last part of the book covers the security perspective in intelligent transportation systems considering blockchain and privacy-preserved mobile crowdsensing.

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July 2021

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Part I
Overview of Transportation Systems

Chapter 1
Transportation Systems

Sidra Iqbal, Uswah Ahmad Khan, and Abdul Wahid

1.1 Background of Transportation Systems

Persistently occurring revolutionary changes in the transportation systems continues to enhance the consumers experience and awareness. These transportation systems are deeply embedded in presently commercial and private businesses all around the globe. It has led the transportation industry to a subsequent level in terms of speed, services, time, and quality. This section focuses on the vicissitudes in the transport systems over the years. The need to evolve the former systems arose from the rapid growth and demand of advanced technologies as depicted in Fig. 1.1. This was due to the fact that new transportation systems were adaptive in nature and were adjustable to the unceasing changes in social, economic, and environmental factors. The foremost changes, which encapsulate the gradual substitution of old systems by the innovative and improved systems, are discussed below:

1.1.1 Roads

In the year 1700s, the early modern highways were constructed by John Loudon McAdam (1756–1836), around the time of Industrial Revolution by using cheap soil and stone concrete paving material (macadam). The roads were embanked a few feet higher than the surrounding terrain to allow drainage of waterway off the surface. The demand for such roads increased in the forthcoming years to eliminate wash

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S. Garg et al. (eds.), *Intelligent Cyber-Physical Systems for Autonomous Transportation*, Internet of Things, https://doi.org/10.1007/978-3-030-92054-8_1

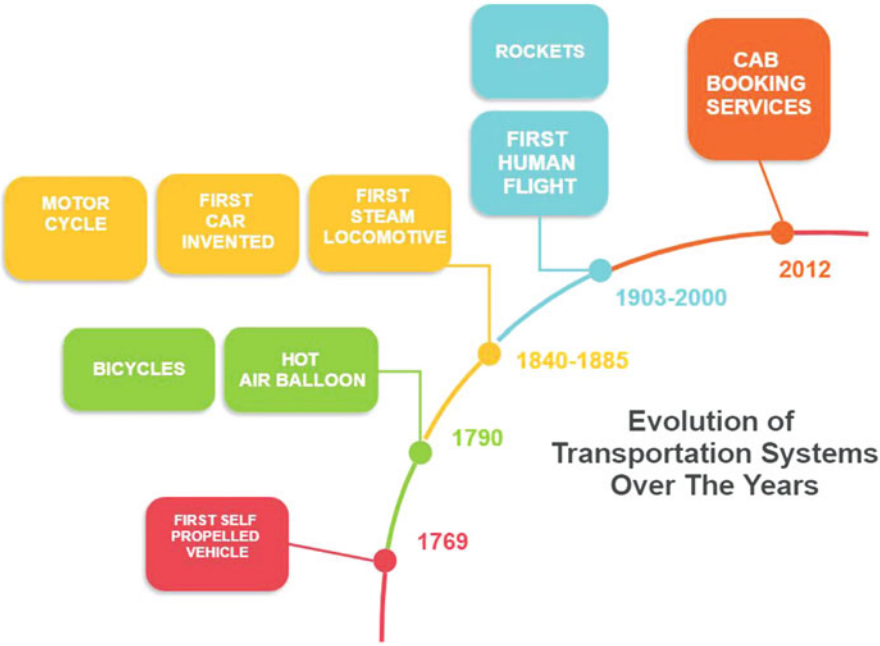

Fig. 1.1 Evolution of transportation systems

ways, bogging systems and dust on both municipal and agricultural roads. With the growth of motor transport in the early twentieth century, major western cities constructed roads initially by using cobblestones, wood paving, tar-bound macadam (tarmac), and concrete. In 1902, the world's first tarmac road was built then and named as Nottingham's Radcliffe Road [6].

1.1.2 Rails

In 1802, the first-ever ("Puffings Devils") steam-powered locomotive operated on smooth rails. It was designed and constructed by Richard Trevithick, a Cornish engineer, referred to as "father of railways" alongside, George Stephenson. Five years later, in 1807, Swansea and Mumbles Railway at Oyster mouth initiated the first passenger-carrying public railway. It was designed on existing tramlines by utilizing horse-drawn carriages. In England, in the 1820s, modern rail transport systems initially appeared [6].

1.1.3 Air

In 1783, the Montgolfier brothers invented the first air mode transport known as the hot air balloons. Jean-François Pilâtre de Rozier and François Laurent d'Arlandes were the chief explicitly confirmed individuals which took the human flight in Paris. They traveled 5 miles (approximately 8km) in the hot air balloon. Later, over a gap of 120 years, a ground-breaking change arose in the air transportation system. The Wright brothers made the first continuous, operated and powered heavier-than-air flight, and named it the Wright Flyer [6].

1.2 Growth of Transportation Industry

The transportation industry maintains a strong hold on the GDP growth of a country. It is one of the largest sectors that has been accumulating labor since its first-ever advancements in the sector. Transport industry pays a major surcharge to the governments which enhance the growth of countries globally. As millions of people, use multiple means of transport on a daily basis, the economic sector is forever to prosper. Different modes of transportation system include subways, metro buses, automobiles, air flights, and delivery of shipments through sea cargo. There is an evident relationship between quality and quantity of foundations of transportation, the stronger the relation, the better the economy [7].

Concentrated infrastructure of transportation and highly dense connected networks are deeply connected to the levels of development. An efficient transport system increases the provision of social and economic opportunities for the general public which highly impact the country nationally and internationally. Not only that, it also facilitates towards a better society by increasing the employment rate, accessibility in markets, and pave ways for investors to invest in the profitable industry of transportation. On the contrary, deficiency in production units of transportation system leads to inflation in a country and it lowers the living standards.

At an aggregate level, a productive transportation system decreases costs, while poor transportation increases such costs. In addition, transportation impacts are not always intended and can have unexpected or unintentional effects. For example, when supplying customers with free or low-cost transit networks, congestion is always an unexpected result. Nevertheless, congestion can also be taken as a good indicator of a rising economy where it is difficult for capacity and infrastructure to keep up with the increasing demands for mobility. Transport bears a major social and environmental load that cannot be overlooked.

1.2.1 Importance of Transportation Industry

Transportation industries play a vibrant role in our day-to-day lives. Without the convenience of transportation, the world would not be able to function effortlessly and smoothly. Over the years, the significance of transportation industry has expressively amplified. Transportation industry provides assistance in moving objects of daily usage from one place to another. Around the globe, millions of citizens are dependent on the availability of different modes of transportation systems in order to transit to offices, schools, and other places of interest. The importance of transportation system assists in several aspects depicted in Fig. 1.2. These different aspects are discussed below.

- **Quick Marketing:** Transportation industry provides considerable assistance in the growth of businesses that contains items which demand "quick marketing" (also known as fast marketing).Short-lived items like fish and green vegetables are swiftly delivered to different customers even in inaccessible market sectors through vehicles thus raising the demand of merchandise [9]. With the rapid advancement in transportation systems, there is a need to keep up with the latest, affordable, and reliable modes of transport to benefit the business. Availability of safe and fast transportation modes such as motorbikes and automobiles (nation-

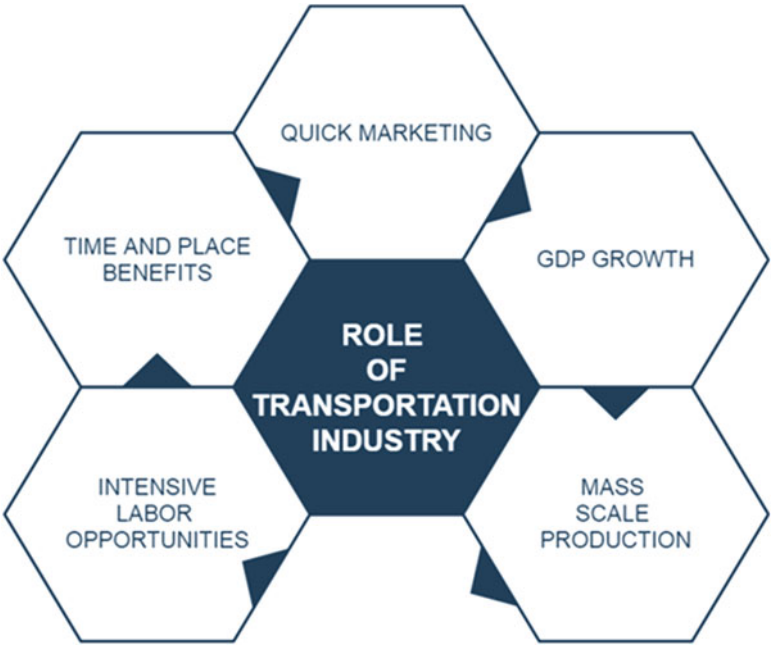

Fig. 1.2 Importance of transportation industry

ally), air cargo, and railway transport (internationally) has enabled effective collaboration between customers and the manufacturers.

- **Benefits of Time and Place:** A transportation system has eased up businesses by shortening the gap between time and place. Due to the climatic factors and the geographical conventions, industries are coerced to situate businesses far from the country local markets where they have little to no demands of the goods. Transport overcomes the barrier between the manufacturing and the utilization forces. Transportation industry has significantly increased the speed of transport by virtue of increased developments in the transportation modes. It enables the items to be disseminated in the minimum conceivable time.
- **Price Stability and Large-scale production:** One of the significant benefits imparted by transportation industry is their ability to dismantle any distinctions in item costs, i.e., products prices remain the same everywhere. When the production of goods is sufficiently enlarged, the transportation helps in delivering massive amounts of these products in the market from where the clients can purchase the products at lower costs. This results in mass production of items and goods. Transport places an evident impact upon the pricing of items by moving wares from surplus to shortage zones. This in turns levels the organic market factors and makes the cost of items stable. Transportation guarantees the progression of products under the control of the buyers throughout the period of utilization. Costs are likewise diminished due to the facility offered by transport for productions of goods at a larger scale.
- **Increases Employment:** Transport expands portability of work and capital. It causes individuals of one spot to relocate to different spots searching for occupations. Indeed, even capital, hardware, and other sort of gears are imported from far off nations through vehicles alone.
- **Economic Growth:** A country around the globe that lacks self-sufficiency relies on other nations to satisfy their necessities. This contributes to the economic growth by increasing employment and labor. Transportation has brought the nations together due to which it is considered to be the largest employment-intake sector. It also encourages the development and empowerment of business. The correlation between economic and transport industry is depicted in Fig. 1.3

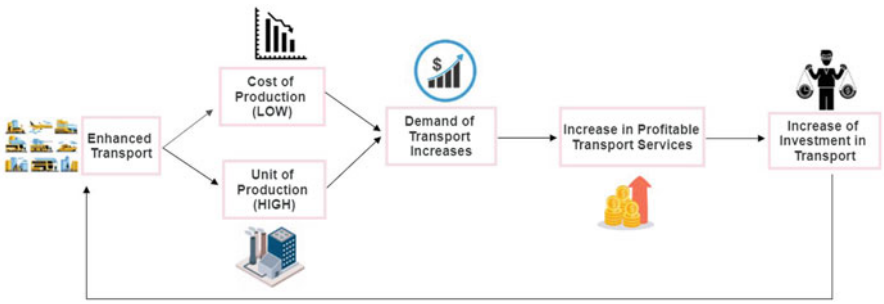

Fig. 1.3 Correlation between economic and transport industry

1.2.2 Growth Factors in Transportation Industry

Transportation systems are significantly concomitant with geography as it is concerned with measuring and assessing the relations between different areas and territories. For a nation's economic and social development, mobility is the elementary concern. Rapid advancements and unceasing emergence of technological aspects to transportation industry can swiftly ease the humans which in turns assist the financial sector, thus improving the country's civilization. The existing transportation industry cannot be pronounced by one factor, but there are several other factors contributing towards the growth of the transportation systems depicted in Fig. 1.4. Some of the factors are illustrated below:

- **Economic Factor:** Economic activities and the movement of all types of supplies from one destination to another are the two sides of a coin that collectively strengthen and reinforce a country's economy. Resourceful transport systems with advanced foundations can expand the business between the clients and the manufacturers. Thus, a proficient transport system can then benefit the overall economy. Reliable transport systems that offer low cost and less time benefits can provide services to markets on a larger scale. This will enable to impose "just in time" services to markets situated at distant places. As the delivery of goods and services has been improved due to the advancement in the transport systems, it enables the consumers to have access to varieties of goods from all across the world. This enables the clients to obtain quality products at lower costs. Efficient transportation with effective communication enables the production of goods and services in regions where it can attain the uppermost advantage. The production of goods in such region can improve the economic productivity as long as the proper transport is accessible for trade. So, for a country to grow economically, it is imperative that it should possess a virtuous transportation system.
- **Political Factor:** The growth of transportation systems is highly dependent on the political factors. Political facets include the safety and security conditions that are imposed on the transport system. It also defines the means in which different operations performed. The political aspect also outlines the trade agreements and contracts with other adjoining entities for the purpose of transit of goods and

Sr no.	Factors	Description
1.	**Economic**	Efficient transit of goods and services improves the economic productivity.
2.	**Political**	Implying safety conditions, trade agreements with other nations.
3.	**Social**	Providing healthcare facilities, social interaction through transport system.
4.	**Technological**	Using technology to make the transport system enhanced, inexpensive and cheaper.

Fig. 1.4 Growth factors

services. It defines the transnational connectivity and the interaction with other nations which can overall improve the country's economy.

- **Social Factor:** Transport system plays a very vibrant role in providing the necessities that improves and enhances the livelihoods. The need of providing healthcare facilities to people has made the use of different modes of transport systems unavoidable. The upsurge participation in cultural events and social interaction has also led to the growth of the transport system. Social activities have been stimulated to an immense extent due to the ease in mobility [10]. Now traveling from one place to another for any kind of societal collaboration is very stress-free. The more is the interaction, the better chances are there to improve and intensify the transit of goods and services among nations or also individuals. It thus humanizes the nation economic conditions.
- **Technological Factor:** Technological advancement has conveyed transportation services that are enhanced, inexpensive, and faster. People are now more likely to move efficiently from one endpoint to another. Similarly the transition of good and services is also enhanced and has become proficient over the period of time. Technology has led to the development of a friendly ecosystem. Use of GPS has headed people to get to their anticipated destination in a shorter period of time [8]. The hi-tech progression has also managed to lessen the fatal traffic accidents. Headlights in the dark assist the driver to drive safely, similarly the driver less automobiles have also led to the reduction of humanoid faults so that accidents can be reduced to an immense extent. Telecommunication has also endorsed the influence of "work from home" due to which the traffic mobbing on the roads can be reduced. Correspondingly, technology has directed the road administrators to highlight the highly congested areas so the traffic can be managed in an efficient way. This is owing to the technological innovations that the prevailing transport systems have made life easier and thought-provoking.

1.3 Challenges to Transportation Industry

With the significant evolution and improvements in the transport system, comes the challenges as well. As the transport system is becoming more saturated and complex, certain other sophisticated innovative and revolutionized mechanisms are required to overcome the challenges. These challenges can be categorized as the social, political and the technical challenges. Each of these is explained in detail in the following sections:

1.3.1 Social and Political Challenges to Transportation Industry

There are different social and political challenges in the transportation industry that needs to be addressed and resolves. Some of them are discussed below:

- **Social Challenges:** Some of the social concerns related to the transportation systems are described below:
  - **Limited Communal Interactions as a Social Challenge:** The transport system has eased the process of people to transit. It has also upgraded the transport of goods and services thus improving trade. But there is a certain level of inequity in the traveling of people belonging to different social groups. Most of people have ownership of personal vehicles and thus have the benefit of moving stress-freely and reaching the destination is shorter period of time and in a comfortable environment. As opposed to this, a person that cannot afford the ownership of vehicles therefore uses public transport which consumes time and is not comfortable. This results in limited social communication. The social interactions between people are also less due to the dichotomy in the modes of transportation available for people belonging to different demographics. Therefore, it is the responsibility of the transport sectors to offer a comfortable and cost-effective environment for people who are using public transport to transit. People living in the urban areas have a variety of transportation modes available for going to their offices, schools, shopping malls, parks, etc. In contrast people living in rural area are more subjected to limited public transport.
  - **Environmental Factor as a Social Challenge:** The social challenges of the transport system can also be considered from the environmental point of view. The transport system has affected the lifestyle of people. There are certain negative health impacts of transport on humans. Pollution is one such distress that has become an important social concern as it risks the human health. The emission of pollutants from the vehicles has polluted the air thus causing breathing issues and other various diseases. Similarly the noise pollution has caused annoyance and psychological instabilities. Similarly, the water pollution has contaminated the rivers and streams leading to different health concerns. This pollution has affected the human health and is therefore a social challenge in the transportation system that needs to be addressed and resolved.

    There should be supervisory agencies that should define standards in order to retain these social concerns. They should monitor the conditions and should impose regulation or penalties if any of the standards are violated. A good transport system is required, which will increase the amount of people using transport thus, improving the country economy.

- **Political Challenges:** There are different political concerns associated with the transport system. Some of them are discussed below:
  - **Inefficient collaboration:** The collaboration between different organizations that are accountable for the transportation management systems lacks efficiency. Due to the limited economic and financial development, initiating the expansion programs and enhancement campaigns for improving the transportation system is usually very less. The need of different transport modes is not properly gratified due to the deficiency in inter modal scheduling and planning. These consequences are due to the inefficient communication between the transport sector and the economic sector. Political pressure is one of the main factors responsible for the ineffectiveness in collaboration between different sectors. This is owing to the partial investment being made in projects that are concerned with the maintenance and preservation of the transport infrastructures. The Regimes are least considerate and sympathetic towards the improvement of transportation systems, which is one of the reasons why the transport systems are not competently enhancing and advancing in most of the countries.
  - **Less Prioritized:** Transport agencies ordinarily propose many stimulating and innovative projects schemes to the government corporate sectors. But still such projects are least prioritized. The initiation of such projects requires full fledge funding. The successful completeness of such projects can revolutionize and transfigure the entire transportation system, thus benefiting the nation from different aspects. One such aspect can be tourism; this can contribute to the economic development as well. As a matter of fact, it is observable that countries with dynamic and robust transport systems are economically strong. Hence, for a country to economically cultivate, vigorous transport systems are probably imperative.

1.3.2 Technical Challenges to Transportation Industry

Due to the extraordinary consumption of different modes of transport, the transportation system is thus becoming multifaceted and saturated. Therefore to efficiently carry out the transit of population, services, and goods, it is necessary that the mobility system should function applicably and appropriately. There are certain technical challenges that the transportation system is facing. Some of these issues are discussed below:

- **Traffic Congestion:** Due to the intensification in use of automobiles, traffic congestion has become the most predominant challenge. Increased quantity of vehicles on the roads has led to the problems of overcrowding and mobbing. Overcrowding leads to traffic jams and roadblocks, thus disturbing the normal day-to-day routine. This congestion also leads to fatal roadside accidents.

Therefore, in order to reduce the traffic congestion, it is highly endorsed to use public transports so that jamming on the roads can be reduced thus saving time.

- **Maintenance Expenditures:** Time is continually evolving and the movement of people as well as services and goods is rapidly mounting. This calls for a need to upgrade the transport system on continuous basis. Upgradation and maintenance of the infrastructures of the transport system requires high costs.
- **Hazardous Accidents:** As the transportation system is constantly developing, high congestion on the roads leads to fatal and hazardous accidents. This is a technical challenge that entails the road administration to persistently monitor the congestion so that the overcrowding should be decreased and people can safely transit. These mobbing also leads to delay and postponement in the transfer of goods from one place to another thus adversely affecting the business as well.
- **Safety:** The safety of the people is the main concern. The transport system requires alerting mechanisms that activates when certain speed limit is crossed. The existing transport system needs upgradation. Additionally, there is a need for latest and hi-tech sensors and cameras to constantly monitor the movement of vehicles so that any abrupt change in the traffic flow can be identified at hand and thus safety measures can be timely taken to avoid any unfortunate circumstances.
- **Parking:** The ever-increasing need for the transport has resulted in the increased number of personal vehicles. Comparing to the older system when there was only the public transport and very few people owned personal vehicles, in today's era almost every family owns a personal vehicle for traveling purposes. This increase in the number of vehicles has led to the problem of parking. People do not find parking spaces easily which causes them to search for vacant spots thus wasting time and fuel. An advance real-time parking is thus needed that will notify the drivers about the vacant parking slots so that the drivers can park their vehicles while saving their time and fuel.

1.4 Impact of Intelligent Transportation Systems

Previously, the transportation systems were more prone to subjective errors. Congestion, poor traffic monitoring, and insufficiency in transport management resulted in disastrous accidents and other mishaps. These challenges called for an upgradation in the existing transport systems and from here the need of incorporating technology to the transport system arose. This gave rise to the intelligent transportation system which overcame most of the challenges that were occurring in the conventional transportation.

The Intelligent transportation system (ITS) has gained prominence as it offers an effective real-time traffic managing and monitoring systems [12]. It has enhanced the quality of transit, provided safety measures to users, helped in reaching the destination in shorter time with less fuel consumption, decrease in traffic overcrowding and most importantly reducing the roadside calamities and disastrous accidents.

The impact of ITS on the lifestyle of people as well as its effect on the nation is huge. Advancement in ITS has led people to make constant use of different modes of transport thus improving their routines. Robust ITS promotes more trade and businesses all across the world contributing to more financial and economic development. A detailed explanation about the ITS is given in the following subsections.

1.4.1 Overview of ITS

Emerging countries are persistently improving their transportation systems. Due to the concentration in economic growth and population, transport systems are facing a number of challenges which includes overcrowding, hazardous accidents, and poor traffic management [3]. These situations call for immediate consumption of the ITS so that such extreme concerns could be fixed to the possible extent. To introduce ITS in a country, it is imperative that the country should know how to efficaciously incorporate technologies into the transportation systems.

ITS is concerned with refining the productivity and proficiency of the services provided by transport system. It involves the transmission of instantaneous information in order to advance the traffic management, reduce congestion, and lessen the road accidents. All these benefits of ITS can be yielded by applying the advance technologies of communication, sensing devices, computers into the transportation system. At the communal level, ITS applications are concerned with reducing the road congestion, minimizing the road accidents thus improving the traffic management. For those managing the road, ITS helps in determining the areas that remains highly congested so that the traffic can be managed in a competent way.

ITS assists in overcoming the socioeconomic issues as well as helps in the economic and financial development of the nations. Intelligent Transportation System supports the development of industrialized countries as well as the developing nations. Proper implementation of ITS can effectively reduce the fuel consumption enabling people to travel in a secure and inexpensive mode. ITS consists of various components. One such component is the Vehicular ad hoc network (VANET) which is considered to be the most significant [4]. VANET uses ITS techniques to impart reliable information regarding the vehicle's location, its speed, upcoming headings, and road conditions [13]. It is hence predictable that further advancement and progression in the Intelligent Transportation System will result in a more user convenient, secure, and efficient transport system.

1.4.2 Applications of ITS

The foremost intention of intelligent transportation systems is to enhance the existing transportation system and improve the quality of transport [2, 5]. Different

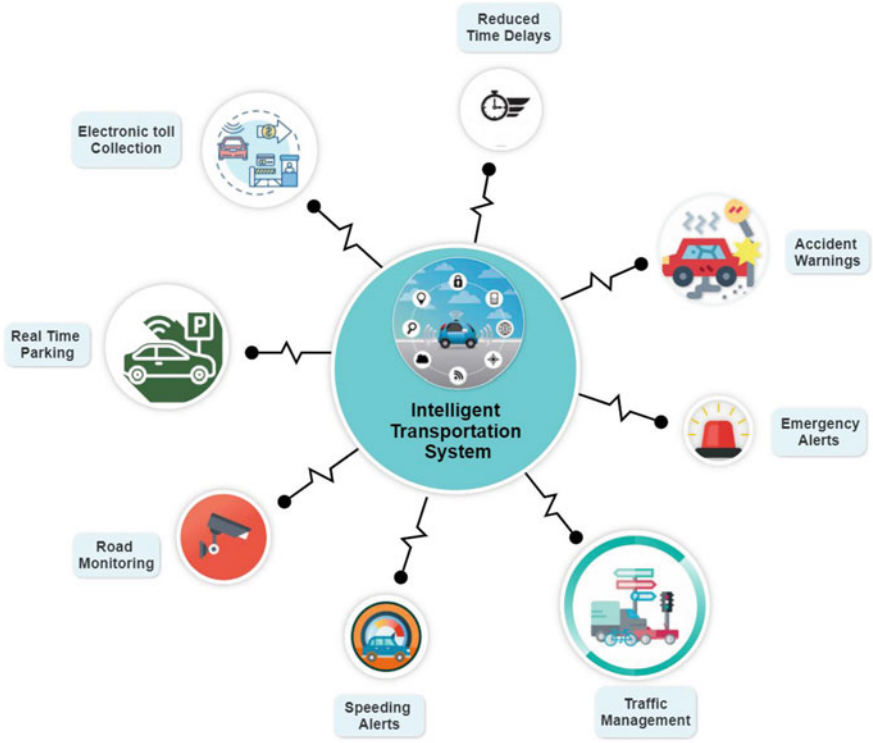

Fig. 1.5 Application of intelligent transport systems

monitoring and managing mechanism are used to enhance the transportation system. There is no doubt that, with the appearance of technology, the transport system has made rapid advancement and improvement. A colossal transformation can be observed that has changed the whole depiction of the transport. This is due to the constant emergence of technologies that has made the transport systems intelligent which are also shown in Fig. 1.5.

On a broader level, the functionalities offered by ITS can be categorized into two aspects, i.e., the Advance Traveler Information Systems (ATIS) and Advance Management System (ATMS). ATIS help people in making decisions regarding traveling whereas AMS focuses on the monitoring and controlling the transportation systems. Progression in ITS has led to the development in both ATIS and ATMS. There are voluminous applications of the intelligent transport systems in both of these categories.

- **Advance Traveler Information Systems:** This system collects, analyzes, and then delivers information to travelers so that they can easily transit from one location to another. It focuses on providing different mechanisms so that people can certainly make decisions about their traveling journeys. It imposes several

models that help in deciding the routes, means of transports, lane restrictions, available parking places, expected time to reach the destination, recommended speed, etc. These applications are discussed below:

- **Emergency Notification System:** This is one of the most significant benefits offered by intelligent transportation system. It is a real-time alerting system that notifies the drivers that an emergency vehicle is passing. This directs the drivers to slow down and give ways so that the emergency vehicles can pass easily.
- **Reduced time and fuel consumption:** Mobility is an advance application of Intelligent Transportation Systems (ITS) that aims at providing the ease of transit. It enables people to move effortlessly from one destination to another. The travel time prediction models help in specifying how much time is required to reach the destination. Amalgamation of vehicles with mobiles, Global Positioning System (GPS), and Media Access Control (MAC) has intended to deliver services such as taking the shortest paths. This saves the time as well as reduces the fuel consumption because we can now reach our desired destination in shorter time by selecting the optimal path amongst different paths.
- **Route Guidance Systems**: Route Guidance Systems (RGS) are used to notify the drivers about the environment such as traffic congestion on the roads, weather conditions, any mishap or accidents on the roads ahead, etc. The route guidance system uses various systems to identify the conditions of the roads and then notifying the drivers. This helps the travelers to timely decide on whether to switch or not to another route. The guidance systems use different algorithms such as inter-vehicular communication, sensor networks, P2P, VANET, neural networks for operating, etc.
- **Real-time parking:** The intelligent transportation system has paved ways for the real-time parking management. It uses cameras, sensors, payment systems, and mobile apps to determine the vacant slots in the parking areas. It then provides information to the drivers about the unoccupied and available parking spaces so that the drivers can easily park their vehicles. This real-time parking has also reduced the traffic jamming and mobbing as shown in Fig. 1.6.
- **Obstacle Alerts:** This warning technology uses radars, sensors, and cameras to warn the driver about any hindrance that is sensed through these devices. This prevents the vehicle from collision. This application warns the drivers about the obstacles approaching either from the forward or backward direction as the in-vehicle sensors are capable of sensing in both the direction.

- **Advance Traffic Management System (ATMS):** This system makes use of real-time information collection, processing, analyzing, and then using it for the management of transport system. The data collected from enriched sources with quality information helps in managing and controlling the operations of the transport systems. It makes use of different mechanism such as emergency warnings, road conditions, transit services, and the transfer of goods and services