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AI enabled applications towards intelligent transportation

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ABSTRACT

Artificial intelligence (AI) is the ability of a machine to perform cognitive functions like perceiving, reasoning, learning and problem-solving which humans are capable of performing at ease. AI has gained traction since the past two decades across the globe due to availability of huge volume of data generated through Internet. There has been a huge benefit to governments and businesses by processing this data using advanced algorithms in the recent past. The robust growth of machine learning algorithms supported by various technologies like Internet of Things, Robotic Process Automation, Computer Vision, Natural Language Processing have enabled the growth of AI. This article is a compilation of various issues plaguing Transport Industry classified under Intelligent Transportation Systems. Some of the sub-systems considered are related to Traffic Management, Public Transport, Safety Management, Manufacturing & Logistics from Intelligent Transportation Systems where AI benefits are put into use. The study takes up specific areas of concern in transport industry and its related issues that have possible solutions using AI. The approach involves a secondary study based on the country-wise data available from various sources. Further, discussions on AI solutions to resolve issues in transport industry across various countries in the globe and in Indian states is taken up.

1. Introduction

Technologies have been problem solvers for businesses in the past; whether it is retail, banking, insurance, healthcare or even sports. Some of these solutions have changed the way businesses are being run through reduction in operating cost, improving efficiency, and increased efficiency. One of the upcoming areas where latest technologies have been successfully implemented is transport industry which is plagued with issues related to traffic congestion, unexpected delay and routing problems leading to monetary loss in organizations.

Transport Industry has been a major contributor to the movement of people and goods across various geographical regions. It plays a significant role in supply chain management system where goods are transferred from one place to another. The industry plays a key role in the movement of goods to the right place at the right time in a logistics chain. In order to reap the complete benefit from a business investment, technologies like Machine Learning, Artificial intelligence, internet of Things among others have been used by governments and organizations.

1.1. Artificial intelligence (AI)

Artificial intelligence (AI) is a broad area of Computer Science that makes machines function like a human brain. AI is also defined as the ability of a machine to perform cognitive functions of a human at ease. The phrase AI was initially coined in the year 1956 by John McCarthy, a computer scientist. This six-decade old concept has gained recent buzz due to the availability of large volumes of data generated through various devices, and availability of efficient hardware, software and network infrastructure. The advent of AI has enabled process automation leading to innovative business solutions [47]. AI provides reliable and cost-effective solutions while addressing uncertainty in the decision-making process. The ability of advanced algorithms to handle complex data has facilitated faster decision-making in businesses due to process automation [10]. With the growing concern related to environment, AI has become a solution provider to resolve climate change and water issues by transforming the traditional sectors and systems. These capabilities have helped governments build sustainable cities that would help protect biodiversity and wellbeing of humans [23].

The United States (US) and China currently dominate the world of AI. A PwC report estimates that AI will contribute $15.7 trillion to the world economy by 2030 - more than the combined current output of China and India. In the US, the academic system has generated and incubated research related to AI; whereas in China, funding and technology is provided by the government to utilize the potential of AI. China plans to invest at least $7 billion till the year 2030. Canada and the United Kingdom have ramped up investment in technology by announcing

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Table 1
AI functions and use cases.

AI Function	Use-cases
Non-linear prediction	Traffic demand modeling
Control functions	Signal control, dynamic route guidance
Pattern recognition	Automatic incident detection, image processing for traffic data collection and crack identification in pavements or bridge
Clustering	Identification of specific class of drivers based on behavior
Planning	AI based decision support systems for transportation planning
Optimization	Designing an optimal transit network, developing an optimal work plan for maintaining pavement network, developing an optimal timing plan for a group of traffic signals

Adapted from (Sadek, Artificial intelligence Applications in Transportation, 2007)[54]

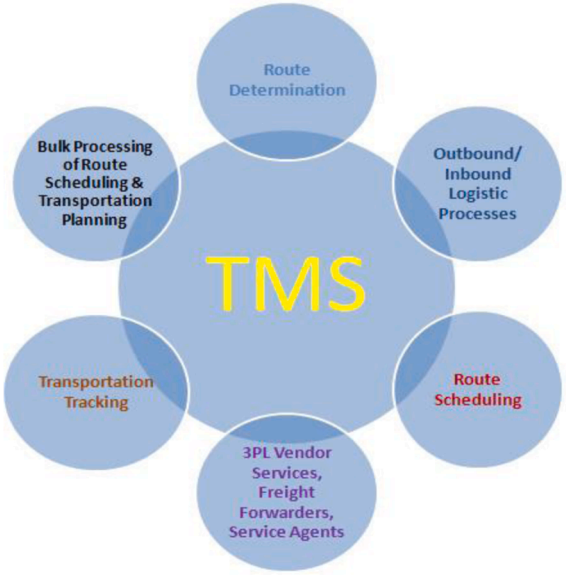

Fig 1. Functions of TMS.
(Source: ValuecConsulting, 2013)

deals to fund private and public AI ventures [20]. Canada had made $125 million commitment in 2017 itself for AI research. The French Government is investing $1.8 billion in AI research until 2022. The country plans to extract data from private companies to be publicly available for research. Russia spends an estimated $12.5 million annually on AI predominantly in military. Among developing countries, India is uniquely poised to be a leader in AI in the next few years. This is due to its strength in technology, favorable demographics and structural advantages due to the availability of data generated through digital transactions [58]. The Indian government set aside $477 million for Digital India project to enhance focus on AI, IoT, big data among other technologies. One of the significant use cases being traffic and crowd management.

1.2. AI and transport

Most of the large cities across the globe face issues related to transport, traffic and logistics. This is due to the fast-growing human population and also due to the increase in the number of vehicles on the road. In order to efficiently create and manage a sustainable transport system, technology could be of immense support. With urban areas struggling with traffic congestion, AI solutions have emerged in accessing real-time information from vehicles for traffic management, and utilizing mobility on demand in trip planning through a single user interface. Safe integration of AI-based decision-making, traffic management, routing, transportation network services and other mobility optimization tools are other possibilities of efficient traffic management (Transportation, 2019)[61]. AI is considered as one of the emerging technologies by World Economic Forum. AI methods that support transportation include Artificial Neural Networks (ANN), Genetic algorithms (GA), Simulated Annealing (SA), Fuzzy Logic Model (FLM) and Ant Colony Optimizer (ACO). The objective of deploying these techniques in transport management is to relieve congestion, make travel time more reliable to commuters and improve the economics and productivity of the entire system [1].

Vehicles that are connected through technology improve driving efficiency through forecasting of traffic conditions on the road [1]. The research article [41] addresses three perspectives.

(i) assessment of accurate prediction and detection models aiming to forecast traffic volume, traffic conditions and incidents
(ii) public transportation as a sustainable mode of mobility by exploring various applications of AI
(iii) connected vehicles aiming to enhance productivity by reducing the number of accidents on highways[40].

Several studies have been conducted across the globe to overcome issues related to the transport industry. The outcome of the research activities with the support of AI technologies around this industry has given hope for this significant area of development.

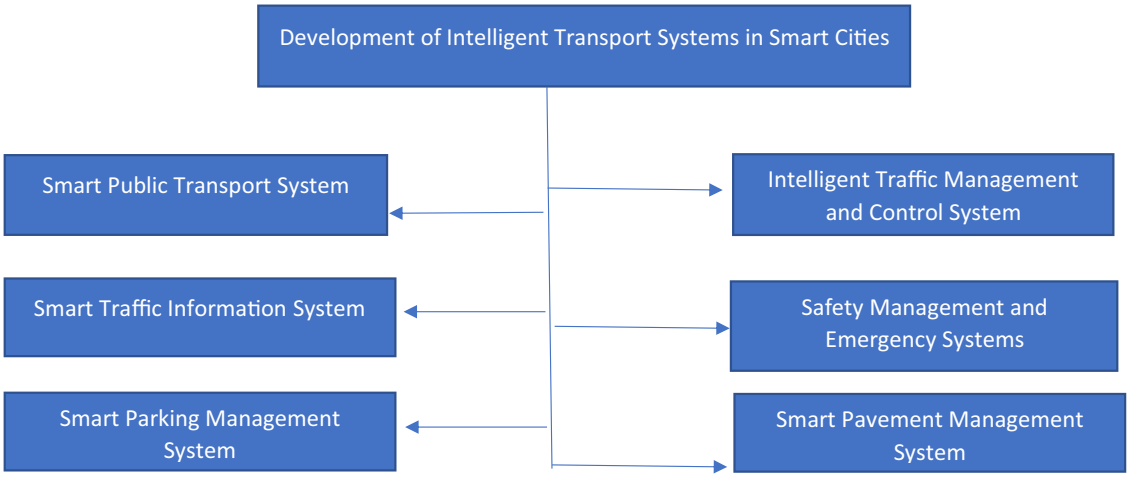

Fig 2. Various sub-systems for development of intelligent transportation systems.
(Source: Agarwal et al., 2015)

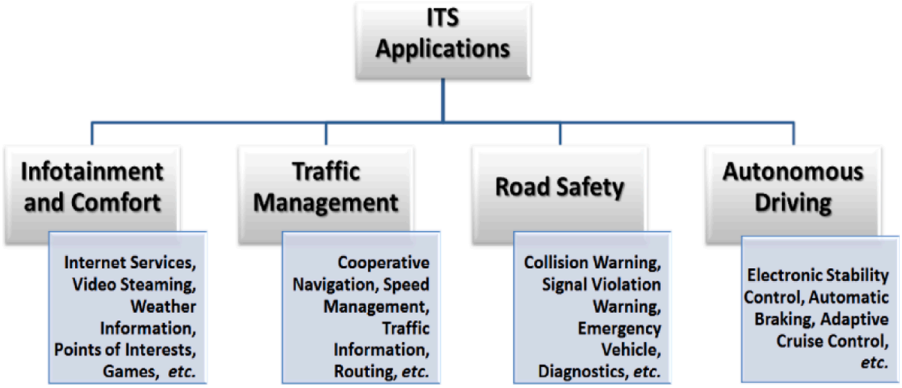

Fig 3. Classification of ITS applications.
(Source: Hamida et al, 201[5]5)

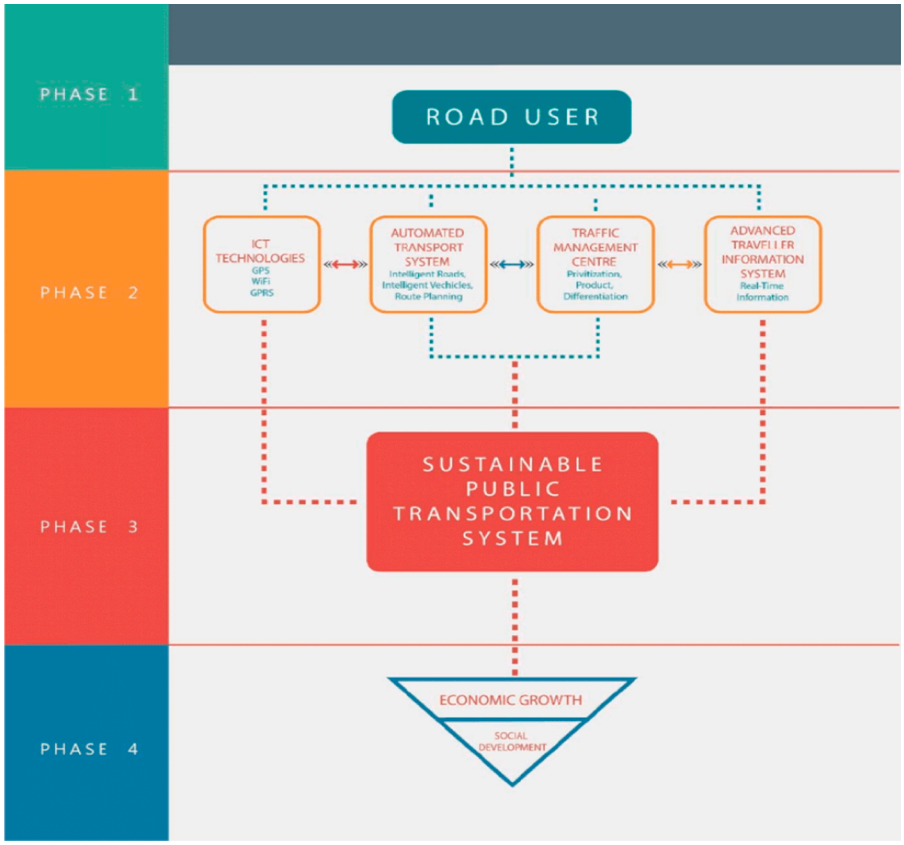

Fig 4. ITS Framework implementation to public transportation system.
(Source: Abijede O [55])

1.3. Intelligent transportation

In the recent years, huge volumes of data are generated with the proliferation of multiple technology devices across sectors. This data has become valuable in the decision-making process of businesses, governments and societies. Transport industry being the life line of an urban set up cannot be left behind in data generation and usage. This sector plays a significant role in urban development because it impacts people, processes and profit. To enable data generation, automobile manufacturers have been pro-active in building devices that can be fitted into vehicles that are used for transporting people and goods. Data generated by these devices are monitored remotely by experts. Governments and businesses are capable of taking real-time decisions based on the data generated through using various applications. Various innovative applications related to transportation and technology are being built in the recent years. The application developers focus on a process-oriented systems approach with a clear goal embedded with a feedback mechanism to measure the outcome of the solutions related to transport industry.

Transport Management Systems (TMS) belong to the area of transportation management specifically concerning the transportation operations. The objective of these systems is to set up effective route planning, load optimization, improved flexibility and transparency using data. As per Gartner, this field is expected to grow at a fast pace [42]. Transportation strategies of a city are linked to an information system for better administration that would focus on capturing,

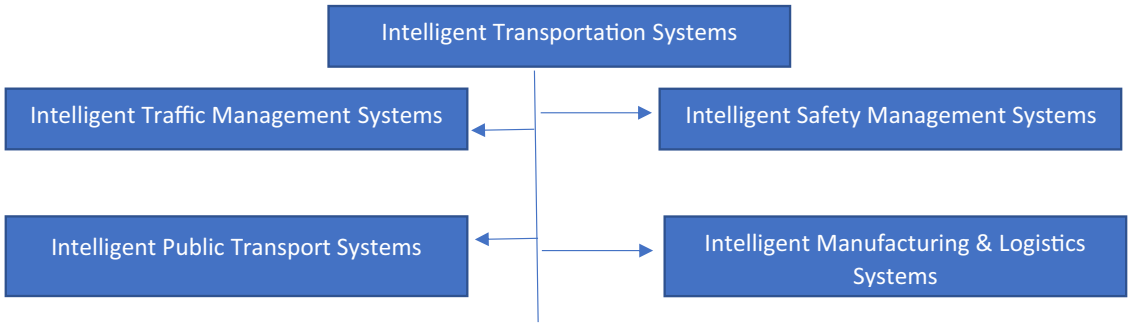

Fig 5. Intelligent transportation systems.

Table 2
Sub-systems of ITS.

Sub-systems of ITS	Description
Intelligent Traffic Management System	Road management on a real-time basis to avoid congestion
Intelligent Public Transport System	Transportation of passengers through road along various routes
Intelligent Safety Management System	Ensuring safety of passengers, vehicles and goods on road
Intelligent Manufacturing & Logistics system	Incorporation of technologies in automobile manufacturing and transportation of goods

Source: Author

processing, transmitting and management of the data thus generated. Since the past couple of decades, due to the emergence of smart technologies, various information systems for logistics, routing, mapping and planning are being developed. These systems have provided increased data processing capabilities to better plan the transportation process leading to Intelligent Transportation Systems (ITS) [13].

Data generated from the users and vehicles are used to build efficient ITS. Building of ITS into the transport systems has ensured increased performance due to information acquisition, exchange and integration across vehicles, city infrastructure and other related activities. It is observed that ITS supports the decision-making process for the city authorities and vehicle users.

The article focuses on Intelligent Transportation Systems that forms part of Transport Management Systems. A desk-based method is adopted up to collate AI techniques to resolve Transport industry issues towards building a sustainable transportation system. Benefits of the various sub-systems of ITS are identified and discussed along with applications of AI which have impacted the Transport industry positively. Data is summarized from research papers, Government reports, Journal articles and reports from consulting agencies. Some of the frameworks adopted in the earlier studies are considered as a benchmark for the current study for identification of the sub-systems. This work will help businesses and governments adopt to the technologies and build relevant solutions as per a given scenario.

2. Literature survey

AI has caused significant disruptions in various industries like healthcare, retail, banking, insurance, entertainment, manufacturing and transportation. Several use cases of AI in transportation have been experimented and adopted justifying the fact that this market is on an upward surge. With the technology advancement related to AI, transport industry has transformed itself into embedding user friendly devices into vehicles. This has led to the building of ITS using the data generated from the devices.

AI in the current form has the ability to solve problems in real time transport thus managing design, operation, time schedule and administration of logistical systems and freight transport. Some of the other applications include travel demand analysis, transport organization, pedestrian and herd behavior analysis. AI techniques allow utilization of these applications for the entire transportation management – vehicle, driver, infrastructure and the way in which these components dynamically offer transport services [59]. AI methods provide smart solutions in areas where it is hard to fully understand the complex relationships between the characteristics of the transportation systems [1]. The research study by [31] focuses on two fields namely – AI and transportation. Though AI brings in enormous opportunities on one hand, it also brings significant challenges related to security on the other hand. The privatization of transportation used for commercial purposes from the mid-2000s has brought new research opportunities and programs with considerable improvement in these fields.

A joint funded research programme between International Association of Public Transport (UITP) and Land Transport Authority (LTA) by name 'AI in Mass Public Transport' was conducted through review of literature, quantitative survey, use-cases, experts' blogs and ideation workshops. The report outlined various use-cases of AI applications[16] in public transport and what the future might hold for AI in public transport systems. The consulting company PwC undertook a nationwide survey to understand the impact of AI among decision makers and regular employees across wide range of sectors such as financial services, technology and manufacturing through online mode. It was found that youngsters were more adaptive towards technologies related to transportation [48].

Early adopters and progressive public transport stakeholders anticipate that AI will be further embedded in the future of mobility [24]. AI is capable of reaching out through diverse approaches, methods and technologies in different degrees that exhibits logical reasoning, problem solving and learning. AI can be hardware based (robots) or software related (Google Maps). Data-driven AI combines machine learning techniques with technologies used for searching and analysing large quantities of data. AI helps detect market trends; identify risks; ease traffic congestion; reduce greenhouse gas and air pollutant emissions; design and manage transport; and analyse travel demand and pedestrian behavior (Niestadt, Debyser, Scordamaglia, & Pape, Artificial intelligence in Transport, 2019)[43]. Data and AI driven applications and services are the major cornerstones to achieve the vision of delivering optimal mobility. In order to build an effective and efficient mobility ecosystem in a city, a holistic approach of mobility management is required. Connected vehicles send data in real-time thus generating immense amount of data. With transportation demands continuing to increase, data growth through devices also grows; thus, creating a need for smarter management of road traffic [57].

Some of the key functions of AI in transportation applications that are currently beginning to be commercialized or under research trials are given in Table 1.

The study by [50] focuses on advanced systems for surveillance, control and management of Intelligent Vehicle-Roadway system. The discussion here is on non-recurring congestion in complex networks. The study suggests an AI based solution approach with multiple real-time

Table 3
Traffic management.

Intelligent Traffic Management Systems				
Source of data	Issues	Role of AI	Benefit	Previous Studies
Vehicles with Intelligent systems	Increased cost due to traffic congestion	Machine learning tools to predict traffic pile up	Better fuel saving capability and lesser pollution to environment	Short-term traffic congestion prediction by evaluating traffic parameters achieved using ML models (Akhtar, Moridpour, 2021)[38]
Data from smart phones	Routing	Alternative route suggestions	Time saving	Driver behavior monitoring systems through data generated from smart phones use ML techniques [17]
Intelligent transport systems	Unpredictable traffic congestion	Identification of polluting substances in air	Curbing of environmental pollution	Multiple air quality indexes are combined using fuzzy logic along with simulated annealing and particle swarm optimization technique to identify air pollution (Ly H. B, 2019) [37]
Traffic lights and vehicles	Peak hour traffic management	Realtime tracking of congestion and algorithms in traffic lights	Control of higher and lower traffic patterns	Real-time information gathered from traffic lights are observed for optimal green-red distribution before AI solutions are deployed for analysis [67]
Data from Vehicles	Increase in the number of vehicles on the road	Pattern identification	Better observation and decision making	The stability of AI techniques, specifically ANN is deployed to predict traffic congestion in heterogenous traffic conditions (Olayode, 2020)[44]

knowledge related expert systems in arterial traffic management. Two AI paradigms – support vector regression (SVR) and case-based reasoning (CBR) are used for the evaluation of large-scale networks and complex simulation models. The study [11] evaluated the outcomes of the two prototypes by comparing the predictions of traffic conditions. In this study, an agent-based control system monitors traffic, road incidents and other transportation activities. The article [22] compares two integrated autonomous agents deployed for intelligent traffic management systems that perform decision support for real-time traffic management around Barcelona.

The study [51] investigates the applicability of autonomous intelligent agents in urban traffic control (UTC). The systems proposed by the study could design, implement, optimize and adjust UTC for dynamic environments. The utility of this model is suggested to be on several intelligent intersection of traffic signaling agents. These agents are capable of responding to real time traffic conditions and maintaining its stability and integrity [7].

Technologies related to autonomous vehicles (AVs) have the potential to impact vehicle safety and travel behavior. They ensure reduction in travel time and increased fuel efficiency. Currently, these technologies have become disruptive in bringing immense benefits to the transportation system. However, challenges related to adoption by larger group of people and prohibitive costs of adoption remain. Regulations with respect to liability, security and data privacy are uncertain from the governments leading to lesser market penetration of autonomous vehicles [18]. The study on the evaluation of the effectiveness of low-speed autonomous emergency braking system found that the vehicles fitted with this technology managed to reduce rear-end crashes by about 38 % [19]. In the current scenario, major problems in transportation are congestion, safety, pollution and increased need for mobility. One of the potential solutions to tackle all these challenges could lie in autonomous vehicles[36]. These vehicles collect data from their physical and digital surroundings through sensor technology[25] and connectivity solutions [68].

Connected cars are capable of accessing the Internet through smart devices and are also capable of communicating with other cars and infrastructure. They draw real-time data from multiple sources supporting drivers through stressful operations during driving. These cars ensure safety and reliability [12]. Pattern recognition is used with image processing for automatic incident detection and identifying cracks in pavements or bridge structures. Clustering technique is used for identifying specific classes of drivers based on driver behavior (Sadek, Artificial intelligence Applications in Transporation, 2007)[54].

The article [35] proposes new models, means, and forms of manufacturing of vehicles using technology. This has led to building of intelligent vehicles with technology adoption in the manufacturing of automobiles. The study discusses about the degree of impact of AI technology on various businesses and economics of a country [15]. The automobile company Ford has successfully integrated AI into mainstream manufacturing processes to provide competitive advantage to the organization. The study focuses on the process planning and the deployment of intelligent systems for manufacturing (Rychtyckyj, Intelligent Systems for Manufacturing at Ford Motor Company, 2007) [52]. The study [64] mentions that the initial demonstrations of technologies used in autonomous vehicles dates back to the year 1939. Most of the autonomous vehicles developed by the company Google rely on video cameras, radar sensors, laser range finders and maps developed by themselves. Autonomous vehicles would impact the functioning of not only the individual companies but also the national and world economy [63].

Manufacturing and logistics generate huge amounts of data due to its networking capabilities with different stakeholders. With transport industry playing a major role in logistics it is only appropriate that the generated data is put to use through application of various technologies in the operations [27]. Future research is recommended through an agent-enabled supply chain optimization by the process of simulation [39]. The study [45] ponders on the fact that whether driverless cars with AI have an adverse impact on humans. Extreme automation might lead to vulnerabilities in the machines. These integrated intelligent systems are vulnerable to systemic risks such as network collapse or hacking by external agencies. The study proposes Industry 5.0 which can democratize knowledge co-production from Big Data.

The research article [62] claims that transport system is the key element in a logistics chain because it provides links among separated logistics activities. The improvement of transportation logistics resulting in contribution to the overall business is due to the influence of

Table 4
Public transport.

Intelligent Public Transport System				
Source of data	Issues	Role of AI	Benefit	Previous Studies
Built-up structures, road surfaces, weather and traffic patterns	Variability in the data	Prediction of variations in the patterns through machine learning algorithms	Planning and Decision making	Short-term traffic congestion prediction done using traffic volume, density, occupancy, travel time, congestion index (Akhtar M, Moridpour S, 2021)
Real time data from drivers and passengers	Traffic congestion	Optimization of routes	Shortens the time of travel	
AI powered vehicles for goods delivery	Variation in delivery time, place	Suggestions to improve driving patterns	Improved productivity and further sales	The most optimal delivery route is arrived at using The Vehicle Routing Optimization to apply predictive intelligence in road transport [26]
Sensors from smart roads	Wear and tear of the road	Automatic alert generation to officers	Road management	A sustainable ITS is achieved with the integration of sensor technology with transportation infrastructure ensuring vehicle and passenger safety (Ibanez et al., 2018)

Table 5
Safety management.

Intelligent Safety Management System				
Source of data	Issues	Role of AI	Benefit	Previous studies
Sensors from Intelligent vehicles	Fatigue and tiredness of drivers	Auto-pilot system activation	Avoid accidents	Multiple integrated sensors in an autonomous vehicle determines the safety and feasibility (Yeong et al., 2021)[66]
Long distance trucks	Continuous driving hours and unknown terrain	Health monitoring of drivers	Prediction of accidents	Real-time measurement of physiological parameters of drivers are fed to web cloud and analyzed using AI using intelligent in-car health monitoring systems [46]
Self-driving vehicles	Low performance and safety issues	Blind spot alert, adaptive cruise control, advanced driver assistance systems	Frees up time of drivers	Self-driving vehicles ensure less effort and investment towards safety strategies for drivers (Littman. 2021)
Real time data transmission	Increased time and cost	Optimization of routes	Prediction techniques to forecast vehicle volume	Autonomous vehicles acquire real-time and accurate knowledge of vehicle position and state leading to better vehicle handling and safety [2]
Monitoring through sensors	Repair or refuelling	Remote control management	Saving of fuel, improve mileage	Intelligent visual tags installed on vehicles provide mobility support and tracking mechanism (Li Q, 2015)[49]

technologies. The research was undertaken to assist logistics managers, researchers and transportation planners to define and comprehend the basic views of logistics and its various applications and the relationship between logistics and transport. Transportation logistics is not only limited to the movement of goods across space and reducing time and costs along the supply chain. Its scope has expanded and it has become part of strategic management too. Hence, it is significant to integrate core business information systems with a set of modern analytical and AI tools to discover relevant knowledge from all sources. This helps in managing uncertainty and achieving competitive advantage [33].

The study [9] incorporated various AI technologies to achieve four perspectives, namely - knowledge acquisition, service logistics, service automation and performance measurement. Transportation plays a larger role in building responsive logistics information system; hence, machine learning concepts support in identification of demand patterns and corresponding replenishment strategy [34]. The study signifies the systematic development of the process of the current logistics scenario [65]. As we observe, intelligent systems have been playing a larger role in the logistics industry with transport industry as its backbone. The function of transportation has undergone a structural change making an impact on the evolution of transportation logistics [8]. On the one hand, due to AI adoption, there might be huge reduction of accidents and fatalities on the roads; on the other hand, we can expect technological unemployment [32].

From the detailed background study on the applications to solve transportation issues, it is evident that AI plays a significant role in building efficient transport systems using data. The current study attempts to represent the various concepts and applications of AI for the development of ITS as part of TMS. Out of the various available applications, the study narrows down on Intelligent Traffic Management System, Intelligent Public Transport System, Intelligent Safety Management System, and Intelligent Manufacturing & Logistics System to build a sustainable Transportation System[53]. In each of these systems, the role of AI and the corresponding benefit is discussed in Section 3. Further, Section 4 discusses AI solutions for issues related to transport industry across the globe and in some of the Indian states. The concluding section collates the various challenges and suggestions for transport industry through AI implementation.

3. Frame-work

From the earlier studies, it is observed that the benefits of AI while building intelligent transportation systems has not been explored sufficiently. The current study explores the ITS applications in transport industry deployed in various countries.

Transport industry being the life line of an economy seems to be grappling with various operational issues across the globe. Issues related to transport industry have led to the slowing down of the progress of a city and in turn a country. TMS are a boon which are systems built to overcome transport issues using various technologies. TMS help businesses plan, execute and optimize the physical movement of goods. Due

Table 6
Manufacturing & logistics.

Intelligent Manufacturing & Logistics System				
Source of data	Issues	Role of AI	Benefit	Previous Studies
Intelligent vehicles	Need for maintenance	Combining data from IoT sensors, maintenance logs – prediction models are created	Better prediction and machine failure	Reduced cost and improved accessibility to low-class population through autonomous vehicles (Anandakumar, Arulmurugan R, Roshini A (2019)) [21]
Connected vehicles	Repairs and maintenance	Connected vehicles scheduling predictive and preventive maintenance	Empowerment of vehicle monitoring businesses	Connected passenger vehicles are better than manually driven vehicles if they function reliably with better user interfaces (Y David, F Donald (2021)[14]
Vehicles fitted with technologies	Increase in production and delivery cost	Shared data across vehicles and routes	Improved cost savings across the entire supply chain, ranging from procurement to research and development	C-ITS – Cooperative ITS provide real time custom-made information to specific drivers (Maxime G et al., 2016)
Network based structure	Large number of invoices due to manual data entry	AI based systems retrieve data with ease from the network	Faster processing of bills, invoices	Smart phone linked home to vehicle connected vehicles to conduct repetitive tasks (Kim Y et al., 2017)[30]
Invoices and documents	Anomalies in invoices, compliance verification	Prediction and tackling of fraud detection	High level of accuracy	
Contracts	Extracting data which is not structured	Natural language processing technologies for interpretation of invoices	Extraction of critical information	

Table 7
AI accomplishments across the globe in transportation.

AI applications	Organization	Country
A self-driving, cognitive electric shuttle – Olli, transports passengers to requested location and provides suggestions on local sightseeing. Olli is powered by IBM's Watson Internet of Things (IoT) for Automotive	Local Motors	United States
Surtrac system was installed in a network of nine traffic signals and it helped predict and detect traffic accidents and conditions by converting traffic sensors into intelligent agents	Rapid flow technologies	Pittsburgh, United States
Otto completed the world's first autonomous truck delivery carrying 50,000 cans of Budweiser beer for over a distance of 120 min	Otto (Uber)	San Francisco, United States
TuSimple, a Chinese start up completed 200 miles of driverless truck drive. The driving system was trained using deep learning techniques	TuSimple	United States
GE's intelligent freight locomotives equipped with sensors detects things on or around the track. There is a 25% reduction in locomotive failure rates	GE transportation	Germany
In-house AI technology of Hitachi reduced the power consumed in driving rolling stock. Right combination of operational data extracted from the rolling stock witnessed 20% reduction in yearly traction power	Hitachi	Japan
The Department of Transportation anticipates AI enhanced demand and forecast modeling in road freight transportation management	DoT	United States
On-time delivery of people and packages through autonomous buses in spite of Non uniformity in weather patterns, traffic patterns, city infrastructure	-	Finland, Singapore, China

to data availability and remote monitoring, TMS ensures timely delivery of goods leading to higher customer satisfaction. This has benefitted businesses through increased sales. TMS improves fleet performance and reduces supply chain expenditure with the use of appropriate tools like route optimization. Since data is collected remotely and keenly monitored, end-to-end understanding of deliveries, outcomes and returns are recorded leading to better transparency. TMS uses technology to plan, execute and optimize the goods movement to help businesses thrive. These applications are used by manufacturers, distributors, retail businesses, and companies which are into logistic business.

The major functions of TMS include route determination, outbound/inbound logistic processes, route scheduling, 3PL vendor services, freight forwarders, service agents, transportation tracking and bulk processing of route scheduling & transportation planning (Fig 1). It is observed that the functions related to TMS are related to goods transportation. TMS integrates the multiple transport applications into a single package for better ease of use.

TMS are made to be more intelligent using AI and Machine Learning to provide accurate predictions. Some of the technologies that are currently being used include: Internet of Things (IoT) devices and sensors, Digital assistants, delivery time prediction solutions, transportation planning solutions, Blockchain among others. Intelligent Transportation Systems (ITS) have unfolded from TMS. A system which has the ability to take suitable decisions as per the given scenario using data generated from the devices installed in the vehicles are known as Intelligent Transportation Systems. Past studies have indicated that an integrated approach to ITS include the transport infrastructure and transport management. ITS being a new type of TMS has been gradually replaced by automated control systems. They have evolved into forecasting of dangerous situations with the potential of being used as a decision-making tool with the use of huge volume of complex data. ITS has also impacted the efficient functioning of transport system through automated data collection in this dynamic environment [29].

A typical ITS requires input data from various devices and sensors. This data is monitored and processed remotely. The insights derived from the processed data is considered as a valuable input for governments and businesses to take decisions. This systems approach ensures continuous improvement in the performance through feedback mechanism. The input data is derived from the various devices fitted in the traffic management infrastructure, vehicles, and road infrastructure. Authorities monitor the data and ensure that timely data is disseminated to the commuters, drivers and pedestrians thus benefiting the stakeholders.

An Intelligent Transport System comprises of a set of sub-systems in the area of Public Transport, Traffic Information,

Parking management, Traffic Management and Control, Safety Management and Emergency, and Pavement Management (Fig 2). This is very specific to smart cities (Agarwalet al., 2015)[3]. In order to build an effective Smart City through ITS, it is important to build system capability into the various operational activities of a city. As given in Fig

Table 8
Adoption of AI by transport corporations.

State Transport Corporation	AI application	Benefits
Bangalore Metropolitan Transport Corporation	AI cameras GPS trackers Facial Recognition	To monitor driver behavior related to sleep due to overwork and speeding
Karnataka State Transport Corporation	Sensors fitted at the front bumper of the bus where the driver waves at it every 3 – 4 min	Sensor cuts off accelerator if the driver does not wave at the sensor long distance luxury buses
Metropolitan Transport Corporation (Chennai)	Intelligent Traffic management system	Automatic number plate recognition cameras powered by OCR reads traffic violations. Automatic generation of challan for payment of a fine which is sent to the violator
Uttar Pradesh State Transport Corporation	Anti-collision system	Continuous monitoring of driver for objects within 180 m range by beeping
Maharashtra Transport Corporation	IVADO & Next AI Canadian companies	Set up AI clusters for various projects including transportation – Investment in R & D, Technologies for transport
Telangana Transport Corporation	Chatbots for customer support	AI answers multiple questions. Difficult question is forwarded to higher authorities
West Bengal Transport corporation	Patha Disha – AI app	Availability of seats on specific buses, estimated arrival time of buses. Tracking behavior – Commuter feedback and behavior
Toronto Transit Commission	Self-driving transit shuttle	Supervised by human drivers initially. An initiative to solve last mile connectivity to public transport
French National Railway Company	Chatbots for transit passengers	Helps travellers plan their daily trip and navigate across the city in the event of inevitable delays
Road and Transport Authority, Dubai	Smart and sustainable transportation using AI – Automated Bus Track Control System, Smart pedestrian signal system	Monitoring the condition of buses – driver fatigue, surveillance cameras across vehicles Improvement of bus efficiency, sensors to allocate pedestrian signal crossing
Ministry of Transport, Singapore	nuTonomy – a self-driving car company partnering with Grab to make autonomous taxi	Self-driving buses and freight vehicles to have an impact on public transport
Transport for London	Sopra Steria provides access to data	Road traffic, bus performance, weather and road works to reduce congestion and road management

2, some of the activities in a city are public transport, traffic management, parking management, pavement management and safety management. Through ITS, commuters, pedestrians, transportation and the overall society is benefitted.

The study undertaken by Hamida et al, 2015[5] classifies the various applications of Intelligent Transport Systems into four main classes as given in Fig 3. They are

(i) infotainment and comfort;
(ii) traffic management
(iii) road safety; and
(iv) autonomous driving.

These applications collect data from vehicles to improve its utility thus ensuring driver safety and enhanced public transport facility. ITS applications are generators of data which in turn assist in the decision-making process by the government authorities to manage public places in a better manner. Some of the applications are related to passenger comfort, improved driver experience, and efficient road management.

The ultimate beneficiary of Public Transportation System are the road users. The Intelligent Transportation Systems (ITS) framework for a sustainable public transportation system considers ICT technologies, automated transport system, traffic management centre, and advanced traveller information system[60]. The framework given in Fig 4 is presented in four phases from the road user as the source of data origin leading to the ultimate economic growth through ITS. Applications that are built around transportation systems need to keep the beneficiaries who generate data in mind. Once the applications are built using ICT, they not only improve process efficiency, but also help achieve sustainability in the transportation system leading to better economic growth.

Some of the applications which are built using ITS ensure traffic management, traffic signal control, vehicle navigation systems, smart parking management among others. ITS requires a network of technologies which operate together across the city infrastructure (Shaheen & Finson, 2019)[56]. The classification of problems of ITS as discussed by [29] include performance monitoring, traffic management, improved transportation process, information support to participants of the movement, and transport infrastructure management.

ITS follows a systems approach and it is logical that the current study considers the various sub-systems of ITS as a classification to explore the benefits of AI solutions. The diagrammatic representation of the sub-systems which are considered for the study is given in Fig 5. These sub-systems related to Transportation Systems (Table 2) are arrived at from the various frameworks depicted in the previous studies. Classification is carried out based on the benefit provided by AI solutions to build an efficient ITS. These sub-systems that are proposed in this study summarize the various activities under ITS.

Each of these sub-systems given in Fig 5 are classified based on the origin of transportation issues and organized in a systematic manner. Further, the benefits accrued from the technology adoption to resolve these issues are highlighted. The article has studied the organizations in the transport industry that adopted AI successfully and benefitted. A compilation of various state or central transport corporations which have initiated the process of AI adoption to resolve transportation related issues is done.

4. Discussions

4.1. AI solutions for Intelligent Transportation

The contribution of AI to the field of transport industry has been immense and extensive. The solutions include autonomous vehicles, traffic management, optimized routing, and logistics thus providing safety of vehicles and drivers. ITS are built using the data generated from the devices installed in the vehicles through AI technologies.

The current study focuses on four sub-systems related to transportation – namely, Intelligent Traffic Management System, Intelligent Public Transport System, Intelligent Safety Management System, and Intelligent Manufacturing & Logistics System. Tables (Tables 3–6) describe the data sources for AI solutions, related issues in the sub-system, role of AI and the benefits achieved.

From Table 3, we observe that AI provides solutions to transportation issues by suggesting alternative routes, real-time tracking of traffic lights during traffic congestion. This helps to manage traffic in an efficient manner eventually leading to curbing of environmental pollution and building sustainable cities.

From Table 4, we observe that AI provides solutions on predicting weather and traffic patterns, road management, alert generation to officers on duty. These systems help drivers, commuters and pedestrians prior to the commencement of their trip. It is significant to have the support of technology to build an efficient public transport system that helps in planning and the decision–making process.

From Table 5, we observe that AI has reduced the number of accidents on roads, predicts accidents based on the road conditions, alerting drivers towards road safety etc. An economy runs successfully when the transport industry is efficient. It is significant to achieve the same by building safe transport system with the help of AI technologies.

From Table 6, we observe that automotive industry is benefitted by AI solutions during the manufacturing process of vehicles. Sensors, cameras and other technologies have played a role in this industry for better benefits. Some of the in-built AI solutions in an automobile have become essential components in passenger vehicle as well as commercial vehicle segments.

4.2. AI accomplishments in transportation across the globe

As observed in the discussions so far, the capability of AI to solve problems related to transportation seems to be a natural fit. Yet, as is the case with AI in every other industry, the adoption of these applications varies across organizations and geographies. Based on the environmental and geographic factors, the applications could be both straight forward and complicated, distant and just-around-the-corner, definite or probable.

4.2.1. AI applications across organizations

Applications of AI in various organizations in the transportation sector is provided in Table 7. United States seems to be fore-runner in these applications. This is probably due to lesser population and better road infrastructure as compared to developing countries like India. Start-ups which are innovative receive good amount of funding to develop prototypes in developed countries. Most of the solutions are experimented during long distance driving as compared to passenger vehicle segment.

4.2.2. Adoption of AI by transport corporations

As per [28] AI is likely to have an increasingly drastic positive impact on city infrastructure by providing accurate predictive behavioral models of individual's movements, their preferences and their goals. Though AI in transportation planning applications have become significant in the recent past, there is a concern of privacy and safety of individuals related to data. There is a possibility of government and legal regulations dictating the pace at which innovation and adoption takes place in this industry due to these ethical considerations.

In the absence of ethical consensus on many aspects of technologies, individual organizations who are on an AI journey must factor ethical considerations. Though few organizations use machines to write code, by and large humans continue to write it. Due to this factor biases, assumptions, perceptions may find their way into the algorithms being developed. Organizations must question themselves: What is ethical AI? Where do governance and ethical AI overlap? How to eliminate bias in AI decision making? etc. [6]. Due to this aspect, there is a variation in the adoption of AI by various governments and city corporations.

Adoption of AI by various transport corporations and its benefits are given in Table 8. Due to the influence of the local government regulations, the adoption seems to be varying across various cities and states of India.

5. Conclusions

The article has compiled the capabilities and benefits of AI to build an ITS. The study proposes a framework with the sub-systems of ITS which are identified based on their capabilities. ITS is one of the important tools for identifying potential issues in the transport industry and this study has suggested solutions for specific issues. It is observed that machine learning algorithms are largely used to predict traffic congestion and route management. A city-wise analysis of AI adoption to overcome transportation issues depicts that most of the developed countries have swiftly adopted these systems. This adoption requires the support of the respective corporations and the leadership as it involves investment and long-term vision by the top management. Some of the organizations and governments are still hesitant in the adoption due to two reasons – either, they are concerned about the risks associated with AI adoption or technology adoption is weak among citizens in these countries. It is observed that developed countries are forthcoming in the adoption of technology associated transport management. To build an effective AI application, we need huge amounts of data as an input to process text, image, video and audio so that decisions taken are appropriate. Lack of knowledge and talent in this space is still a weakness in bringing out newer solutions catering to this sector. Due to this, AI applications in logistics companies roughly cost about 3-10% of the turnover creating a barrier in its adoption.

AI applications raise numerous ethical, social, economic and legal questions. AI based applications being data driven, have an issue of cybersecurity and data privacy especially in autonomous vehicles. When faced with life-versus-life situations, it is critical to understand how an AI algorithm in a fully automated vehicle would take decisions as compared to humans. A survey conducted by Eurobarometer on autonomous systems found that respondents were very comfortable with autonomous vehicles transporting goods rather than travelling in such vehicles themselves (Niestadt, Debyser, Scordamaglia, & Pape, Artificial intelligence in Transport, 2019). Lack of clear policies, resistance to adopt new technology, lack of establishment of ethical regulations have made AI solutions quite elusive for many organizations. In future, transport industry would receive data from vehicles and commuters on real-time basis through intelligent systems. Overall, AI is capable of providing better travel experiences to the mankind.

The article has attempted to identify and collate various AI techniques to resolve specific issues related to transport industry. The outcome of this article would benefit governments and organizations who want to invest in new technologies for specific applications related to transport industry in order to bring a positive impact on their businesses. The article would help organizations who would like to deploy technology solutions for resolving transport issues. This will also help them take initiatives and investment decisions in this industry to provide sustainable solutions to the business and societies.

5.1. Scope for further studies

Due to the conceptual nature of the present study, it may lack generalizability of application in different scenarios. An impact study based on primary data collected from the stakeholders involved in the transport industry can be taken up in future.

Some of the research questions could be:

Behavioural study – preference of passengers in boarding an autonomous vehicle versus a human driven vehicle, Have the number of accidents been reduced since the adoption of AI in the transport industry? Is the implementation of AI in transport industry bring in better ROI for businesses? Has AI ensured improved efficiency in the transport industry? What is the role and significance of the regulatory authority under a government to deploy various AI solutions in the transport industry?

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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