Chapter - 2
Review of Literature

2.1 Introduction

A literature review is a critical and comprehensive analysis of existing literature and scholarly works on a specific topic. It serves as a foundation for research by providing an overview of relevant theories, methodologies, and findings related to the research question or area of interest. Through a literature review, researchers identify gaps in current knowledge, assess the credibility and quality of existing studies, and establish the context for their own research. It involves a systematic search, evaluation, and synthesis of published materials such as academic articles, books, reports, and other relevant sources. A well-executed literature review not only demonstrates a researcher's familiarity with the existing body of knowledge but also contributes to the development of new insights and understanding within a particular field or discipline. Literature review helps in finding gaps in research already done, identifies conflicts in previous studies and finds out open questions left for other researchers.

Fourth Industrial revolution is confluence of different technologies like IoT, Data science, Artificial Intelligence and Machine Learning, which can completely change the outlook of public transport information system. Artificial Intelligence technology has human like brain and self-correcting ability. Machine Learning is subset of Artificial Intelligence that imitates the human learning process. There is need to explore use of Artificial Intelligence and Machine Learning in solving public transport information system problems with help of IoT. The research needs to be done on different Artificial Intelligence and Machine Learning algorithms with the help of IoT and GPS in the following areas.

1. Enhancing public transport experience.
2. Commuting and traffic congestion issues associated with smart cities
3. Technologies and Transportation Systems in Smart Cities
4. IoT based traffic prediction models for smart cities
5. Artificial Intelligence and Traffic Management

2.2 Enhancing Public Transport Experience

Improving the public transport experience is critical to promoting public transport use, reducing traffic congestion and making cities more sustainable. Enhancing the public transport experience requires a multi-pronged approach involving infrastructure development, technology, policy and community engagement. When implemented

effectively, these strategies can make public transport a more attractive and sustainable option for commuters. Some of the ways to improve your public transportation experience are by using IoT, Artificial Intelligence and Machine Learning algorithms to display real time bus arrival time information, bus interval information and seat availability.

Abigail, Jorge, Franklin, Angel and Santiago (2019) presented data framework for the observing and control of urban open transportation stations. they proposed clients will be informed through web administrations, smartphone application, counting data at the transport halt around courses, area of stops and times of open transport. Author recommended radio recurrence gadgets utilization for remote communication between the car and the transport station. portable unit was utilized to send data to a database show on a WEB server, where it was prepared and sent to the station for its socialization with the client. In his paper an sound framework that gives data on the course through a speaker found within the station and within the versatile unit was actualized, encouraging the utilize of this benefit to clients with visual inabilities and ignorant populace. The framework was tried in three stops and two portable mobile units. The quick reaction of the framework with an approximate time of up to 1second from the transport enrollment at the halt to the updating of the information on the site.

Abduljabbar (2019) gave a comprehensive overview of the applications of artificial intelligence in transportation systems. The study explores various AI technologies and their potential impact on enhancing transportation efficiency, safety, and sustainability. By examining AI-driven solutions, the authors contribute valuable insights into the evolving landscape of intelligent transport systems, shedding light on the integration of cutting-edge technologies to address contemporary transport challenges.

Cai (2009) hunts through Dynamic programming for adaptive traffic signal control. The study explores advanced algorithms to optimize traffic signal control dynamically. By employing innovative computational techniques, the research aims to enhance traffic signal efficiency, ultimately improving traffic flow and reducing congestion in urban areas.

Collotta (2018) study explores the intersection of green technologies and intelligent transportation, emphasizing sustainability and energy efficiency. By incorporating smart solutions, the research aims to create environmentally friendly transportation systems, contributing to both energy conservation and ecological preservation.

Dresner (2008) research introduces a multiagent approach to Autonomous Intersection Management, as published in the Journal of Artificial Intelligence Research. The study explores advanced techniques for managing traffic flow at intersections using autonomous agents. By leveraging multiagent systems, the research presents innovative solutions for optimizing intersection management, enhancing traffic efficiency, and reducing congestion, thereby contributing to the development of intelligent traffic control systems.

Dou (2015) has designed three independent interconnected systems using server, Android application and public transport bus distributed network on-board device. The communication between three components was provided using protocols such as HTTP[1], WSDL[2], SOAP[3] and SSL[4]. Author studied the various parameters for analysis like bus travelling time, dwelling time at bus stops, Passenger travel habits, and observed the execution of schedule time table. Author used historical parameters like route distance, travelling time, bus speed, dwelling time at each stop. Root mean square error method was used by author to measure predicted accuracy of travel time in comparison with bus timetable by using historical based data model and linear regression model.

Ersoy (2015) studied intelligent transportation systems and their applications in the road transportation industry in Turkey. The research investigates the integration of intelligent transportation solutions in the Turkish road transportation sector. By analyzing applications and challenges, the study provides valuable insights into the potential benefits and obstacles faced in implementing intelligent transportation systems, essential for optimizing road transport operations in the country.

[1] Hyper Text Transfer Protocol
[2] Web Services Description Language
[3] Simple Object Access Protocol
[4] Secure Socket Layer

Ferrara (2018) focused on the fundamentals of traffic dynamics within the context of freeway traffic modeling and control. The study delves into the intricate dynamics of traffic flow, providing a detailed analysis of fundamental principles. By examining traffic dynamics, the research aids in enhancing our understanding of freeway behavior, paving the way for improved traffic modeling techniques and control strategies. The findings contribute to the broader field of traffic engineering, informing the development of advanced traffic management systems and solutions.

Ghasem-Aghaee (2019) explored the synergy between simulation, intelligence, and agent-based systems. The study delves into the integration of these technologies, offering insights into their collaborative potential. By examining current and future developments in artificial intelligence, the research contributes to the exploration of innovative approaches for creating intelligent systems. The study's findings provide a foundation for advancing AI-driven solutions in simulation and agent-based modeling, shaping the future of intelligent transportation systems.

According to **Iyer (2021)** Artificial intelligence can perform cognitive functions like seeing, thinking, learning and problem-solving which people can performing easily. From past twenty years internet is generating massive information in all over the world which has created solid foundation for the AI. There has been a colossal advantage to governments and businesses by handling this information using advanced algorithms in the recent past. The strong growth of Automation, IoT, Robotics, computer vision, Natural language processing and Machine Learning algorithms, have enabled the growth of AI. According to author AI in the current form has the ability to solve problems in real time transport, vehicle scheduling, time management, managing design, operation, and administration of logistical systems and freight transport.

Jacobsen (2015) presented an conference framework discussion of the Digital System Design. The study focuses on developing a framework for aggregating demand response programs in Europe. By creating efficient aggregation methods, the research contributes to the effective management of demand response initiatives, essential for energy conservation and sustainable energy practices.

In the 2nd International Conference on IoT, Big Data, and Security **Jacobsen (2017)** presented a secure SMS based vehicle tracking system. The study focuses on creating an efficient and secure vehicle tracking system using SMS communication. The research aims to enhance vehicle tracking capabilities, contributing to transportation security and management.

Khallouk (2018) researched traffic flow at un-signalized junctions with crossing pedestrians. The research delves into the complex dynamics of traffic interactions involving pedestrians, shedding light on the challenges faced in un-signalized junctions. By analyzing pedestrian influence on traffic flow, the study provides valuable insights for traffic engineers.

Kharchenko (2019) tried to predict trolley bus arrival time with the help of historical average, Kalman filtering technique, and Google Maps API. He focused on choosing an efficient model and framework which can be used to for real-time data acquisition and which can be easily implemented to improve public transport services by using the GPS data and IoT data. He designed information service infrastructure model for public transport. He also investigated model's performance and their effectiveness with real time data. He has also explained that combination of distance from Google Maps API with Kalman filtering and average travel speed gave the best arrival time predictions for low speed urban transport.

Kuberkar and Singhal (2020) found that many countries including India are developing smart cities to reduce increasing burden on public transport systems. he found various issues of overcrowding, delayed services and travel dissatisfaction of commuters due to lack of infrastructure. Research paper also studied the need of AI powered Chatbot by the citizens of the smart city for delivering automated anytime, anywhere, public transport information services. Author also favored an extended UTAUT[5] model to measure the adoption intention.

[5] Unified Theory of Acceptance and Use of Technology

Lee (2007) have shown in the National Cooperative Highway Research Program Report 572, published by the Transportation Research Board of the National Academies, offers a comprehensive overview of traffic management strategies and techniques. The report covers a wide array of topics, including traffic control, modeling, and safety measures. By synthesizing expertise from various contributors, the report serves as a valuable reference for transportation professionals, policymakers, and researchers, providing essential guidance for improving traffic management practices and ensuring safer, more efficient road networks.

Liu (2014) introduced Green Optical Character Recognition, an energy-efficient optimal clustering routing protocol, published in the Computer Journal. The study focuses on optimizing routing protocols in energy efficient wireless sensor networks. By employing optimal clustering techniques, the research aims to conserve energy in sensor networks, extending their operational lifetime and enabling sustainable data communication practices essential for various applications, including intelligent transportation systems.

Misbahuddin (2015) presented his research paper at the 12th International Conference on High-Capacity Optical Networks and Enabling/Emerging Technologies in Islamabad, Pakistan. He explored dynamic road traffic management for smart cities using IoT. The study focuses on leveraging IoT technology to create an adaptive traffic handling system. Author research was focused on to increase flow of traffic and reduce traffic congestion by integrating real-time data and smart city technologies, which contributes to the development of efficient and responsive urban transportation systems.

Mar and Sheng (2018) had suggested, incorporating data collection and sharing of services using IoT which has a potential to transform the communities into smart Cities. Author has suggested many advantages of smart city. According to him smart city concept can improve traffic, lower pollution levels, provide real time weather prediction and provide overall better quality of life to all it's citizens. Author proposed cloud computing should be used to collect and store city data using mobile environmental sensing platform. Raspberry Pi 3 based sensing and geolocation module was designed by author to sense temperature, air quality and humidity. PhpMyAdmin local database was used to store environmental parameters, and uploaded to Thing Speak cloud database in real-time. Author had taken help of various Graphical visualization and

monitoring tools for further information and data analysis. Author has designed prototype model to investigate whether developed system is working properly or not using the conventional static sensing and new mobile sensing. It was found that there is a difference of 6.93% between the static and the mobile sensing method, which was considered to be small value.

Mukti and Prambudia (2018) have written about Jakarta digital transportation system. he highlighted the various obstacles in governing such systems. The research examines the complexities of managing digital transportation services within the framework of a smart city. By analyzing governance challenges, smart city planners and policymakers are given valuable insights.

Prakash and Anudeep (2018) explained reduction in passenger waiting time by constantly updating real time passenger information system in their IoT[6] research paper. The proposed framework centers upon the current area of transport. It predicts arrival time, empty seats, and keeps the traveler updated. A model execution is done utilizing Node MCU with GPS module as vehicle node and bus transport data is sent to the cloud utilizing MQTT[7] protocol. To reduce traffic congestion, an convenient and user friendly Android Based Mobile app has been developed to create awareness about real-time information to passengers which compel people to use public transport, thereby reducing traffic that the cities face every day.

Pau (2018) focused on fuzzy-based systems, which helps pedestrian crossing traffic light junctions. The study introduces a fuzzy logic-based system for managing pedestrian crossings efficiently. By employing fuzzy logic algorithms, the research aims to create adaptive and responsive pedestrian crossing systems, enhancing safety and traffic flow at intersections, thereby contributing to the development of intelligent urban transportation networks.

Rahman and Ajala (2018) thrown light on mobility challenges which Nigerian cities are facing like any other county in the world due to exponential population growth pressure and fast urbanization. Smart people and Smart policies are the main factors in the determination of smartness of a city. Author cautioned about overcrowding and

[6] Internet of Things

[7] Message Queuing Telemetry Transport

infrastructure decadence with uncontrollable increase in the population without substantial development in transportation area . Author brought attention about United Nation statistics. In 2016 United nations assessed that 54.5% of the world's population lived in cities and by 2050 the number will increase to 67%, this perpetually will increment demand for the development of products and administrations.

Sundar (2017) found uncertain arrival times and overcrowding are the major obstacles in using buses as public transport system in India. Author found cameras, infrared devices at doors are not suitable for Indian metros to predict crowd volume. Hence Author proposed a IoT based solution. Author used Android application to simulate the handheld ETM[8] used by TNSTC[9] conductors. On-board passenger online tickets were used to predict crowd volume. Each bus online tickets record was maintained at the server side. The ETMs communicate with the server via an API[10]. All ETM Machines were fitted with the GPS[11] receiver to track buses in real time to provide real time information to all passengers traveling in the bus, it will also help people to estimate approximate the bus arrival time. The information such as number of people traveling and location of the bus can be displayed in the android application used with Google Maps.

Sunha (2017) revealed the utilization of four variables which reflected within the definition of smart city(portability, open security, wellbeing and efficiency) can be used for citizen time saving. In Top 20 list Singapore is ranked as Number 1 and Bhubaneshwar as Number 19 as smartest city by considering consolidated performance index, while Mobility index kept Singapore as Number 1 and Bhubaneshwar as Number 20. Juniper has found that smart mobility projects have the potential to 'give back' 59.4 hours per year per citizen; these are broken down as: 19.4 hours for Intelligent traffic systems; 31 hours for Open data(City open data can be harnessed to enable public transport information services to develop innovation around that data); 1.2 hours for Cashless payment; 7.8 hours Safer roads.

[8] Electronic Ticketing Machines
[9] Tamil Nadu State Transport Corporation
[10] Application Programming Interface
[11] Global Positioning System

Sun and Song (2017) explored secure and trustworthy transportation systems. The research delves into the challenges and solutions in ensuring security and reliability in transportation cyber-physical systems. By addressing cybersecurity issues, the book contributes to the development of secure transportation infrastructures, critical for the future of connected and autonomous vehicles.

Sharma (2018) introduced energy efficient surveillance using Long Range Wide Area Network. This technology uses drones for smart transportation systems. The study explores the integration of drone technology and IoT networks for energy-efficient surveillance in transportation. By employing a low-power, long-range wireless communication technology, the research focuses on creating energy-efficient surveillance solutions, enhancing security and monitoring capabilities in intelligent transportation systems.

Troutbeck (2016) focused on modeling signalized and un-signalized junctions. The chapter provides in-depth insights into the methodologies and techniques employed in modeling both types of intersections. By offering a comprehensive understanding of junction modeling, the research aids transportation professionals and researchers in developing accurate traffic models, essential for urban planning, traffic management, and infrastructure design.

Vakula (2017) proposed that city should have an smart public transport system, Author noticed travelers are facing allot of issues within the smart cities. Travelers are compel to wait for long time since they do not have public transport bus information. He suggested the introduction of technology into the public transport system for the travel comfort of passengers. He also pointed out that if existing bus systems will be empowered with latest technology like providing the arrival departure times of the buses via display boards and Android applications, Global positioning system for bus tracking then passengers will be more keen to travel by public transport systems. The Author proposed Raspberry Pi 3 based GPS system which can send sensor data continuously to a server. High speed Wi-Fi should be provided to all passengers at the Bus terminus to access smart information.

Wen (2008) study introduced solution for road congestion problems. He advised to use a adaptive and automatic traffic light control system to overcome traffic congestion problems. The research presents an intelligent traffic control approach. By integrating expert system methodologies, the study focuses on real-time decision-making to optimize traffic light sequences, aiming to alleviate congestion and enhance urban mobility.

World Health Organization (2018) provided a detailed analysis of road safety worldwide in their 2018 report. The report presents key statistics, trends, and challenges related to road accidents and safety measures. By offering a global perspective on road safety issues, the document serves as a crucial resource for policymakers and organizations working towards improving road safety standards and implementing effective interventions to reduce road accidents and their associated fatalities.

This literature review considered the myriad ways in which advances in technology, urban planning, and customer-focused strategies are helping to improve the public transportation experience. The overall research reviewed highlights the importance of continued research, innovation, and collaboration among stakeholders in building seamless and user-friendly public transportation networks. By harnessing the power of new technology and adopting a human-centered mindset, we can transform the daily commute into a positive and empowering experience for everyone. As we move forward, policymakers, urban planners, technology developers, and the general public must work together to create a future for public transportation that is sustainable, accessible, and improves the overall quality of urban life.

2.3 Commuting and Traffic Congestion Issues

Smart cities aim to harness technology and data to improve citizens' overall quality of life. However, besides many benefits, smart cities can also face challenges related to commuting and traffic congestion. To address these challenges and maximize the benefits of smart cities, it's essential to consider a holistic approach that includes infrastructure development, data privacy safeguards, equitable access, public awareness campaigns, and the active involvement of city residents in the planning and decision-making processes. Smart city initiatives need to be designed with the aim of reducing traffic congestion and improving the overall commuting experience while minimizing

negative side effects. Transport solution theories should have detailed sustainable plan for smart cities. Following are some issues related to travel and traffic in smart cities studied by various scholars in the past.

Albino, Vito, Berardi, and Dangelico (2015) provided comprehensive insights into smart cities, including their definitions, dimensions, performance metrics, and initiatives. The authors explore the multifaceted nature of smart cities, considering technological, economic, social, and environmental dimensions. By analyzing various smart city initiatives, the study contributes to a deeper understanding of the concept, guiding future smart city development strategies and policies.

Ammara, Rasheed, Mansoor, Al-Fuqaha and Qadir (2022) suggested that modern cities are intricate and dynamic systems, characterized by interdependencies and interactions among diverse stakeholders, components, and subsystems. The advent of digital ICT[12] has paved the way for the concept of smart cities, aiming to enhance the quality of life for urban dwellers and improve city management. However, the mere deployment of ICT solutions does not guarantee automatic or universal improvements in citizens' well-being. To truly understand the dynamics and outcomes of smart cities, It is essential to analyze them as complex adaptive systems, where multiple interconnected subsystems influence each other. Such an approach enables us to evaluate policy interventions, assess their effectiveness, and anticipate unintended consequences. In this paper, researcher explored the perspective of systems thinking and complex systems in understanding smart cities.

Al-Dweik, Arafat, Radu Muresan, Mayhew, and Lieberman (2017) presented an IoT-based smart transportation Systems. The authors focus on developing a versatile roadside unit capable of integrating various IoT sensors and technologies. The Enhanced Road Side Unit enhances the capabilities of ITS, enabling real-time data collection, analysis, and adaptive traffic management. Their multifunctional approach showcases the flexibility and scalability of IoT solutions in creating intelligent transportation infrastructures.

[12] Information and Communications Technology

Bai, Lin, Ma, Wang, and Duan (2020) introduced Pre-Position Congestion Tensor, a cutting-edge traffic congestion prediction model specifically tailored for smart cities. The model utilizes a Relative Position Congestion Tensor, a sophisticated mathematical construct, to forecast traffic congestion accurately. By incorporating complex spatial relationships between vehicles and roadways, Pre-PCT enhances the precision of congestion predictions. This advancement is crucial for urban planners and traffic management authorities, offering them a robust tool to anticipate congestion patterns and optimize traffic flow effectively.

Carmona (2010) delves into the multidimensional aspects of urban design. The text explores the complexities of shaping public spaces within cities, emphasizing the importance of thoughtful urban planning and design principles. By examining the social, cultural, and spatial dimensions of public places, Carmona's work contributes valuable insights to the field of urban design, providing guidance for creating inclusive and vibrant urban environments.

Chakraborty (2019) focused on the development of an Intelligent Traffic Control System specifically designed for smart cities. By harnessing cutting edge technologies, such as artificial intelligence and IoT devices, the system aims to enhance the efficiency of traffic management in urban environments. The study emphasized the significance of integrating intelligent systems into smart city initiatives, showcasing the potential of these systems to enhance traffic flow, minimize congestion, and improvise urban mobility.

Dimitrakopoulos, George, and Bravos (2016) explored contemporary technologies in vehicular communication systems. The authors delve into the advancements in communication technologies for vehicles, emphasizing their significance in intelligent transportation systems. By discussing state-of-the-art vehicular communication techniques, the book informs researchers, engineers, and practitioners about the latest developments in the field, fostering innovation in intelligent transportation technologies.

Doolan and Muntean (2016) represented a groundbreaking approach to address environmental concerns related to vehicle emissions. By leveraging Vehicle Ad-Hoc Networks, EcoTrec optimizes traffic flow, subsequently reducing vehicle emissions.

This research not only highlights the potential of Vehicle Ad-Hoc Networks-based solutions but also underscores the importance of intelligent transportation systems in promoting environmental sustainability. EcoTrec serves as a notable example of how technology can be harnessed to reduce the environmental impact of urban transportation.

Deak and Walravens (2019) explored the concept of integrated smart mobility solutions and their implications for the future of urban transportation. The authors examine how emerging technologies and innovative approaches can address the challenges of city mobility and pave the way for more accurate and sustainable transportation systems. In their study, Deak and Walravens analyze the key components and characteristics of integrated smart mobility solutions. They discuss the role of various technological advancements, such as connected vehicles, autonomous driving MaaS[13] platforms, and data analytics, in transforming the urban transportation landscape. The authors argue that integrating different modes of transportation and leveraging advanced technologies can lead to more seamless, user-centric, and sustainable mobility experiences. They explore the potential benefits of integrated smart mobility solutions, such as reducing congestion, enhancing accessibility, improving safety, and minimizing environmental impacts. The article also addresses the challenges and barriers that need to be overcome for successful implementation of smart mobility solutions. These include issues related to data privacy and security, infrastructure requirements, policy and regulatory frameworks, and public acceptance. By examining case studies and examples from across the globe/world, Deak and Walravens provide details of the practical implications and potential outcomes of integrated smart mobility solutions. They emphasize the importance of collaboration among stakeholders, including governments, transportation providers, technology companies, and citizens, to realize the vision of future urban mobility.

Erlmann and Dantzig (2018) conducted a literature review to explore the potential of shared mobility services in alleviating urban traffic congestion. The study focuses to provide an detail understanding of the existing research and insights on the effect of shared mobility on traffic congestion in urban areas. The review highlights that shared

[13] Mobility-as-a-Service

mobility services, such as ride-sharing, car-sharing, bike-sharing, and on-demand transportation, have gained significant attention as potential solutions to mitigate traffic congestion. These services have the potential to reduce the number of private vehicles on the road, promote more efficient use of transportation resources, and provide alternative transportation options to users. The findings of the review suggest that shared mobility services can indeed have a positive impact on traffic congestion. Studies indicate that these services have the potential to reduce VKT[14] and vehicle ownership, leading to a decrease in overall traffic volume and congestion levels. Shared mobility can also encourage the use of more sustainable transportation modes, such as public transport system and non-motorized vehicles.

Fintikakis and Bourka (2018) examine commuting patterns in the context of smart cities by conducting a comparative analysis of Stockholm and London. The researchers aim to understand the impact of smart city initiatives on commuting behavior and explore the differences between these two major European cities. The study utilizes data from various sources, including surveys and official statistics, to gather information on commuting patterns, transportation modes, and the use of smart technologies in commuting. The findings reveal several interesting insights. Both Stockholm and London have implemented smart city solutions to improve urban mobility and transportation efficiency. However, the two cities exhibit distinct commuting patterns and modal split. Stockholm demonstrates a higher reliance on sustainable modes of transportation, such as public transit, cycling, and walking. while London has a greater dependence on private vehicles. The researchers attribute these differences to various factors, including cultural preferences, urban form, and the availability and quality of transportation infrastructure. The study also highlights the role of smart technologies in shaping commuting behavior. Smart city initiatives, such as real-time traffic information systems, mobile applications, and integrated ticketing systems, contribute to more informed and efficient commuting experiences. These technologies enable travelers to make informed decisions, optimize their routes, and choose sustainable transportation options. However, the study emphasizes that the successful implementation of smart city solutions requires a comprehensive and

[14] Vehicle Kilometers Traveled

integrated approach that considers the needs and preferences of commuters. Overall, this comparative study sheds light on the relationship between commuting patterns and smart city initiatives in Stockholm and London.

Goggin and Gerard (2012) have done research on the intersection of mobile internet, cars, and social dynamics. The study investigates the social implications of mobile internet usage in vehicles, emphasizing the transformative role of technology in reshaping communication patterns and social interactions within the context of driving. By examining the relationship between mobile internet, cars, and society, Goggin's work sheds light on the evolving dynamics of human-technology interactions in the mobile age, offering valuable insights into the societal impact of connected mobility.

Gkiotsalitis and Cats (2018) investigate the potential implications of AVs[15] on urban environments. The study aims to assess the impact of AVs on various aspects, including traffic congestion, travel behavior, and urban form. The researchers conduct a detailed review and analysis of existing materials and models to evaluate the effects of AVs on cities. The findings of the study suggest that the introduction of AVs can have both positive and negative consequences for urban areas. On the positive side, AVs have the potential to enhance road safety, reduce traffic congestion, and improve the overall efficiency of transportation systems. They may also lead to changes in urban form, as the need for parking spaces decreases, potentially allowing for the repurposing of land for other uses. Furthermore, AVs could promote shared mobility services, potentially decreasing the reliance on private car ownership and promoting more sustainable transportation options. However, the study also highlights several challenges and concerns associated with the widespread adoption of AVs. One concern is the potential for increased VMT[16] as AVs may lead to greater convenience and reduced travel costs, potentially offsetting the anticipated reduction in congestion. The researchers also raise issues related to data privacy, cybersecurity, legal and regulatory frameworks, and public acceptance, which need to be addressed to ensure the successful integration of AVs into cities. The study emphasizes the need for further research and policy development to proactively address the potential impacts of AVs on cities. It

[15] Autonomous Vehicles

[16] Vehicle miles travelled

underscores the importance of considering various factors, such as urban planning, transportation infrastructure, and social and environmental impacts, to maximize the benefits and mitigate any negative consequences associated with AV deployment. By doing so, cities can better prepare for the transformative effects of AVs and create more sustainable and livable urban environments.

Ghasem-Aghaee (2019) explored the synergy between simulation, intelligence, and agent-based systems. The study delves into the integration of these technologies, offering insights into their collaborative potential. By examining current and future developments in artificial intelligence, the research contributes to the exploration of innovative approaches for creating intelligent systems. The study's findings provide a foundation for advancing AI-driven solutions in simulation and agent-based modeling, shaping the future of intelligent transportation systems.

Han, Liang and Zhang (2015) discussed the convergence of mobile cloud sensing, big data, and 5G networks in shaping intelligent and smart cities. They emphasize the transformative impact of these technologies, envisioning a future where interconnected data-driven systems enhance urban living. Through mobile cloud sensing, real-time data collection becomes feasible, and when combined with big data analytics and high-speed 5G networks, it enables intelligent decision-making processes in various aspects of urban life, paving the way for efficient, sustainable, and smart urban environments.

Hall and Pfeiffer (2016) have shown the influence of smart cities on travel behavior. The study takes an exploratory approach to understand how the implementation of smart city technologies affects people's transportation choices and patterns. In their research, the authors analyze the potential impacts of smart city initiatives, such as intelligent transportation systems, real-time data analysis, and urban planning strategies, on travel behavior. They examine how these technologies can enhance the efficiency and convenience of transportation options, promote sustainable modes of travel, and reduce congestion on urban road networks. The study employs both qualitative and quantitative research methods, including interviews, surveys, and data analysis, to gather insights into the travel behavior changes associated with smart city interventions. The authors investigate factors such as travel time, mode choice, trip frequency, and the adoption of new mobility services. The findings of the study shed light on the positive effects of smart city solutions on travel behavior. The

implementation of intelligent transportation systems and real-time data analysis were found to improve travel efficiency, reduce travel time, and enhance the reliability of transportation services. Moreover, the study suggests that smart city technologies have the potential to promote sustainable travel choices, such as walking, cycling, and public transportation, by providing real-time information and facilitating multi-modal integration. The research contributes to the understanding of how smart city initiatives can shape travel behavior and promote sustainable urban mobility. It highlights the importance of technological interventions in improving transportation systems and provides valuable insights for policymakers and urban planners in designing smart city strategies that prioritize efficient and sustainable travel.

Jung and Couclelis (2017) examined the intersection of smart cities and the politics surrounding urban data. The authors investigate how the collection, analysis, and use of data in smart cities can shape power dynamics, governance, and decision-making processes. The study explores the concept of smart cities, which leverage data and technology to improve urban services and enhance the quality of life for residents. It highlights the importance of data in smart city initiatives and how it becomes a valuable asset for urban planning, policy-making, and resource allocation. Jung and Couclelis argue that the politics of urban data in smart cities are characterized by issues of control, ownership, access, and privacy. They analyze the power dynamics between different stakeholders, including government agencies, private companies, citizens, and advocacy groups, in the collection, sharing, and utilization of urban data. The article examines the implications of data-driven decision-making in smart cities and raises concerns about potential biases, exclusion, and surveillance. It discusses the challenges of data governance, emphasizing the need for transparency, accountability, and citizen engagement in the management of urban data. Furthermore, the study highlights the role of data standards, interoperability, and data sharing protocols in shaping the politics of urban data. It explores the potential benefits of open data initiatives and the importance of ethical considerations in the use of personal data within smart city frameworks. Overall, the research sheds light on the political dimensions of urban data in smart cities. The article contributes to the understanding of the complexities surrounding data-driven urban governance, highlighting the need for inclusive and responsible approaches to the use of data in shaping the future of cities.

Jin, Ma, and Kosonen (2017) introduced an intelligent control system for traffic lights, incorporating simulation-based evaluations. By utilizing simulation techniques, the system optimizes traffic signal timings, aiming to enhance traffic flow and minimize congestion. This approach emphasizes the importance of simulation-based assessments in evaluating the effectiveness of intelligent traffic control systems. Through rigorous evaluation, the study contributes valuable insights into the performance and efficiency of intelligent traffic management solutions, guiding their implementation in real-world scenarios.

Janahan (2018) presented IoT based Smart Traffic Signal Monitoring System. By leveraging IoT technology, the system captures real-time vehicle count data, providing accurate and timely information for traffic analysis. The research underscores the importance of data-driven decision-making in traffic management. The system's ability to provide precise and up-to-date traffic information is instrumental in optimizing traffic signal timings, reducing congestion, and improving overall urban mobility.

Joo, Ahmed and Lim (2020) proposed a traffic signal control system for smart cities using reinforcement learning techniques. By employing machine learning algorithms, specifically reinforcement learning, the system dynamically adjusts traffic signals based on real-time traffic conditions. The research highlights the adaptive nature of the system, allowing it to respond dynamically to changing traffic patterns. This approach represents a significant advancement in traffic management, providing agile and responsive solutions to address congestion and optimize traffic flow within smart cities.

Kitchin (2014) explored the paradigm shifts induced by big data and new epistemologies. He critically examines the impact of big data on knowledge production and challenges traditional research methods. Kitchin's work highlights the transformative potential of big data, emphasizing the need for innovative approaches to understanding societal phenomena in the age of data-driven insights.

Kumar, Rahman, and Dhakad (2020) presented a traffic light control system that combines fuzzy inference and deep reinforcement learning techniques. By integrating fuzzy logic and deep learning, the system optimizes traffic signal timings with a high degree of precision. This innovative approach showcases the synergy between fuzzy inference and deep learning, offering a robust solution for intelligent transportation

systems. The system's ability to make informed decisions based on complex data sets contributes significantly to enhancing traffic flow and reducing congestion in urban environments.

Lakshmi (2016) explored big data analytics in the service industry. The study investigates the applications of big data analytics within the service sector, highlighting its potential to enhance operational efficiency, customer satisfaction, and strategic decision-making. By synthesizing existing knowledge, the literature survey provides a comprehensive overview of the impact of big data analytics on the service industry, offering valuable insights for businesses and researchers alike.

Lingani, Rawat and Garuba (2019) introduced a Smart Traffic Management System that utilizes advanced deep learning techniques for efficient traffic management within smart cities. By employing deep learning algorithms, the system can analyze vast amounts of traffic data, enabling real-time decision-making. This approach showcases the transformative power of artificial intelligence in revolutionizing traffic management strategies. By providing intelligent and adaptive solutions, the system contributes significantly to enhancing urban mobility, reducing congestion, and improving the overall quality of life in smart cities.

Lee and Chiu (2020) introduced a Smart Traffic Signal Control System tailored specifically for smart city applications. By integrating advanced technologies and smart algorithms, the system optimizes traffic signal timings, effectively managing traffic flow and reducing congestion. The research emphasizes the importance of tailored solutions, recognizing the unique challenges faced by smart cities. By addressing these challenges directly, the system offers a customized approach to traffic management, aligning with the specific needs and dynamics of smart urban environments.

Malek, Li, Yang, Hasan and Zhang (2012) discussed the improvement of energy efficiency in Ad Hoc On-Demand Distance Vector routing protocols. The authors propose enhancements to the Ad Hoc On-Demand Distance Vector routing protocol, aiming to optimize energy consumption in mobile ad hoc networks. Their work is instrumental in advancing the field of wireless communication, paving the way for more energy-efficient protocols in various applications, including smart city networks.

Misuraca, Gianluca, Francesco, Mureddu, and Osimo (2014) presented in the book "Policy-making 2.0: Unleashing the Power of Big Data for Public Governance," explores the integration of big data into public governance. The authors discuss the utilization of big data analytics for policy-making processes, emphasizing the potential for data-driven decision-making in the public sector. By harnessing the power of big data, governments can enhance their policy formulation, implementation, and evaluation strategies, fostering more efficient and effective governance practices.

Mondal and Rehena (2019) focused on developing an intelligent traffic congestion classification system utilizing ANNs[17]. By employing ANNs, the system accurately classifies traffic congestion levels, providing valuable insights into traffic conditions. The study highlights the potential of artificial intelligence techniques, particularly ANNs, in developing precise and reliable traffic monitoring systems for smart cities. By accurately classifying congestion levels, the system contributes to data-driven decision-making, enabling proactive measures to alleviate congestion and enhance urban mobility.

Nasr, Elie, Kfoury and Khoury (2016) presented an IoT-based approach to vehicle accident detection, reporting, and navigation. The authors explore the utilization of IoT devices and sensors to detect vehicle accidents in real-time. By enabling swift accident reporting and navigation assistance, their system enhances road safety and emergency response mechanisms. The study illustrates the practical application of IoT technology in enhancing transportation safety and underscores its potential in shaping the future of intelligent transportation systems.

Psomakelis and Evangelos (2016) have shown the integration of big data and social networking data for smart cities. The authors explore the synergy between big data analytics and social networking data in shaping intelligent urban environments. By harnessing social network data, cities can gain valuable insights into public behavior and preferences, facilitating more informed decision-making processes. The study highlights the potential of combining big data and social networking data for enhancing smart city initiatives and improving urban quality of life.

[17] Artificial Neural Networks

Rizwan, Patan, Suresh, and Rajasekhara (2016) introduced a real-time smart traffic management system for smart cities, leveraging the IoT and big data technologies. The authors propose an intelligent system capable of real-time data analysis and traffic management. By integrating IoT devices and big data analytics, the system optimizes traffic flow, reduces congestion, and enhances overall urban mobility. Their innovative approach demonstrates the potential of IoT and big data in revolutionizing urban transportation systems.

Silva and Silva (2019) conducted a systematic review exploring the relationship between congestion charging and smart cities. The study aims to provide a comprehensive understanding of the impact of congestion charging policies in the context of smart city initiatives. By examining a range of relevant literature, the authors analyze the key findings and trends associated with the integration of congestion charging schemes and smart city technologies. The review highlights that congestion charging policies have been implemented in various cities worldwide as a means to alleviate traffic congestion and promote sustainable urban mobility. The integration of smart city technologies, such as advanced sensors, data analytics, and intelligent transportation systems, has played a crucial role in the successful implementation and management of congestion charging schemes. The findings indicate that smart city initiatives have enhanced the effectiveness and efficiency of congestion charging policies. By utilizing real-time data and predictive analytics, cities can optimize pricing structures, dynamically adjust congestion charges, and provide personalized travel information to users. The integration of smart technologies has also facilitated the seamless collection and processing of toll payments, improving the overall user experience and administrative processes. Furthermore, the systematic review identifies various benefits associated with the integration of congestion charging and smart city concepts. These include the reduction of traffic congestion, improvement of air quality, promotion of sustainable transportation modes, and generation of revenue for infrastructure investments. The review also discusses the potential challenges and barriers to the implementation of congestion charging schemes in smart cities, such as public acceptance, equity considerations, and technological requirements. The systematic review emphasizes the significant role of smart city technologies in enhancing the effectiveness of congestion charging policies. The findings provide valuable insights for policymakers and urban planners in understanding the synergies

between congestion charging and smart city initiatives. The study suggests that the integration of these approaches can contribute to more sustainable and efficient urban transportation systems.

Sochor and Dvorak (2020) provides a comprehensive overview of the effects of smart city solutions on urban mobility. The researchers conducted a systematic review of existing literature to analyze the impacts of various smart city technologies and initiatives on transportation systems and commuting patterns. The review highlights several key findings. Firstly, it emphasizes the positive effects of smart city solutions on improving transportation efficiency and reducing traffic congestion. Smart technologies such as intelligent transportation systems, real-time traffic management, and advanced data analytics have shown promise in optimizing traffic flow, enhancing public transportation services, and facilitating multi-modal integration. The study also recognizes the potential of smart mobility services, including ridesharing, carpooling, and bike-sharing, to encourage sustainable transportation choices and decrease private vehicle ownership. These services, often facilitated by mobile applications and digital platforms, have the potential to enhance connectivity and provide flexible alternatives to traditional commuting patterns. Furthermore, the review identifies the importance of data-driven decision-making and urban planning in achieving effective smart mobility solutions. The analysis highlights the role of big data, Internet of Things devices, and sensor networks in gathering real-time information about transportation patterns, which can inform policy interventions and enable responsive transportation management. However, the study also acknowledges the challenges associated with implementing smart city solutions. These include issues of data privacy and security, interoperability of different systems.

Zafar, Haq, Sohail, Chughtai and Muneeb (2022) revealed that in the future, as smart cities continue to evolve, the abundance of data from diverse sources and different levels of difficulty will be initiated, fused, treated, and employed. Within the realm of city traffic planning in smart cities, one of the most pressing challenges revolves around predicting and mitigating traffic congestion. Traffic congestion is a multifaceted phenomenon influenced by numerous factors. In addition to vehicular mobility, elements such as road network characteristics, weather conditions, holidays, and peak

hours significantly contribute to congestion, particularly on arterial roads within cities. This paper introduces a novel approach to addressing this challenge by proposing

a hybrid deep learning model based on the combination of GRU[18] and LSTM[19] architectures. The model is applied to city-wide traffic data, which is aggregated from various heterogeneous sources. To support the implementation of the proposed model, a customized data pipeline has been developed. This pipeline incorporates a series of algorithms designed to handle tasks such as map matching, handling data sparsity, removing outliers, adjusting zero speeds, and mapping road segments using OSM[20]. Rigorous experimentation has been conducted to showcase the enhanced performance of the proposed method. Comparative analysis demonstrates that our methodology achieves an impressive 95% accuracy, outperforming other deep neural network models commonly used in this domain.

In summary, this literature review considered the dynamic interface of technology and transportation systems in the context of smart cities. The transformative potential of technological advances such as the IoT, artificial intelligence, and data analytics is being demonstrated in designing more efficient, sustainable, and connected urban mobility solutions. As smart cities seek to address challenges such as rapid urbanization, environmental issues, and increased demand for seamless transportation, the integration of innovative technologies is proving to be a key driver of change.

2.4 Technologies and Transportation Systems

Smart cities use a variety of technologies and transportation systems to improve mobility, reduce traffic congestion, and improve citizens' overall quality of life. By integrating different transportation technologies and systems such as smart transportation systems, mobility as a service, electric vehicles, smart parking solutions, fleet management systems, data analytics and artificial intelligence, smart cities aim to create a more efficient, resilient, accessible urban transportation network while improving the overall quality of life of residents.

[18] Gated Recurrent Unit
[19] Long Short-Term Memory
[20] Open Street Map

Cunha, Amaral, Silva and Pinheiro (2021) presented a comprehensive review of the existing literature on smart public transportation in smart cities. The authors recognize the importance of efficient and sustainable public transportation systems in the context of smart cities, where technological advancements and data-driven solutions are utilized to improve urban mobility. The study employs a systematic literature review methodology to analyze and synthesize relevant research articles from various sources. The authors identify key themes and trends in the literature, including the use of emerging technologies, data analytics, intelligent transportation systems, and innovative mobility services to enhance public transportation in smart cities. The findings of the literature review highlight several aspects of smart public transportation. Firstly, the integration of smart technologies, such as Internet of Things devices, sensors, and real-time data collection systems, enables the provision of real-time information to passengers, optimized route planning, and improved operational efficiency. Secondly, the utilization of data analytics and machine learning algorithms enables the prediction of demand patterns, congestion management, and personalized services for passengers. The review also emphasizes the importance of sustainable and multimodal transportation solutions, including the integration of public transit with other modes of transport, such as cycling and car-sharing. Furthermore, the authors discuss the role of policy and governance frameworks in promoting and supporting the development of smart public transportation systems. The study concludes by highlighting the need for further research and implementation of smart public transportation initiatives in real-world settings. The findings provide insights for policymakers, urban planners, and transportation authorities to develop strategies and interventions that enhance the quality, efficiency, and sustainability of public transportation in smart cities. Overall, the research work contributes to the understanding of smart public transportation in the context of smart cities and provides a valuable resource for researchers and practitioners interested in this field.

Gohar, Sagheer, Javaid, Anpalagan, and Khan (2019) provided an in-depth analysis of fog computing in the context of ITS[21]. The authors explore the architecture, opportunities, and challenges associated with leveraging fog computing for transportation management in smart cities. The paper begins by highlighting the

[21] Intelligent Transportation Systems

limitations of traditional centralized cloud computing in handling the massive data generated by ITS. It then introduces the concept of fog computing as a decentralized paradigm that brings computation, storage, and networking closer to the edge of the network. The authors discuss the architecture of a fog-enabled ITS, which involves the integration of fog nodes, smart vehicles, road-side units, and cloud infrastructure. They emphasize the advantages of fog computing in enabling real-time data processing, reducing latency, enhancing privacy and security, and enabling context-aware decision making. The opportunities presented by fog computing in the context of transportation management are explored in detail. These include improved traffic management and congestion control, efficient routing and navigation, enhanced driver safety and assistance, and support for emerging applications such as autonomous vehicles and smart parking. The paper also addresses the challenges associated with fog computing in ITS, such as resource constraints, network scalability, interoperability, data management, and security issues. The authors discussed potential solutions and research directions to overcome these challenges. Overall, the paper provides a comprehensive overview of the architecture, opportunities, and challenges of fog computing in the context of intelligent transportation systems. It highlights the potential benefits of leveraging fog computing in smart cities to enable efficient and reliable transportation management. The insights provided in this paper can serve as a valuable resource for researchers, practitioners, and policymakers working in the field of smart transportation and urban planning.

Kaur and Kaur (2017) provided an in-depth analysis of the applications and advancements of the Internet of Things in the transportation sector. The authors aim to present a comprehensive understanding of the potential benefits, challenges, and future directions of IoT implementation in transportation systems. The article begins with an introduction to IoT and its relevance to the transportation domain. It highlights the key characteristics of IoT, such as connectivity, sensing capabilities, and data processing, that make it well-suited for improving transportation systems. The authors emphasize the importance of IoT in enabling the collection and analysis of real-time data, which can be utilized for enhancing various aspects of transportation, including traffic management, vehicle safety, and passenger experience. The review then discusses the applications of IoT in transportation, covering areas such as smart traffic management, intelligent vehicle systems, fleet management, and passenger information systems. The

authors provide detailed insights into how IoT technologies can be leveraged to improve efficiency, reduce congestion, enhance safety, and enable predictive maintenance in transportation systems. Additionally, the article examines the challenges and issues associated with the implementation of IoT in transportation. These challenges include data security and privacy concerns, interoperability of devices and systems, scalability, and the need for reliable connectivity. The authors discuss potential solutions and strategies to overcome these challenges, such as standardization efforts and the development of robust communication protocols. Furthermore, the authors discuss emerging trends and future directions in IoT for transportation. They highlight the integration of IoT with other technologies, such as artificial intelligence and big data analytics, to enable advanced transportation management and decision-making. In summary, Kaur and Kaur provide a comprehensive review of IoT for transportation, encompassing its applications, challenges, and future prospects. The article serves as a valuable resource for researchers, practitioners, and policymakers in understanding the potential of IoT in transforming transportation systems and addressing the associated challenges.

Khan, Salah and Zeadally (2019) explored the applications, opportunities, and challenges of fog computing in the context of intelligent transportation systems. The authors delve into the potential of fog computing to address the limitations of traditional centralized cloud computing in handling the massive data generated by ITS. The paper begins by providing an overview of ITS and the increasing demand for real-time data processing and decision-making capabilities. It introduces the concept of fog computing as a decentralized computing paradigm that extends cloud services to the edge of the network. The authors highlight the advantages of fog computing in terms of low latency, location awareness, mobility support, and efficient resource utilization. The applications of fog computing in ITS are discussed, including traffic management, vehicle-to-vehicle and vehicle-to-infrastructure communication, intelligent routing, and autonomous vehicles. The authors emphasize the potential benefits of fog computing in enabling real-time data analytics, adaptive traffic control, enhanced driver safety, and improved overall transportation efficiency. The challenges associated with fog computing in ITS are also addressed in the paper. These challenges include resource management, security and privacy concerns, network connectivity, interoperability, and scalability. The authors discuss various approaches and solutions to overcome these

challenges, including workload distribution, data caching, security mechanisms, and standardization efforts. In all the research work provides a comprehensive analysis of the opportunities and challenges of fog computing in the domain of intelligent transportation systems. It highlights the potential of fog computing to revolutionize transportation management by enabling real-time data processing and decision-making capabilities at the network edge. The insights presented in this paper can serve as a valuable resource for researchers, practitioners, and policymakers working on the integration of fog computing in intelligent transportation systems.

Pereira, Rodrigues and Saleem (2018) conducted a comprehensive survey on IoT-based transportation systems. The aim of the research is to provide an overview of the applications, challenges, and opportunities associated with IoT in the transportation domain. The authors begin by introducing the concept of IoT and its potential impact on transportation systems. They discuss how IoT technologies can be integrated into various components of transportation systems, including vehicles, infrastructure, and users. The study then presents a survey of existing literature, focusing on different applications of IoT in transportation, such as smart parking, traffic monitoring, fleet management, and road safety. Authors also highlight the key challenges and issues that arise in the implementation of IoT-based transportation systems, including data security, privacy concerns, interoperability, and scalability. They discuss the importance of addressing these challenges to ensure the successful deployment and operation of IoT solutions in transportation. Furthermore, the study identifies several opportunities and benefits that IoT brings to transportation systems, such as improved traffic management, reduced congestion, enhanced safety, and increased efficiency. The authors emphasize the potential of IoT to revolutionize the way transportation systems are designed, operated, and experienced. In conclusion, the paper provides a comprehensive survey of IoT-based transportation systems, covering applications, challenges, and opportunities. It serves as a valuable resource for researchers, practitioners, and policymakers interested in understanding the potential of IoT in transforming transportation systems and addressing the associated challenges.

Vlahogianni, Karlaftis and Golias (2014) in their comprehensive review, provided an overview of the state of the art in short-term traffic forecasting and shed light on future directions in this field. They recognize the importance of accurate traffic forecasting for

efficient transportation management and discuss the advancements and challenges in this area. The article begins by highlighting the significance of short-term traffic forecasting in various transportation applications, such as traffic control, congestion management, and travel time estimation. The authors emphasize the need for accurate and reliable forecasting models to enable efficient traffic management and improve overall transportation system performance. The article also addresses the challenges and limitations of existing traffic forecasting models, including data availability, model complexity, and uncertainty. The authors then review the different approaches and methodologies employed in short-term traffic forecasting. They discuss the traditional time series analysis methods, such as ARIMA[22], as well as more advanced techniques like ANN, SVM[23], and hybrid models that combine multiple methods. The authors highlight the need for real-time data, such as traffic sensor data and weather information, to improve the accuracy of forecasting models. They also discuss the importance of incorporating non-linear relationships and dynamic traffic patterns into the models. Furthermore, the authors explore emerging trends and future directions in short-term traffic forecasting. They discuss the potential of big data analytics, machine learning, and data fusion techniques in improving the accuracy and reliability of forecasting models. They also highlight the importance of considering the impact of emerging technologies, such as connected and autonomous vehicles, on traffic forecasting. In conclusion, Vlahogianni, Karlaftis, and Golias provide a comprehensive review of short-term traffic forecasting, discussing the existing models, challenges, and future directions. The article serves as a valuable resource for researchers, practitioners, and policymakers involved in transportation planning and management, highlighting the importance of accurate traffic forecasting for the development of efficient and sustainable transportation systems.

Zanella, Bui, Castellani, Vangelista and Zorzi (2014) provided a comprehensive overview of the Internet of Things and its role in the development of smart cities. The authors present the concept of the IoT as a paradigm where physical objects are connected to the internet and can interact with each other and with the environment to

[22] Autoregressive Integrated Moving Average
[23] Support Vector Machines

enable a range of applications and services in urban environments. The article begins by introducing the concept of smart cities and the key challenges faced by urban areas, including sustainability, energy efficiency, transportation, and public safety. The authors argue that the IoT can play a vital role in addressing these challenges by enabling the deployment of interconnected devices and systems for monitoring, control, and optimization of various urban services. The authors then delve into the technical aspects of the IoT, discussing the key enabling technologies such as wireless sensor networks, radio frequency identification, and cloud computing. They highlight the importance of communication protocols, data management, and security in ensuring the effective operation of IoT systems in smart cities. Furthermore, the article presents a comprehensive classification of IoT applications in smart cities, covering areas such as transportation, energy management, healthcare, environmental monitoring, and public safety. The authors provide detailed insights into the potential benefits and challenges associated with each application domain, highlighting the need for interoperability, scalability, and privacy protection. The article also discusses several case studies and initiatives where IoT technologies have been applied in real-world smart city projects. These examples illustrate the potential of the IoT to transform urban environments and improve the quality of life for citizens. In conclusion, Zanella et al. provide a comprehensive overview of the Internet of Things for smart cities, covering its concepts, technologies, applications, and challenges. The article serves as a foundational reference for researchers, practitioners, and policymakers interested in understanding the potential of the IoT in shaping the future of urban environments and addressing the complex challenges faced by cities.

Literature review on Technology and transportation system, reminded me the profound impact, technology has on transforming the transport environment. By exploring innovative solutions, data-driven insights, and integrating cutting-edge technologies, it is clear that our transportation system is on the verge of transformation. As we navigate the intersection of technology and transportation, we sincerely hope that this research will contribute to the ongoing debate and stimulate further research and advancement in this field. The potential to improve the efficiency, sustainability and safety of our transport networks is huge, and the path to a smarter, more connected future is both exciting and challenging.

2.5 IoT Based Traffic Prediction Models

IoT-based traffic prediction models are an integral part of smart cities as they can help manage traffic effectively, reduce traffic congestion, and improve overall mobility. IoT-based traffic prediction models for smart cities can significantly improve the efficiency of transportation systems, reduce traffic congestion, and improve citizens' overall quality of life. These models must be flexible and adaptable to accommodate changing traffic patterns and urban infrastructure. The steps involved in developing an IoT-based traffic forecasting model for a smart city are data collection, data processing, data analysis, predictive modeling, visualization and reporting, feedback loops, communication and evaluation. Review of work already done in this field is as follows.

Abbas (2011) researched article explores bio-inspired neuro-fuzzy-based dynamic route selection to avoid traffic congestion. Published in the International Journal of Scientific and Engineering Research, the study presents an innovative approach to optimizing traffic routes. By leveraging bio-inspired computational models and fuzzy logic, the research proposes adaptive routing strategies. These strategies enable vehicles to dynamically select routes, avoiding congested areas and optimizing travel times. The study contributes to the development of intelligent traffic management systems, promoting efficient and congestion-free urban mobility.

Amadeo (2016) the authors discuss information-centric networking for the IoT. The study explores the challenges and opportunities presented by IoT devices and their information-centric networking. By addressing the unique requirements of IoT communication, the research contributes valuable insights into optimizing data transmission and management, enhancing the efficiency of IoT-based applications, and fostering the development of smarter and more connected cities.

Bhardwaj, Malik, Chauhan, and Rana (2021) conducted a comprehensive survey on IoT-based traffic prediction models for smart cities. The study was published in the Journal of Ambient Intelligence and Humanized Computing. The authors aimed to provide an extensive overview of IoT-based traffic prediction models specifically designed for smart cities. They reviewed various research articles and studies in this domain to identify the current state-of-the-art approaches and advancements. The survey focused on the use of Internet of Things technologies for traffic prediction in

smart cities. It explored different models and techniques employed for this purpose. The authors discussed the application of machine learning and deep learning algorithms in traffic prediction, emphasizing the integration of IoT devices and sensors to gather real-time traffic data. Furthermore, the authors highlighted the challenges and limitations faced by existing IoT-based traffic prediction models. They identified areas of improvement and potential future research directions, such as incorporating additional data sources, considering heterogeneous traffic scenarios, and enhancing prediction accuracy. Overall, the survey provides a comprehensive analysis of IoT-based traffic prediction models in the context of smart cities.

Balasubramanian (2023) explained in the context of smart cities, the rapid increase in the number of vehicles has led to congestion, pollution, and disruptions in the transportation of goods. Additionally, road accidents continue to cause numerous fatalities and permanent injuries each year. To address these challenges, the implementation of an IoT-based TMS[24] has gained prominence. This system utilizes autonomous vehicles and intelligent devices equipped with sensors to collect, transmit, and analyze traffic data. Machine learning techniques are also employed to improve the efficiency of the transportation system. This research work focuses on the development of an ATM[25] system integrated with an AALS[26] to effectively manage traffic congestion and detect accidents. To ensure secure transmission of traffic-related data, the SEE-TREND[27] mechanism is utilized. The proposed design incorporates various scenarios to address potential issues in the transportation system. The ATM model continuously adjusts the timing of traffic signals based on the traffic volume and predicted movements from nearby junctions. By allowing vehicles to pass through green lights in a progressive manner, the system significantly reduces travel time and alleviates traffic congestion. The experimental results demonstrate that the proposed ATM system outperforms traditional traffic management methods and holds promise for enhancing transportation planning in smart city environments. Furthermore, the integration of ATM with SEE-TREND facilitates secure transmission of traffic data, resulting in

[24] Traffic Management System
[25] Adaptive Traffic Management
[26] Accident Alert Sound System
[27] Secure Early Traffic-Related Event Detection

reduced traffic congestion, minimized waiting times for vehicles, decreased accident rates, and an overall enhanced travel experience. In summary, the IoT-based Traffic Management System presented in this study offers an innovative solution to address traffic congestion and improve road safety in smart cities. The combination of adaptive traffic management, accident detection, and secure data transmission contributes to a more efficient and sustainable transportation system for the benefit of both commuters and city governance.

Coutard and Olivier(2014) collaborated research effort delves into urban megatrends and outlines a European research agenda. Published in a comprehensive report, the study explores the transformative trends shaping urban environments. By identifying key megatrends, such as demographic shifts and technological advancements, the research provides a strategic framework for future urban development initiatives. The report offers essential guidelines for policymakers, researchers, and urban planners to address the challenges and opportunities posed by urbanization and emerging technologies, guiding the creation of sustainable and resilient smart cities.

Chong, Hon Fong, and Kiat Ng (2016) presented at the IEEE Student Conference focuses on the development of IoT devices for traffic management systems. By leveraging IoT technology, the study explores innovative approaches to enhance traffic management efficiency. The research contributes to the growing field of intelligent transportation systems, emphasizing the integration of IoT devices to optimize traffic flow, reduce congestion, and improve overall urban mobility.

Chowdhury (2016) research focused on a priority-based and secured traffic management system for emergency vehicles using IoT. The study addresses the critical need for efficient traffic management to facilitate emergency vehicle movement. The research proposes solutions to ensure the swift and secure passage of emergency vehicles, improving response times and enhancing overall urban safety and security.

Mamoona and Humayun (2022) proposed an IoT-based architecture for smart traffic management in metropolitan areas, with a specific focus on Riyadh, Saudi Arabia. The aim is to address the problem of excessive traffic congestion during peak hours by utilizing modern technologies such as IoT, cloud computing, 5G, and big data. The proposed architecture involves the deployment of IoT devices and agents that collect

and count vehicles, with real-time data being stored in the cloud through message agents. The system utilizes messaging agents as actuators to broadcast real-time traffic information on dashboards and Google Maps, helping citizens make informed decisions and save time on the roads. Wi-Fi-enabled controllers facilitate timely message transmission. A case study is conducted to validate the accuracy and effectiveness of the proposed architecture. The proposed solution has the potential to significantly reduce traffic congestion and improve mobility in metropolitan areas. It leverages IoT technologies to provide real-time traffic updates and early warning messages to drivers, enabling them to choose the most efficient routes and avoid unexpected traffic incidents. The study also highlights future directions for the system, including optimizing route recommendations based on real-time data, enhancing traffic signal control in different environments, and addressing IoT security considerations. Overall, the proposed IoT-based architecture offers a promising approach to tackle traffic congestion in cities like Riyadh. By integrating advanced technologies, the system aims to provide efficient traffic management, enhance communication between drivers and the transportation network, and improve the overall travel experience in urban areas.

Neelakandan (2016) as author focused on large-scale optimization to minimize network traffic in big data applications using MapReduce. The study delves into the realm of computational power, energy information, and communication. By employing the MapReduce framework, the research aims to enhance the efficiency of processing vast volumes of data. This approach holds significance in the context of big data applications where optimizing network traffic is crucial for seamless data processing and communication. The paper discusses the methodologies and techniques applied to achieve these objectives, contributing valuable insights to the domain of big data analytics.

Neelakandan and Paulraj (2020) presented an innovative Automated Exploring and Learning Model for data prediction utilizing a Balanced Cellular Automata-Support Vector Machine approach. The study focuses on developing a robust model capable of predictive data analysis. By integrating Cellular Automata-Support Vector Machine, a hybrid approach leveraging cellular automata and machine learning, the authors propose an automated system for exploring data patterns and making predictions. The study emphasizes the importance of balancing the learning process to enhance the

accuracy and reliability of predictions. This model showcases advancements in automated predictive analytics, offering valuable applications in various fields.

Ou, Haoyuan, Zhang, and Wang (2016) presented the development of an intelligent traffic control system based on the Internet of Things and FPGA[28] technology in Proteus. Published in the Traffic journal, the research explores the integration of IoT and FPGA technology for traffic control applications. By leveraging these technologies, the system enhances traffic management capabilities, offering efficient solutions to address urban traffic challenges. The study showcases the potential of cutting-edge technologies in shaping intelligent transportation systems.

Pattanaik, Singh, Gupta and Singh (2016) introduced a Smart Real-time Traffic Congestion Estimation and Clustering Technique for urban vehicular roads. The research addresses the challenge of real-time traffic management in urban areas by proposing an efficient congestion estimation and clustering method. The study explores innovative techniques to assess traffic congestion levels and cluster vehicular data for effective traffic management. By leveraging advanced algorithms, the proposed approach aims to enhance the real-time decision-making process, ensuring optimal traffic flow in urban road networks. The research contributes valuable insights to the development of intelligent traffic management systems.

Ramachandra, Sujit, Reddy, Vivek, Vellore, Karanth, and Kamath (2016) introduced a novel dynamic traffic management system integrating on-board diagnostics and Zigbee protocol. Published in the International Conference on Communication and Electronics Systems, the study explores advanced technologies to optimize traffic management. By combining on-board diagnostics and wireless communication protocols, the system enhances real-time data collection and analysis, enabling data-driven decision-making for traffic management and contributing to more intelligent urban mobility solutions.

[28] Field Programmable Gate Array

Rego, Garcia, Sendra, and Lloret (2018) presented a SDN[29] based control system designed for efficient traffic management during emergency situations in smart cities. The research emphasizes the significance of adaptive and responsive traffic management systems, especially during emergencies. By utilizing SDN technology, the proposed system offers dynamic control and optimization of traffic flow, ensuring swift response to emergency scenarios. The paper discusses the architecture and implementation details of the SDN-based control system, highlighting its potential to enhance urban safety and resilience during critical situations.

Saeed and Yousaf (2016) focused on the impact of cognition on user authentication schemes in vehicles. By employing fuzzy logic and artificial neural network technologies, the study enhances user authentication protocols. The research addresses the critical issue of vehicle security, offering advanced cognitive solutions to prevent unauthorized access. The proposed authentication scheme contributes to enhancing vehicle safety and security, promoting the development of intelligent and secure transportation systems.

Subbulakshmi and Prakash (2018) explained the challenges of mitigating eavesdropping in wireless CRNs[30]. The study introduces a novel approach combining fuzzy-based learning and multilevel Stackelberg game theory to enhance network security. The proposed method focuses on optimizing spectrum utilization and minimizing eavesdropping risks. By integrating fuzzy logic and game theory, the research provides a comprehensive solution for ensuring secure communication in CRNs. The study underscores the importance of intelligent security mechanisms in cognitive radio environments, emphasizing the role of advanced computational techniques in enhancing network resilience.

Satpathy, Mohan and Das (2020) introduced a novel healthcare diagnosis system utilizing an IoT-based fuzzy classifier with Field-Programmable Gate Array technology. The study focuses on advancing healthcare diagnostics through intelligent systems. By integrating fuzzy logic and FPGA, the proposed system enhances the accuracy and efficiency of disease diagnosis. The study explores the application of IoT

[29] Software-Defined Network
[30] Cognitive Radio Networks

devices in healthcare, emphasizing the synergy between IoT technology and advanced computational techniques. The research contributes to the evolution of smart healthcare systems, showcasing the potential of IoT-driven diagnostic solutions.

Sarrab, Pulparambil, and Awadalla (2020) in spite of the broad research conducted on smart traffic system frameworks, smart traffic observing remains an dynamic area of study, driven by emerging innovations just like the Internet of Things and Artificial Intelligence. The consideration of these innovations has the potential to revolutionize decision-making forms and contribute to the development of urban environments. In any case, most existing traffic estimation strategies primarily center on highway and city traffic administration, with limited consideration given to vital minister streets and closed campuses.

Subramani, Berlin, Tripathi, Sandesh, Devi, Bhardwaj, Natarajan and Arul Kumar (2021) found that with the ever-increasing population and stagnant traffic density, traffic prediction has emerged as a significant challenge in today's cities. This situation leads to wasted time, fuel, environmental damage, and even fatalities as people get trapped in congested traffic. Although the field of control system and estimation of traffic congestion has received limited attention from researchers, existing approaches often lack the desired accuracy. To address this issue, they proposes an improved IoT-based traffic estimation and traffic signal control system for smart cities, employing the OWENN algorithm and an Intel 80286 microprocessor. The proposed system consists of five phases: IoT data collection, feature extraction, classification, reducing traffic IoT values, and traffic signal control system. Initially, IoT traffic data is collected from a dataset. Then, the system extracts essential features such as traffic, weather, and direction information. These taken out features are fed into the OWENN classifier, which accurately identifies areas with high traffic congestion. Furthermore, if a specific direction within an area experiences heavy traffic, the system optimizes IoT values using the IBSO[31] technique. Finally, the traffic signal control is implemented through the utilization of an Intel 80286 microprocessor. The OWENN algorithm plays a vital role in both traffic signal control and traffic estimation stages. It demonstrates remarkable accuracy, achieving an impressive 98.23% accuracy rate, surpassing

[31] Improved Binary Swarm Optimization

existing models, and a high F-score of 96.69%. The experimental results reveal the superior performance of the proposed system compared to cutting edge methods. In conclusion, they presents an efficient IoT-framework approach for traffic signal control and traffic estimation in smart cities. By incorporating the OWENN algorithm and Intel 80,286 microprocessor, the system enhances accuracy and effectiveness, offering a encouraging solution to address the problems posed by traffic congestion in city areas. Effective communication and engagement with the public, particularly when users do not possess smart devices, poses a significant challenge. To address these issues, IoT-based system model was designed to collect, process, and store real-time traffic data in scenarios where traditional methods may be inadequate. Their main objective is to provide real-time traffic information on traffic congestion and rare incidents through roadside, thereby enhancing overall mobility. The citizen time can be save using these early-warning messages, particularly during rush hours, while also broadcasting traffic information from administrative offices. A prototype of the proposed system is implemented to evaluate its practicality, and experimental results demonstrate accurate vehicle detection and low relative error in road occupancy prediction. By leveraging IoT technology and roadside message units, this research contributes to improving the efficiency of traffic management and providing timely information to the public. The findings highlight the potential of the proposed system model in enhancing urban mobility and facilitating informed decision-making. However, further research and development are necessary to refine and expand the system's capabilities and ensure its seamless integration into smart city environments.

Theodoridis, Mylonas, and Chatzigiannakis (2013) focused on traffic components of smart city by exploring innovative approaches for creating intelligent urban environments. The authors emphasize the integration of IoT technologies to enhance city infrastructure and services. The framework proposed in the research aims to leverage IoT sensor, real-time data collection and analysis for efficient urban management. By emphasizing the synergy between IoT systems and city functionalities, the study underscores the potential for creating smarter and more responsive cities.

Thakur, Tanvi Tushar, Ameya Naik, Sheetal Vasari, and Gogate (2016) presented at the International Conference on Communication and Signal Processing, the authors propose a real-time traffic system utilizing the Internet of Things. By harnessing IoT-enabled sensors and communication protocols, the system enables dynamic traffic management strategies. The research highlights the potential of IoT technology in creating adaptive and responsive traffic management solutions, leading to more accurate and sustainable city transportation system. The research contributes valuable insights into the practical implementation of IoT solutions to transform urban spaces into intelligent, data-driven environments.

Tchuitcheu, Bobda and Pantho (2020) presented the implementation of an IoT smart camera system for optimizing traffic lights in smart cities. The smart cameras are used with traffic lights to enhance traffic control mechanisms. By leveraging IoT technology, the informed system offers real-time monitoring and flexible control of traffic signals. The research emphasizes the role of smart cameras in capturing real-time traffic data and enabling intelligent traffic management. The study contributes to the advancement of smart city infrastructures, showcasing the potential of IoT-driven traffic optimization solutions.

Yao, Gao, Wang, Zhang, Jiang and Han (2019) introduced a IoT Traffic Capsule Network tailored for smart cities. The study focuses on refining traffic classification methods using advanced deep learning techniques. By employing Capsule Networks, the proposed mechanism enhances the accuracy of IoT-driven traffic classification. The research emphasizes the importance of precise traffic data analysis for smart city applications. The study showcases the integration of cutting-edge machine learning algorithms with IoT technology, highlighting their synergy in optimizing traffic management strategies. The research contributes valuable insights to the field of smart city technologies, showcasing innovative approaches to traffic. By putting more emphases on the synergy between IoT systems and city functionalities, the study underscores the potential for creating smarter and more responsive cities.

Zhou, Wang, Ma and Zhang (2020) published a paper titled "An IoT-based traffic prediction model for smart cities using deep learning algorithms" in the journal Sensors. The authors presented a traffic prediction model that utilizes Internet of Things technology and deep learning algorithms in the context of smart cities. The goal of the study was to improve the accuracy and efficiency of traffic prediction by leveraging real-time data from IoT devices. The proposed model incorporated deep learning algorithms, such as CNNs[32] and LSTM[33] networks. These algorithms were employed to extract meaningful features from the collected IoT data and generate predictions for traffic conditions. The authors conducted experiments and evaluated the performance of their IoT-based traffic prediction model using real-world traffic data. They compared the results with other traditional prediction models and demonstrated the superiority of their approach in terms of accuracy and prediction capabilities. The findings of the study indicated that the integration of IoT devices and deep learning algorithms can significantly enhance the accuracy of traffic prediction in smart cities. The authors highlighted the potential applications and benefits of their model in improving traffic management and optimizing transportation systems in urban areas. Overall, the research provides insights into the development of an IoT-based traffic prediction model using deep learning algorithms. It showcased the potential of this approach in the context of smart cities and contributed to the advancement of intelligent transportation systems.

At the end of this literature review on "IoT-based traffic prediction models" I was reminded the transformative potential that the IoT offers to improve the efficiency and reliability of transportation systems. Research on the integration of data-driven approaches, machine learning algorithms, and IoT technologies has provided valuable insights into the dynamics of urban traffic patterns. This study highlights the importance of using the IoT in the context of traffic prediction and provides a glimpse into a future where cities are equipped with intelligent systems that can adapt to the ever-changing demands of urban mobility.

[32] Convolution Neural Networks

[33] Long short-term memory

2.6 Artificial Intelligence and Traffic Management

Giffinger and Gudrun (2010) critically examine the effectiveness of smart city ranking systems as instruments for city positioning. By evaluating various methodologies, metrics, and indicators used in city rankings, the study raises important questions about the relevance and accuracy of such assessments. The research prompts discussions on the nuances of smart city evaluations, challenging existing paradigms and advocating for more comprehensive and context-specific approaches to accurately gauge cities' smart capabilities.

Iker, Alessandro and Saioa (2016) comprehensively explored the concept of smart cities, delineating its current state and potential future trajectories. Investigating the essence of smart urban development, the research delves into advanced technologies, data-driven decision-making processes, and sustainable urban practices. By dissecting the multifaceted aspects of smart cities, the study illuminates the intricate interplay between technology, governance, and urban infrastructure, offering crucial insights for urban planners and policymakers striving to create intelligent and sustainable urban environments.

Kikuchi (2009) work, featured in Transportation Research Part C: Emerging Technologies, which explores the transformative role of artificial intelligence in transportation analysis. Kikuchi delves into diverse approaches, methodologies, and applications of AI in addressing intricate transportation challenges. By harnessing machine learning and data analytics, the research showcases how AI techniques optimize transportation systems, emphasizing efficiency, safety, and sustainability.

Navarathna, Pramathi, Vindhya and Malagi (2018) highlighted the diverse applications of artificial intelligence in smart city contexts. Focusing on post-2018 advancements, the study highlights emerging trends and innovative AI solutions adopted by cities to address urban challenges. Their work provides insights into the evolving landscape of AI technologies in shaping smart urban ecosystems.

Tarawneh (2023) explained, how the integration of artificial intelligence into smart cities has revolutionized urban mobility by enhancing traffic flow and reducing accidents. This transformative approach involves optimizing traffic management through intelligent decision-making, leveraging AI algorithms and IoT devices. A robust network infrastructure forms the backbone of successful smart cities, enabling diverse applications and efficient data analysis. In this context, ensuring driver safety is paramount. Remote monitoring of drivers and vehicles emerges as a vital strategy, empowering smart cities to prevent accidents effectively. His research proposed a holistic framework that utilizes real-time traffic data, AI algorithms, and IoT devices to analyze driver behavior, vehicle performance, and road conditions. By remotely monitoring these parameters, the framework not only enhances driver safety but also facilitates timely interventions, thereby saving lives. Additionally, it offers real-time road status updates to drivers and enables cost-effective vehicle maintenance, contributing significantly to a safer, smarter, and more efficient urban environment.

Kumar and Ratan (2023) Analyzed the usefulness of various machine learning algorithms in managing traffic and their real-world applications. Traffic framework is a critical aspect of modern transportation systems, and AI has the power to improve it significantly. they used a dataset from traffic cameras in Delhi to evaluate the performance of four machine learning algorithms: Linear Regression, Decision Tree, Random Forest, and Support Vector Regression. they compared the algorithms based on three performance metrics: Mean Absolute Error, Mean Squared Error, and R-squared. The results showed that Random Forest and Support Vector Regression performed better than Linear Regression and Decision Tree. The real-world applications of AI in traffic management are promising, but ethical considerations must be taken into account. Overall, this research contributes to the growing body of literature on AI for traffic management and provides insights into the potential of machine learning algorithms to improve traffic flow and reduce congestion.

Sreelatha , Mahalakshmi and Yadav(2023) clarified AI based independent traffic control which alludes to the administration and control of traffic stream. In order to gather real-time information on traffic conditions, sensors, cameras, and communication systems are utilized. This information is at that point assessed and handled by AI Algorithms to deliver experiences and make judgment. AI-fuelled

autonomous traffic regulation points to increase framework effectiveness by reducing vehicle blockage, expanding security, and all of the above. The advantage of utilizing independent activity control utilizing AI is the ability to handle and collect huge genuine time information and conclusions are drawn. This empowers the system to alter the activity flow quick in reaction to moving traffic circumstances. Calculations based on AI can moreover be used to learn from past traffic designs and circumstances to form future figures and conclusions that are more precise. For independent activity control, an assortment of AI calculations, which incorporates support learning machine learning, and profound learning, can be applied. Calculations based on Profound learning can be utilized to decipher photographs, video information from cameras, and spotting designs, and patterns in traffic information can be achieved through machine learning calculations. Algorithms for support, learning can be used to memorize from the past and make choices based on compensate signals. To ensure their dependability and security, it is vital to create beyond any doubt that these frameworks are designed and conveyed with the correct assurances. This AI-powered framework can also alter in real-time to moving activity designs and street conditions, making the activity directing handle more responsive and energetic. As a result, there may be a change in traffic-related outflows reductions and fuel productivity. In general, the AI is utilized for the improvement of clever transportation frameworks which has progressed noteworthy, which has the potential to revolutionize activity administration and guarantee a more successful, secure, and feasible transportation framework.

Literature review on “Artificial Intelligence and Traffic Management" reminded me that the integration of AI technologies, machine learning algorithms, and data-driven decision-making processes holds great potential for tackling the complex challenges of modern transportation systems. This literature review revealed new insights into the application of AI in traffic management, highlighting its ability to increase efficiency, reduce congestion, and improve overall transportation sustainability. As we stand at the threshold of a transformative era of smart cities, the research in this area will contribute to the development of intelligent transportation systems.