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AN ANALYTICAL RESEARCH ON TRANSPORTATION ASSET MANAGEMENT OF SMART CITIES

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Abstract-
More than 25% of the energy used in smart cities is connected to smart mobility and transportation, which are important components of smart cities overall. Leisure, private, public, commercial, freight, product distribution, and special transit are the seven key categories of smart transport. Transportation may be categorised from a management perspective as active, contract-based, semi-active, simple cooperating, inactive or non-cooperating, and simple cooperating. This strategy may be used with public transit, including with its users. An vast distribution network of sensors and actuators linked into an Internet of Things (IoT) system may be used to broadly watch, analyse, and manage the transportation system. The advantages that the IoT can provide for smart city transport management are briefly covered in the article. In particular, it outlines the idea, methodology, and necessary sub-model advances, which describe the issues with total system optimisation; it also deals with the application of a hierarchical approach to overall transportation management.

Keywords— *Smart City, Smart, Intelligent Transport Management, Transport Optimization, Car Following, Obstacle Avoidance, Formation Motion, Total Management, IoT.*

INTRODUCTION

Transportation asset management involves the strategic planning, operation, and maintenance of transportation infrastructure and assets. It encompasses a range of elements, including roads, bridges, tunnels, public transit systems, and other transportation facilities. The effective management of these assets is essential for ensuring the safe and efficient movement of people and goods within urban areas. Smart cities, on the other hand, are urban environments that leverage advanced technologies and data-driven approaches to enhance the quality of life for residents. These cities integrate various systems and services, including transportation, energy, communication, and governance, to create sustainable and livable urban environments. In December 1959, Richard Feynman (received a Nobel Prize in 1965 for his contribution in the development of quantum electrodynamics) offered a prize of $1000 to the first person to make a motor l/64th of an inch cubed, and to the first person to produce written text at 1/25,000 scale. Soon after, 60 years ago, California Institute of Technology graduate William McLellan designed a motor only 15/1000ths of an inch in diameter. The second prize was won by Tomas Newman, a Stanford graduate student, who used electron-beam lithography in 1985. During the same period, the development of the computer accelerated, microchips' capacity increased while their price was cut, and personal computers were designed. In 1975, the first personal computers, MITS Altair 8800, were sold as kits. In 1976, the Apple I and, a year later, Apple II, the first color computer, were created. Another critical technology, mobile communication, was born in 1899 when Marconi created the practically usable radio. The first cellular mobile phone, weighing 1.1 kg, was introduced by Motorola. Today, 5G mobile phones (like iPhone 11 Pro Max) have about 15–20 million times more capacity and RAM and are around 150 times lighter than the computer of Apollo 11 controlling the first manned mission to land on the Moon. As early as the 1950s, scientists tried to connect their computers and exchange data. The Transmission Control and Internet Protocols (TCPs, IPs) were defined in 1973. These allowed us to develop the Internet. Later, the Domain Name System (1986) and the World Wide Web (1989) were introduced. Finally, the wide band of information transmission, data processing, control theory, and, especially, soft computing (evolved in 1981) resulted in artificial intelligence and the Internet of Things, and, thus, in large natural technogenic systems. It is a human-made (-genic) technical/technological (techno) system based in nature (ground-soil, water-rivers). This term includes the possible management of transport in emergencies, like a disaster caused by an earthquake. By using the more comprehensive approach, smart city transport is an ecological–socio-technogenic system. The transportation system is a whole complex system, the effective operation (usage) of which becomes top-level tasks. Technology development briefly characterized above catalyzes the development of operation of cities and transportation on new smart and intelligent, more effective, and greener levels. Nowadays, society and policymakers are continuously working on smart city developments, while the economy found it a well-explanted future business. Depending on the researchers' or developers' point of view, smart cities have 5–8 significant components as smart infrastructure, transportation, environment, services, governance, people, living, and economy. From these, smart mobility/smart transportation is one of the most important for society and the economy. It uses 30.8% (the year 2017) of energy from total energy consumption in the EU-28.

Challenge	Description
Aging infrastructure	Deterioration and maintenance needs of existing transportation assets
Congestion	Traffic congestion leading to delays and reduced efficiency
Sustainability	Environmental impact and the need for sustainable transportation solutions
Safety	Ensuring safe transportation for users and minimizing accidents
Limited funding	Financial constraints in funding transportation infrastructure projects
Technological advancements	Integration of emerging technologies for efficient and smart transportation systems
Data management and analysis	Collection, processing, and utilization of transportation data for informed decision-making
Multimodal integration	Seamless integration and coordination of different modes of transportation
Urbanization and population growth	Accommodating increasing population and urbanization challenges

Table 1- Key Challenges in Transportation Asset Management

Benefit	Description
Enhanced efficiency	Improved traffic flow, reduced congestion, and optimized resource utilization
Enhanced safety	Implementation of intelligent systems to enhance safety measures and reduce accidents
Improved sustainability	Adoption of sustainable practices, reduced emissions, and promotion of green transportation
Better user experience	Real-time information, improved accessibility, and enhanced user satisfaction
Cost savings	Efficient use of resources, reduced maintenance costs, and optimized asset lifecycle
Data-driven decision-making	Utilization of data analytics and insights for informed decision-making
Improved system reliability	Predictive maintenance, early detection of issues, and enhanced system performance

Table 2- Benefits of Smart Transportation Asset Management

LITERATURE SURVEY

Transportation asset management in smart cities is a multidimensional and complex topic that requires a comprehensive understanding of various factors and perspectives. This literature review aims to provide an overview of the existing literature related to transportation asset management in smart cities, focusing on the identified references. **DeMaio (2013)** discusses the concept of smart bikes as a form of public transportation in the 21st century. The author explores the benefits and challenges of incorporating smart bikes into urban transportation systems. **Wolniak and Jonek-Kowalska (2022)** examine the creative services sector in Polish cities, shedding light on the role of creativity and innovation in shaping urban development and transportation systems. **Zayed (2017)** presents a study on city readiness for cycling, proposing an index to assess the readiness of cities to promote cycling as a mode of transportation. The study highlights the importance of infrastructure and policies in fostering cycling-friendly cities. **Savastano et al. (2023)** analyze citizens' value perceptions of smart mobility in smart cities through ICT applications. The study explores the role of technology in enhancing the mobility experience of residents and its impact on their perception of value. **Herdiansyah (2023)** examines the concept of a smart city based on community empowerment, social capital, and public trust in urban areas. The study emphasizes the importance of citizen engagement and participation in shaping smart transportation systems. **Garret (2023)** provides insights into the cost-benefit analysis of cycling infrastructure, highlighting the economic advantages of investing in cycling facilities and promoting active modes of transport. **Benevolo et al. (2016)** discuss smart mobility in smart cities, focusing on the integration of various transportation modes and the use of technology to improve transportation efficiency and sustainability. **Kunytska et al. (2023)** present a comparative overview of sustainable and smart mobility strategies in different countries. The study explores the various approaches and initiatives undertaken to promote sustainable transportation in smart cities. **Dhingra and Chattopadhyay (2016)** analyze the advancement of smartness in traditional settlement areas, examining the case of Indian and Arab old cities. The study highlights the role of technology in transforming traditional cities into smart and efficient urban spaces. **Lara et al. (2016)** provide a comprehensive and human-centered characterization of smart cities, emphasizing the importance of considering social aspects and human well-being in the development of smart transportation systems. **Albino et al. (2015)** present a comprehensive analysis of smart cities, including their definitions, dimensions, performance, and initiatives. The study provides a framework for understanding the key components and characteristics of smart cities. **Ku et al. (2022)** investigate the effect of a smart mobility hub on urban metabolism and retrofitting. The study explores how integrating smart mobility solutions can contribute to sustainable urban development. **Huang et al. (2022)** examine the motivators and barriers of smartphone app incentives for encouraging cycling. The study explores the role of technology in promoting cycling as a sustainable mode of transportation. **Agriesti et al. (2022)** propose a framework for connecting mobility challenges in low-density areas to smart mobility solutions, using Estonian municipalities as a case study. The study emphasizes the need for tailored solutions in addressing unique mobility challenges. **Jan Wisniewski-RESETl (2019)** discusses the public bike-sharing schemes in Paris and their impact on the environment. The article examines the benefits and challenges of bike-sharing programs in promoting sustainable transportation. **Winslow and Mont (2019**) analyze the sustainable value creation and institutionalization strategies of bicycle sharing programs in Barcelona. The study highlights the role of collaborative governance and stakeholder engagement in the success of such initiatives. **Guo et al. (2021)** investigate the role of dockless bike-sharing as a feeder mode of metro commute. The study explores the built environment factors that influence the integration of dockless bike-sharing with metro systems, highlighting the potential for enhancing last-mile connectivity. **Komninos (2002)** discusses intelligent cities, focusing on the role of innovation, knowledge systems, and digital spaces in shaping urban development and transportation systems. The study provides insights into the concept of intelligent cities and their implications for transportation. **Fontes et al. (2022)** propose a cluster-based approach using smartphone data for identifying bike-sharing docking stations in Lisbon. The study highlights the potential of data-driven approaches in optimizing bike-sharing systems and improving their accessibility and usability. These references provide a diverse range of perspectives on transportation asset management in smart cities. They address various aspects, including the role of technology, sustainability, citizen engagement, infrastructure, and policy considerations. The literature reviewed emphasizes the importance of effective asset management practices in promoting efficient, sustainable, and inclusive transportation systems in smart cities. The findings from these studies contribute to the understanding of the challenges, opportunities, and potential solutions in the field of transportation asset management in the context of smart cities.

IMPORTANCE OF EFFICIENT TRANSPORTATION SYSTEMS IN SMART CITIES

Efficient transportation systems are vital components of smart cities due to their significant impact on various aspects of urban life. Well-managed transportation systems contribute to economic growth, environmental sustainability, and social well-being. Here are some key reasons highlighting the importance of efficient transportation systems in smart cities:

(i) Economic Growth- Efficient transportation systems facilitate the movement of goods and people, supporting economic activities and commerce. They enable businesses to operate smoothly, ensure timely delivery of goods, and enhance trade and productivity.

(ii) Sustainability- Sustainable transportation systems promote the use of eco-friendly modes of transport, such as public transit, walking, and cycling. By reducing reliance on private vehicles and minimizing carbon emissions, these systems contribute to environmental preservation and the mitigation of climate change.

(iii) Livability- Accessible and well-connected transportation networks enhance the quality of life for residents. Efficient public transit systems, convenient mobility options, reduced congestion, and improved traffic management contribute to shorter travel times, reduced stress, and enhanced overall livability in smart cities.

(iv) Transportation Efficiency- Inadequate asset management practices contribute to increased congestion, longer travel times, and reduced transportation efficiency. These issues hamper the seamless movement of people and goods within smart cities, impacting productivity and economic growth.

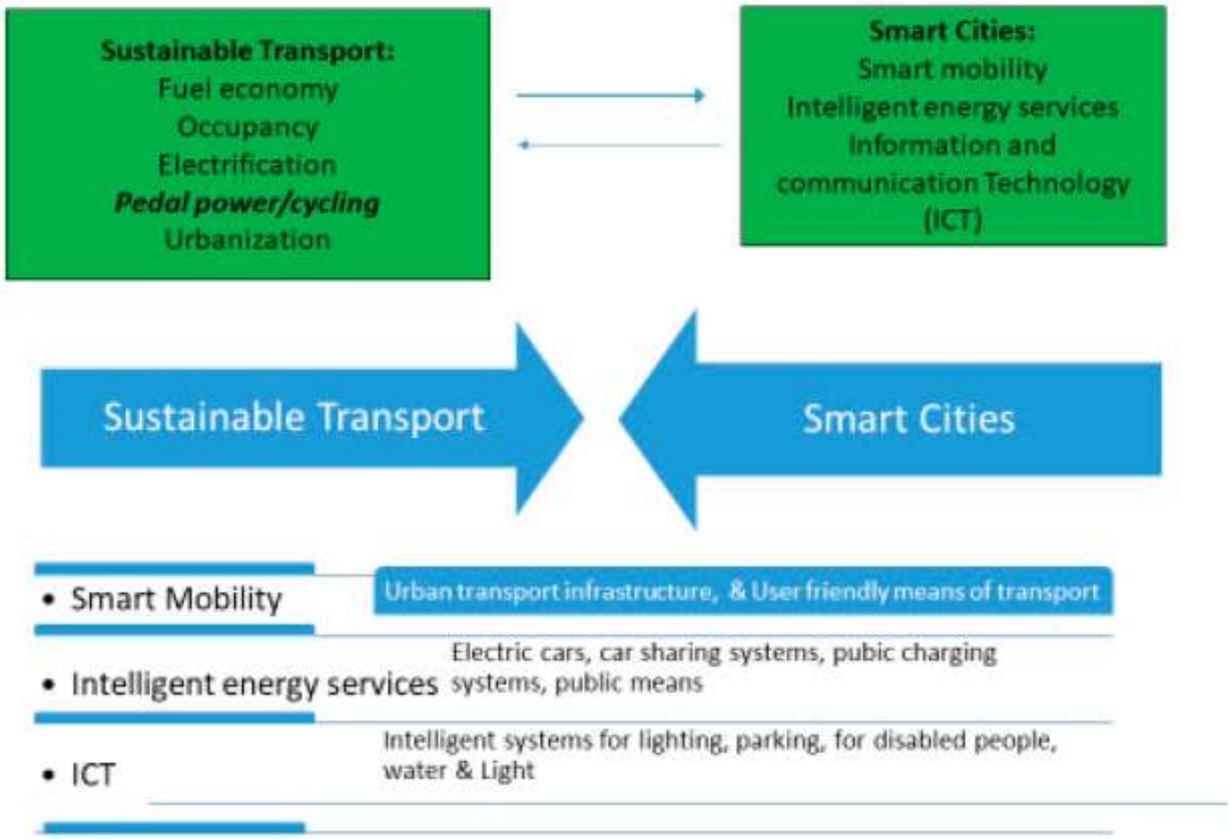

Figure 1- Analysis of Sustainable Transport for Smart Cities

(v) Public Safety- Inadequate maintenance and monitoring of transportation assets can compromise public safety. Aging infrastructure and lack of timely repairs pose risks to commuters, pedestrians, and cyclists, potentially leading to accidents and injuries.

(vi) Quality of Life for Residents- Transportation plays a crucial role in residents' daily lives, affecting their access to essential services, employment opportunities, and social activities. Poorly managed transportation assets can result in longer commutes, increased stress levels, and reduced overall quality of life for residents.

Addressing these problems and challenges in transportation asset management is crucial for the overall functioning and development of smart cities. By implementing effective strategies, leveraging emerging technologies, and adopting proactive maintenance approaches, smart cities can enhance transportation efficiency, promote sustainability, drive economic growth, ensure public safety, and improve residents' quality of life. By the end of this chapter, readers will have a comprehensive understanding of the key issues and challenges in transportation asset management within smart cities.

They will also recognize the gaps and limitations in current practices and understand the implications of these problems on the overall functioning and development of smart cities.

METHODOLOGY

This methodology employed in the analytical research on transportation asset management of smart cities. It outlines the systematic description of the urban transportation system within the context of smart cities and introduces the hierarchical approach to total transportation management. Additionally, it discusses the general optimization method used to analyze and optimize transportation assets in smart cities.

(i) Systematic Description of the Urban Transportation System in Smart Cities- In the context of smart cities, the urban transportation system plays a crucial role in ensuring safe, efficient, and sustainable mobility for both people and goods. It is a sub-system of the overall transportation system, with fast interconnections to global transportation networks such as highways, railways, and airports. The transportation means in smart cities encompass various modes, including road, rail, water, and air transport.

These means comprise a wide range of vehicles and solutions, such as trams, underground railways, high-speed rail, cars, bicycles, scooters, and even emerging forms of transport like urban air transportation with drones and air taxis. Achieving a well-integrated and coordinated urban transportation system is essential for effective transportation asset management in smart cities.

(ii) Hierarchical Approach to Total Transportation Management in Smart Cities- To analyze and manage transportation assets in smart cities, a hierarchical approach is adopted. This approach recognizes the diversity of vehicles and transportation forms used in the transportation system. Vehicles are classified based on their participation and cooperation with the operation center, as well as their role in the transportation system. The hierarchical classification includes various segments of the transportation system, such as leisure transportation, private transportation, public transportation or mass transportation, business travel, freight transportation, product distribution, and special transportation. Each segment serves a specific purpose and has distinct characteristics and requirements. Furthermore, within each segment, vehicles can be categorized into different classes based on their level of cooperation. These classes include non-detected vehicles, vehicles appearing on surveillance screens (with unknown cooperation status), semi-active or simple cooperating vehicles, active or cooperating vehicles, connecting vehicles that actively exchange data, contract-based vehicles with specific preferences, and supporting partners like weather forecast systems and emergency management organizations. This hierarchical approach enables a more comprehensive understanding of the transportation system in smart cities and facilitates effective management of transportation assets.

(iii) General Optimization Method for Transportation Asset Management in Smart Cities- The analytical research on transportation asset management in smart cities employs a general optimization method to analyze and optimize the transportation system. The optimization problem is formulated as a nonlinear optimization problem with objective functions and constraints. To find optimal solutions that enhance the performance, efficiency, and sustainability of transportation assets in smart cities. This involves minimizing or maximizing specific objective functions, such as minimizing travel time or maximizing resource utilization, while satisfying various constraints related to safety, environmental impact, and operational requirements. While the focus of the research is on transportation asset management in smart cities, the hierarchical classification of the transportation system allows for tailored objective functions and constraints that address the unique characteristics and challenges of smart cities. By applying this methodology, the research aims to provide valuable insights into the analysis and optimization of transportation assets in smart cities, contributing to more efficient and sustainable urban transportation systems.

Figure 2- Flowchart

CONCLUSION

The research aimed to analyze and optimize transportation asset management in smart cities. Through the systematic description of the urban transportation system, it was established that the transportation system in smart cities is a crucial sub-system that ensures safe, efficient, and sustainable mobility of people and goods. The integration of various transportation means, including road, rail, water, and air transport, is essential for the overall transportation management in smart cities. By adopting a hierarchical approach to total transportation management, the research classified transportation vehicles based on their cooperation and participation in the transportation system. This hierarchical classification provided insights into the different segments of the transportation system, such as leisure transportation, private transportation, public transportation, business travel, freight transportation, product distribution, and special transportation. It also identified different levels of cooperation among vehicles, from non-detected to supporting partners. The research utilized a general optimization method to analyze and optimize transportation assets in smart cities. By formulating the optimization problem as a nonlinear optimization problem with specific objective functions and constraints, the research aimed to enhance the performance, efficiency, and sustainability of transportation assets.

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