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Exploring Transportation Systems with a Focus on Smart Mobility

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A B S T R A C T

Objective: The rapid growth of urbanization and the automotive industry in recent years has significantly increased the demand for transportation in both work and daily life. This rise in transportation demand has led to growing issues such as urban traffic congestion, energy consumption, and environmental pollution. Consequently, the immense social, economic, and environmental pressures have intensified the challenges faced in urban transportation development.
Methods: This study examines the various problems related to urban transportation, including environmental pollution, reduced energy resources, increased material and human losses due to accidents, challenges in managing and supervising urban transportation, and the rising demand during peak hours, particularly in densely populated cities worldwide. The research explores the role of smart cities in addressing these challenges by improving transportation flow and ensuring safe and efficient mobility.
Results: Urban transportation systems, particularly in peak hours, have become a significant concern for global cities, with rapid growth in demand for efficient transportation services. In response, the development of smart cities provides a framework for overcoming these challenges by facilitating smooth transportation for both people and goods, reducing congestion, and offering real-time data and up-to-date information to transportation users.
Conclusion: Transportation, as a critical link in every aspect of life, is recognized as an essential infrastructure for industrial development and improving social welfare. The concept of smart cities is central to solving urban transportation challenges, offering solutions such as managing traffic congestion, providing real-time information, and promoting environmentally friendly methods of transportation.

1. Introduction

Today, transportation issues such as environmental pollution, depletion of energy resources, increasing financial and non-financial damages caused by accidents, challenges in monitoring and managing intercity transportation, increased wasted time, and the rapid growth in transportation demand—especially during peak hours in major cities worldwide—have become serious problems. Urban transportation poses a growing challenge for travelers and city officials. Intelligent Transportation Systems (ITS), leveraging new technologies, offer effective management and responsive solutions to traffic conditions.

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ITS can significantly transform how passengers commute in densely populated urban areas, providing better and safer services to city residents while reducing costs for municipalities. By implementing smart transportation, municipalities gain new opportunities to promote green and efficient transportation methods, reduce congestion, and improve the quality of life. (Karon & Zochowska, 2018)

Mirbaha and Asadollahi (2011): In their study, they explored the functional processes of intelligent transportation systems in managing intercity traffic. They proposed various services and sub-services for traffic management in intercity regions, emphasizing the critical role of traffic management centers in advancing ITS goals.

Aghasi (2011): This research highlighted the applications of ITS in urban transportation planning. The study concluded that managing large fleets in metropolitan areas is highly complex using traditional methods, which often have significant shortcomings. ITS can effectively address traffic challenges and improve traditional fleet management deficiencies.

Sadigh Bavar and Hadigheh Jovani (2011): They investigated the ITS equipment needed for traffic management in Shiraz. Based on comprehensive studies, they proposed specific equipment tailored to the city's financial and climatic conditions to enhance traffic management.

Anvari et al. (2011): This paper analyzed the role of vehicular communication technologies in ITS, focusing on their potential impact and applications.

Jabbari et al. (2011): This research evaluated the adaptability of urban transportation systems with ITS to improve urban safety. The findings highlighted the high potential of public transportation systems to transition toward ITS, offering significant improvements in safety and security.

Zaghi and Ghati (2012): Their study assessed the feasibility of designing ITS architecture using cloud computing infrastructure in Iran. The proposed architecture and its implementation were analyzed based on the country's specific conditions.

Titi Dezh et al. (2014): They prioritized ITS solutions for improving road freight transportation in Amirabad Port. Using multi-criteria decision-making methods (AHP), they identified "weigh-in-motion systems" as the top priority, followed by smart entry scheduling, cargo monitoring, automatic identification systems, and route planning.

Qureshi and Abdullah (2013): Their study on ITS aimed to integrate and synthesize various applications and technologies, exploring their broad applications and functionality across different regions.

Syrina et al. (2016): This research examined the impact of information uncertainty in road transportation systems. Using agent-based microscopic traffic simulation, the study analyzed how different levels of data accuracy affected system performance.

Agourio et al. (2017): They developed a methodology for integrating smart elements into transportation systems, enabling multivariate simulations for system development.

Kurjagin and Kalchik (2017): Their work proposed innovative ITS solutions based on biological vehicle control systems, designing unique architectures for autonomous vehicle systems.

Olga Korovalpova (2017): This study introduced a risk assessment algorithm for ITS projects, emphasizing the importance of identifying and mitigating potential risks during system design and implementation.

2. Material and Methods

2.1. Research Methodology

The present study employs a descriptive research method with an applied objective, aiming to review theoretical literature and practical experiences related to intelligent transportation. This has been achieved through a documentary-library research approach, focusing on gathering and analyzing relevant information and studies.

3. Results

3.1. Theoretical Foundations

3.1.1. Smart City

A smart city is an urban area that utilizes numerous electronic internet-based sensors to collect data, which is then used to efficiently manage assets, resources, and services (Gohar & Rahman, 2018). It integrates data from residents, sensors, and managed assets to monitor and oversee systems such as traffic and transportation, power plants, infrastructure, waste management, crime detection, information systems, schools, libraries, hospitals, and more (Silva et al., 2018).

The efficiency of urban operations and services in a smart city relies on Information and Communication Technology (ICT) and various physical devices connected via the Internet of Things (IoT) network (Rizk-Allah et al., 2018). City leaders can directly interact with the community and urban infrastructure, tracking urban dynamics using smart urban technology. ICT improves the quality, performance, and interaction of urban services while reducing costs, resource consumption, and enhancing connectivity among people (Esmaeilian et al., 2018; Sathishkumar et al., 2020).

3.1.1.1. Advantages of Smart Cities

Some of the key benefits of smart urban transportation include:

- Quality of Life: Enhanced efficiency and accessibility of public transportation improve the quality of life, reduce citizens' costs, and make cities more attractive to tourists.
- Pollution Reduction: Intelligent transportation systems promote the use of public transport by offering real-time information on schedules and delays, encouraging eco-friendly habits like carpooling and bike-sharing.
- Safety and Security: Improved monitoring of public transportation aids in identifying emergencies, disasters, or terrorist attacks. At advanced stages, these systems can significantly reduce city-wide traffic accidents.
- Mobility Marketplace: Open transportation data creates opportunities for mobile applications that assist travelers in utilizing citywide transportation services (Dunn et al., 2013).
- Challenges of Smart Cities
- Despite their benefits, smart city implementations face some challenges, particularly concerning energy consumption and responsible data management:
- Energy Consumption: Smart cities require vast numbers of sensors, which depend on power. For mobile sensors, this necessitates batteries, while fixed sensors may use solar power but are often connected to the city’s power grid. The large scale of required sensors (estimated in trillions) creates challenges in powering devices and sourcing materials like copper, far exceeding current global production levels (Seuwou et al., 2020).

- Data Management: Smart cities rely heavily on data collection, including anonymous but critical information about citizens. For example, cars need to collect positional data, and urban sensors passively track signals from smartphones. To ensure the sustainable growth of smart cities, governments must establish responsible laws and policies for managing and protecting data privacy (Parvania et al., 2014).

3.2. Smart Transportation

Urban transportation systems are integral to most civic activities, influencing all aspects of quality of life in urban areas (Wang et al., 2019). A smart city primarily focuses on reducing congestion by utilizing rapidly evolving technologies and sensors (Meenaakshi Sundhari et al., 2020). These technologies optimize traffic data and oversee transportation systems under the concept of green mobility.

Smart city platforms generate and share massive streams of data between vehicles, traffic signs, and infrastructure. A connected transportation network enhances mobility and safety, fostering collaboration among vehicles, infrastructure, public transportation, and citizens (Jegadeesan et al., 2019).

Smart city systems can be implemented in specific communities to tackle challenges like improving commute experiences, increasing safety for riders and pedestrians, and providing alternative transportation options (Ruhlandt, 2018).

3.3. Main Components of the Intelligent Transportation System

- Traffic Data Collection:

This system uses devices such as GPS devices, road cameras, and vehicle identifiers to collect real-time data. These devices gather information about the location, speed of vehicles, and traffic conditions.

- Data Transmission:

The intelligent transportation system transmits the collected data from sensors to a management center, where it is analyzed and sent to applications for further processing.

- Traffic Data Analysis:

In this phase, the collected data is customized for further analysis and then sent to user interfaces for review and decision-making.

- Providing Information to Travelers:

Finally, the information is made available to citizens, which can be accessed via radio, web browsers, or text messages. This data informs citizens about traffic conditions and helps them plan optimal routes (Khodayar et al., 2013).

3.4. Perspectives and Experts

- The Theory of Smart Growth in Cities:

The theory of smart growth is an urban and regional planning and transportation theory that emphasizes preventing urban sprawl. To achieve this, it focuses on growth in city centers and promotes compact land-use allocation or a tendency toward public transport, walkable cities, and bike-friendly environments. This includes mixed-use development and a variety of housing options. Additionally, the theory takes into account long-term regional sustainability considerations while focusing on short-term goals.

This theory aims to achieve a unique sense of community and place, increase options for transportation, employment, and housing, equitably distribute the costs and benefits of development, preserve and enhance natural and cultural resources, and improve public health. It is difficult to pinpoint the exact date of the introduction of the term "smart growth" or the specific location where it originated, but it can be said that the foundations of this theory were laid in Canada and the United States in response to developments starting in the early 1960s. Over the course of the 1970s and 1980s, in response to urban sprawl, the smart growth theory gradually took shape based on sustainability principles. Eventually, it was formalized into a coherent theory (Abbaszadegan & Rostam Yazdi, 2008: 38).

Hopkins, from the U.S. Institute for Ecological Health, has stated the objectives of smart growth. Accordingly, the strategy of smart city growth is the dynamic and flexible management of urban growth, with a coordinated focus on both efficiency and environmental quality of urban spaces through the use of various tools. The American Planning Association defines the goals of smart growth as creating a sense of local community and place, protecting and enhancing valuable natural and cultural resources, equitably distributing benefits and costs, expanding options for transportation, employment, and housing, safeguarding regional sustainable development, and promoting public health and healthy communities.

- The U.S. Environmental Protection Agency also outlines the goals of smart growth as follows:

Smart growth balances development and the environment. It involves the reuse of land, the preservation of open spaces and sensitive areas, and the protection of water resources and air quality (Hopkin & Knap, 2001: 314). In line with these ideas, in the late 1990s in the United States, the smart growth movement emerged as a new planning approach and became increasingly popular in Canada and the U.S. This approach, in addition to local spatial planning, emphasizes compact mixed-use development, multiple access options, and pedestrian transport (Grant, 2007: 6). Among the main promoters of smart growth are the U.S. Environmental Protection Agency and the American Planning Association. The American Planning Association defines smart growth as a combination of planning experiences, regulations, and development practices that make optimal use of land through dense building forms, development between spaces, and moderation in parking and street standards. Their goals include reducing excessive development, land recycling, environmental protection, and ultimately creating desirable neighborhoods (Haddadan Yazdi, 2006: 42). According to Bullard, this movement seeks to manage growth by creating healthy, livable, and sustainable communities (Bullard, 2007: 3). Flint argues that new urbanism, smart growth, and sustainable development all act to manage growth (Flint, 2006: 132).

In this approach, contrary to modern, functionalist urban planning based on the Athens Charter, which divided the city into four distinct zones—residential, recreational, transportation, and communication (Mahdizadeh, 2000: 73)—the emphasis is on mixed land use, pedestrian access, and environmental protection (Saeidnia et al., 2016: 29). The American Planning Association believes that "mixed-use development," by meeting the needs of the community's residents, plays an essential role in revitalizing urban areas. This type of development includes advantages such as liveliness, sustainability, social engagement, accessibility, safety, increased social thinking, and enhanced efficiency of infrastructure (American Planning Association, 2008: 163). On the other hand, sustainable access is facilitated by integrating land-use planning, ensuring "proximity," rather than merely facilitating car use (Sarafi, 2001: 23).

3.5. Urban Transportation Theories in Different Years

- Urban Transportation Theories until the 1910s

From the beginning of urbanization in the world until the mid-19th century, which coincided with the invention of the automobile and the introduction of motorized vehicles, pedestrian movement was the dominant mode of transportation within cities, and human-scale designs shaped the dimensions of streets. This era can generally be referred to as the "calm period in urban transportation," which lacked significant or sudden changes in the structure of urban mobility systems. The main modes of transportation during this time relied on human and animal power, with the invention of the wheel being perhaps the most notable milestone in the evolution of such tools.

The first traffic restrictions on the movement of freight vehicles (wagons) were implemented in Roman cities. However, in the late 19th century, with the introduction of urban rail transport, train stations and railways became important traffic hubs and gateways into cities, leading to dramatic changes in the structure of urban areas. Furthermore, the mass production of automobiles, which especially accelerated with the beginning of the 20th century, transformed the private car — previously a luxury item — into a public means of transportation and an essential part of family life. This shift led to an increase in the distance between workplaces and residences, contributing to the expansion of suburban living.

During this period, which saw a sudden rise in the urban population and revealed numerous social, environmental, cultural, and structural issues due to the lack of necessary infrastructure, various scholars evaluated and critiqued the urban problems from different perspectives, offering different solutions. In this context, the linear city theory, garden city, and grade-separated intersections are considered the most important and influential ideas related to urban transportation.

The linear city theory, proposed at the end of the 19th century by Arturo Soria y Mata, a politician interested in urban issues, may be one of the first ideas that emphasized city development centered around public transportation routes. Soria y Mata envisioned the linear city as long and narrow strips of buildings on either side of a main transportation route, which would use rail lines to transport passengers during the day and cargo at night. He believed that all urban problems were caused by transportation issues.

In the garden city concept, introduced by Ebenezer Howard, the transportation system and the placement of the city's physical and social center were based on a network of public rail transportation. In Letchworth, the first garden city built in 1904, and in Welwyn, the second garden city built in 1920 and the first satellite town of London, the railway network divided the city into four sections (Ostrovsky, 1992).

Eugene Enard was another early scholar who, at the beginning of the 20th century, when motorized transport in cities was on the rise and the underground railway was under construction, paid attention to transportation issues and proposed solutions, particularly for his hometown, Paris. His main suggestions included the separation of different types of traffic, the creation of grade-separated intersections, and the roundabout design, all of which were introduced by him for the first time.

3.6. Urban Transportation Theories from 1920 to 1970

From the first half of the 20th century until the early 1960s, the focus and emphasis were on facilitating the movement of motor vehicles in every possible way. This became an inseparable part of any urban transportation and traffic planning. During this period, separating pedestrian and vehicular paths to maximize the efficiency of new transportation systems was emphasized, with pedestrians and their needs not being prioritized. The "Radiant City" theory by Le Corbusier and the spatial structure of large cities, such as those by Tange, can be examined from this perspective. As some theorists believe, during the 1960s, Le Corbusier's recommendations were implemented, and streets became "machines for producing traffic" (Pakzad, 2007: 32). In his "Radiant City" proposal from 1930, Le Corbusier emphasized the needs of modern transportation and suggested dividing traffic into three levels: metro, pedestrian-exclusive areas, and automobile paths. However, according to Jacobs, like the garden city planners, he removed pedestrians from streets and exiled them to parks (Jacobs, 1993: 24).

According to Tange, urban spaces, as a setting for communication, should be increasingly coordinated with the expansion of transportation systems. He stated that "the main principle of urban design today is thinking of a spatial organization as a network of connections, as a living organism with growth and change" (Tange, 1970: 128).

In the United States, the first signs of attention to public transportation as a center for development can be seen during this period. Private investors developed residential areas around suburban tram lines to maximize economic returns, leading to the theory of transit-oriented development. Urban historian Sam Bass Warner, in his book on suburban trams, described how public transportation and suburban land development interacted to decentralize urban areas. He referred to the American city as "a city of two parts; a work city separate from a residential city" (Dittmar et al., 2004: 5).

From the late 1960s, especially with the visible problems in cities caused by excessive personal car traffic, serious movements emerged to focus on pedestrians, protect them, and increase the quality and usage of public transportation. One of the key theories during this period was Colin Buchanan's "Environmental Zones," which had a traffic-oriented approach. In general, from the early 20th century until the end of the 1960s, the dominant approach in cities was car-centric transportation. Public transport was not given much attention, and the few systems that existed (such as buses) were subordinated to cars.

However, from the early 1970s, there was a fundamental shift in the perspectives of scholars regarding urban transportation. In a reversal of the past, prioritizing personal vehicles became a negative value, and public transportation and non-motorized modes of mobility were emphasized. One of the main theories proposed during this time was "Intelligent Urbanism," which, in line with transformations in various urban issues, also focused particularly on public transportation (urbanism principles of intelligent planning, Wikipedia).

"Intelligent Urbanism principles are a set of ten general rules aimed at guiding the formation of urban plans and projects. They seek to harmonize and integrate urban planning and management concerns. These principles include environmental sustainability, heritage protection, appropriate technology, infrastructure efficiency, spatial construction, social permeability, transportation-oriented development, regional connectivity, human scale, and organizational cohesion."

Overall, intelligent urbanism supports pedestrian-centric design based on human dimensions, integrated transportation systems, a balance between appropriate modes of movement, key intersections, and public transportation. However, it is not an anti-car approach (Saeedinia et al., 2016: 34).

3.7. Urban Transportation Theories from 1980 to the Present

Starting in the 1980s, the previous car-centric transportation approach faced significant challenges. The need to adjust the movement of motor vehicles in cities, particularly in residential areas, emerged as a central principle. Consequently, theories emphasizing the integration of vehicular and pedestrian movement gained traction during this period. Some of the most important urban transportation theories since 1980 are as follows:

One of the key theories introduced in this period is the Woonerf model, or traffic calming. Although conceptually developed in the late 1960s, it gained widespread public and practical application in the early 1980s. Woonerfs are essentially residential streets designed to reduce vehicle speed and prioritize pedestrian and daily life movement. This concept gained significant traction, especially in Germany and the Netherlands. A Woonerf in Germany or the Netherlands refers to a street or group of streets in a neighborhood where pedestrians and cyclists have legal priority over motor vehicles. By 1999, the Netherlands had implemented more than 6,000 Woonerf projects.

- Studies on Woonerfs highlight five common features:

Clear gateway design: Streets are marked to reinforce neighborhood identity, signaling to drivers that they are guests in the area.

- Curved pathways: Streets include intentional curves to break drivers' line of sight and reduce speed.
- Urban furniture and elements: Benches, play equipment, fences, and vegetation are used to slow traffic while providing amenities for residents, creating a pedestrian-friendly environment.
- Traffic speed deterrence: Continuous curbs are removed, and drivers are guided by street furniture, trees, and varied paving to prevent speeding.
- Parking: Necessary parking is provided but in a manner that avoids making the street feel like a parking lot.

However, Woonerfs also have some drawbacks. The high costs of redesigning streets, maintaining street furniture, social equity concerns, and the fact that traffic may simply shift to nearby streets are notable issues associated with the Woonerf model.

In the late 1980s, investment in public transportation networks expanded significantly, and transportation hubs became key focal points for urban development. The Transit-Oriented Development (TOD) theory, which also includes terms like Transit-Adjacent Development and Public Transport-Related Development, was introduced around this time. TOD is a planning concept that describes the development of dense, mixed-use areas near public transit hubs (such as bus, metro, or train stations). In the late 1990s and early 2000s, with an increasing focus on social approaches and urban design near transport terminals, Public Transport-Oriented Development (PTOD) became recognized as the most comprehensive approach. This approach emphasizes mixed land uses, high-quality neighborhood design, reduced private car use, and the expansion of non-motorized transport modes, especially walking and cycling.

The core distinguishing factors of PTOD include "three D’s": Density, Diversity, and Design, which set it apart from standard Transit-Oriented Development.

Additionally, the 1990s coincided with the global rise of Sustainable Development principles, and thus the term Sustainable Transportation entered urban studies discourse. Sustainable transportation is defined as transportation systems that meet current human mobility needs without compromising future generations' ability to meet their own mobility needs. As such, public transportation, non-motorized modes such as walking and cycling, and other green transport types fall under this umbrella.

Smart Growth is another important theory that emerged in the late 20th century, rooted in sustainable development principles. It specifically addresses urban sprawl and suburbanization by focusing on city centers, public transportation-based development, and compact, mixed-use, walkable land use. Smart Growth emphasizes sustainable regional development within a short time frame. Its goals include:

- Achieving a unique sense of community and place.
- Expanding transportation options, employment, and housing choices.
- Equitably distributing development costs and benefits.
- Protecting and enhancing natural and cultural resources.
- Promoting public health.

Moreover, the more elements such as compact neighborhoods, transit-oriented development, and pedestrian- and bike-friendly design are included in urban planning, the smarter and more sustainable the growth is considered.

Finally, in the lead-up to the 21st century, there has been increasing emphasis on integrating urban design and public transportation systems, particularly rail systems, to establish denser, mixed-use, walkable communities around transit hubs. One of the key theories in this regard is the Transportation Villages concept, which focuses on creating vibrant and sustainable communities centered around public transport stations. Michael Bernick and Robert Cervero proposed the following four principles for designing Transportation Villages:

- The village should be within 500 meters (5 minutes walk) of a public transport station.
- The public transport station and its surrounding public and urban spaces should serve as the central focal point of the village.
- The station should facilitate connections between residents, workers, and other areas, providing easy access to downtown, key activity centers, and other popular destinations.
- The surrounding public spaces should act as major social gathering points and places for special events and community activities.

3.8. Applications of Intelligent Transportation Systems (ITS)

The operation of Intelligent Transportation Systems (ITS) is based on the collection of data, analysis, and the use of the results in traffic management, operations, and research concepts, where location plays a critical role. One of the key components of ITS is the Traffic Management Center (TMC), which is a vital unit responsible for collecting and analyzing real-time data for better control and management of traffic and public transportation. The TMC operates primarily as a technical system managed by transportation organizations. It automates data collection, processes it to generate accurate traffic information, and then communicates this data to travelers. The entire process can be examined in more detail as follows:

1. Data Collection

Strategic planning requires precise, widespread, and quick information gathering through real-time observation. Data in ITS is collected through various hardware devices that form the foundation of ITS functions. These devices include automatic vehicle identification systems, GPS-based automatic vehicle location systems, sensors, cameras, and more. These devices feed data to servers that are generally located in central data collection units, storing large volumes of data for further analysis.

2. Data Transmission

The fast, real-time transfer of information is critical for the successful operation of ITS. This aspect involves transferring the collected data from the environment to the TMC and then sending the analyzed information from the TMC to travelers. Traffic updates are shared with passengers via the internet, text messages, or in-vehicle units. Other communication methods include Dedicated Short Range Communications (DSRC) using radio waves, Continuous Air Interface with Long and Medium Range (CAILM) using mobile phone connections, and infrared links.

3. Data Analysis

Once data is collected and received at the TMC, it undergoes several processing stages. These stages involve error correction, data cleaning, data synthesis, and logical analysis. Specialized software is used to identify and correct inconsistencies in the data. Afterward, the data is further analyzed and integrated to forecast traffic scenarios. This processed data is then used to generate appropriate information for the users.

4. Travel Information

Travel Advisory Systems (TAS) are used to keep passengers informed of transportation updates. These systems provide real-time data such as travel times, travel speeds, delays, accidents, detours, roadworks, and other traffic conditions. This information is disseminated through various electronic devices such as Variable Message Signs (VMS), highway advisory radio, internet platforms, text messages, etc.

Given the rapid urbanization and the increasing number of vehicles on the road, the use of ITS is becoming a necessity for managing traffic efficiently. Some of the key systems and devices involved include:

- Advanced Traffic Management Systems (ATMS)
- Advanced Traveler Information Systems (ATIS)
- Advanced Vehicle Control Systems (AVCS)
- Advanced Public Transport Systems
- Advanced Rural Transportation Systems
- Advanced Commercial Vehicle Operations (CVO) Systems (Zhou et al., 2011)

3.8.1. Benefits of Intelligent Transportation Systems (ITS)

ITS offers numerous benefits for cities and communities, including:

- Improved Quality of Life: Efficient and accessible public transportation systems reduce costs and improve citizens' quality of life by making commuting easier and more affordable.
- Reduction in Pollution: ITS supports environmental policies by promoting public transportation use, which leads to a reduction in private car usage and a decrease in emissions.
- Improved Transportation Safety: Monitoring and tracking public transportation networks can facilitate rapid responses to accidents or emergencies, improving overall safety.
- Smart Parking Solutions: Through sensors, security cameras, and internet connectivity, cities can alleviate parking congestion by sharing data on available parking spaces through mobile apps.

In conclusion, the implementation of ITS improves the overall functionality, safety, and environmental impact of urban transport systems, making them smarter and more sustainable (Yigitcanlar et al., 2019).

3.9. Examples of Urban Transportation Technology

Regardless of the advantages and disadvantages of smart cities, this technology is already in use and continues to grow. Throughout the United States and across the globe, smart sensors and controllers are actively deployed in rail networks, passenger information systems, and public transport. Below are some examples of smart urban transportation systems:

3.9.1. Miami Dade Intelligent Traffic Management

- Miami-Dade County is the most populous county in Florida, with over 2.5 million people. Traffic flow management in the urban areas, including the city of Miami and its surrounding areas, involves the operation of over 2,700 signalized intersections. The county manages these intersections and continuously increases the number of marked and mid-block intersections each year.
- The Advanced Traffic Management System (Dade ATMS) in Miami-Dade utilizes Digi 4G LTE mobile routers as part of the communication infrastructure in the traffic cabinets. This system is designed to reduce congestion, minimize delays, and enhance mobility across the county (Silva et al., 2018)

3.9.2. Southern Pennsylvania Transportation Authority (SEPTA) Positive Train Control (PTC)

- SEPTA (Southern Pennsylvania Transportation Authority) implements Positive Train Control (PTC) technology, which is an advanced system that helps to prevent train accidents by automatically controlling train speed and movements based on various conditions. This system is a critical safety feature for the transit network in the southeastern Pennsylvania area, helping to avoid collisions and improve the safety and efficiency of the railway system.

3.9.3. Suburban Mobility Authority for Regional Transportation (SMART)

- The SMART system operates in the suburban areas of Detroit, Michigan, and provides rapid transit services. It integrates modern technology to optimize public transportation routes, manage vehicle fleets in real-time, and improve passenger experiences by providing timely updates and alerts. This helps commuters access faster and more reliable transit services.

3.9.4. Advanced Traffic Management System (ATMS) – Miami-Dade

- As part of its efforts to reduce congestion and delays, Miami-Dade County employs an Advanced Traffic Management System (ATMS), which is designed to improve the overall mobility of the region. The system includes real-time monitoring and control of traffic signals and the ability to dynamically adjust them to manage traffic flow efficiently, thus reducing traffic jams and improving travel times.

These examples highlight how technology is transforming urban transportation, improving traffic management, safety, and overall mobility. Smart transportation systems like these are increasingly being adopted around the world to address the challenges of urbanization and growing transportation demands.

Global Experiences in Intelligent Transportation

- Seoul, South Korea

The government of Seoul, in collaboration with private telecommunications companies, has successfully designed bus routes based on the analysis of mobile phone location data. This approach allows the city to optimize bus services during late-night hours (from midnight to 5 AM) by considering the demand for various routes. The system analyzes which routes have the highest demand and adjusts the bus services accordingly. This data-driven solution helps to efficiently provide transportation services when they are most needed, ensuring better coverage and availability (Shin & Lee, 2020).

- Glasgow, Scotland

Glasgow has implemented an intelligent transportation system that allows passengers to access comprehensive real-time information about bus schedules. Passengers can track the current location of buses, seat availability, estimated arrival times, the next bus stop, and the number of passengers already on the bus. This level of information enhances the overall passenger experience, making the use of public transport more convenient and efficient for commuters (Shin & Lee, 2020).

- New Orleans, USA

In New Orleans, emergency response services have been optimized by strategically positioning ambulances in areas with high call frequencies. This system follows an emergency call pattern model, enabling faster and more efficient deployment of ambulances to areas where they are most likely to be needed. This intelligent approach improves the city's emergency response times, ensuring that medical assistance can be provided quickly during critical situations (Shin & Lee, 2020).

These global examples demonstrate how intelligent transportation technologies are being utilized to improve service efficiency, optimize resource allocation, and enhance the overall commuter experience. Each city has tailored its systems to address specific local needs, showcasing the adaptability and potential of smart transportation solutions worldwide.

4. Discussion

The transition to intelligent transportation systems (ITS) is an essential and complex process for cities around the world. The implementation of such systems requires overcoming numerous challenges, including technical, cultural, and operational barriers. Most notably, it demands a significant shift in the mindset, attitudes, and behaviors of individuals and organizations. In an increasingly interconnected and rapidly evolving world, adhering to traditional transportation frameworks will lead to obsolescence and inefficiency. Therefore, embracing innovation is crucial for both individuals and organizations to thrive in modern societies.

As cities continue to integrate smart transportation systems, they are reaping a variety of significant benefits. These include enhanced safety, modernized transport infrastructure, and more efficient traffic management. The use of data analytics, sensors, and real-time information, as seen in global examples such as Seoul, Glasgow, and New Orleans, illustrates the potential for smarter, more responsive urban mobility solutions. Such systems allow for improved flow of traffic, reduced congestion, and more sustainable public transport options. Additionally, they facilitate a more seamless travel experience, where passengers can easily access critical information such as bus locations, arrival times, and available seating, leading to higher satisfaction levels and greater reliance on public transport.

One of the key advantages of ITS is its ability to optimize operational performance. By automating certain processes, such as traffic signal management or route planning for public transport, cities can improve efficiency, reduce delays, and enhance the overall management of urban mobility. This not only benefits daily commuters but also boosts the productivity of personnel and enhances organizational control, contributing to the smoother functioning of city transport networks.

The increasing reliance on intelligent transportation technologies also has far-reaching implications for urban planning and development. Smart transportation systems enable cities to grow in a more sustainable manner, ensuring that infrastructure can accommodate the needs of larger populations without compromising the environment. For instance, integrating electric vehicles, bicycle-sharing programs, and public transport systems into a smart grid can help reduce carbon emissions and minimize traffic congestion. As a result, cities with ITS become more resilient and better equipped to manage the challenges associated with rapid urbanization.

Moreover, the financial advantages of adopting ITS should not be underestimated. Over time, these systems help cities reduce maintenance costs, optimize resource allocation, and improve overall operational efficiency. These cost savings can be redirected into other vital areas, such as education, healthcare, and social services, further enhancing the quality of life for residents. The integration of ITS also attracts investment, boosting the local economy and positioning cities as leaders in innovation.

However, it is important to recognize that the implementation of ITS is not without its challenges. One of the major obstacles is the resistance to change from both individuals and organizations accustomed to traditional methods. Shifting to a smart system requires the adoption of new technologies, the development of new skill sets, and, in many cases, significant infrastructure upgrades. Furthermore, the costs involved in setting up such systems can be prohibitive for some cities, particularly in developing regions. Ensuring equitable access to the benefits of ITS for all citizens, regardless of socioeconomic status, remains a critical issue that needs to be addressed.

The widespread adoption of smart transportation systems offers a transformative opportunity for cities to become safer, more efficient, and more sustainable. As technology continues to evolve, it is clear that those who resist change risk falling behind, while those who embrace innovation will create more livable, efficient, and forward-thinking urban environments. As highlighted by Barton and Infield (2004) and Chen et al. (2009), the future of transportation lies in the hands of cities that are willing to invest in cutting-edge solutions and rethink traditional approaches to urban mobility.

Embracing ITS will not only enhance the quality of life for citizens but also contribute to the broader goals of sustainable development, economic growth, and social equity.

5. Conclusion

n conclusion, the adoption of Intelligent Transportation Systems (ITS) offers significant advantages for urban mobility, including enhanced safety, improved efficiency, and reduced environmental impact. The integration of advanced technologies such as real-time data analysis, GPS systems, and automated traffic management not only optimizes traffic flow but also contributes to more sustainable and responsive urban environments. As cities continue to embrace these innovations, they stand to benefit from greater operational efficiency, cost savings, and a higher quality of life for residents.

However, the successful implementation of ITS requires overcoming challenges such as resistance to change, high initial costs, and ensuring equitable access to these technologies. To facilitate the transition, it is recommended that cities invest in comprehensive planning, public awareness campaigns, and cross-sector collaboration. Furthermore, efforts should be made to provide training and support for both citizens and urban planners to effectively manage and maximize the potential of ITS.

Ultimately, as cities worldwide move towards smart transportation solutions, embracing ITS is key to creating sustainable, efficient, and resilient urban systems that meet the demands of a rapidly evolving world.

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