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A Smart City Traffic and Congestion Management System Using Machine Learning

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Abstract

A thriving transportation system is one of the most discussed issues at the onset of the twenty-first century, representing one of the many global challenges. Technology is essential in addressing contemporary transportation challenges as smart cities (SC) develop. Smart cities represent a modern evolution of civilization globally, utilizing advancing technologies, including machine learning, to manage urban initiatives and tackle urban difficulties. Traffic is a significant obstacle in urban development due to multiple factors, including inadequate planning. The creative strategies, demonstrated by integrating shopping and delivery services in SC, will mitigate traffic congestion issues. This research analysis identifies the concepts of Actor-Network Theory (ANT) and pragmatic theory as foundational research and integration improvement techniques. The study employed data-gathering methods such as interviews, states, and media coverage, which are crucial for comprehending the intricate connections of brilliant city efforts. The data analysis illustrates that the ANT and practical framework underpin the development of future urban environments.

Keywords: Smart City, Congestion, Traffic Management, Machine Learning.

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Introduction

Traffic management has become a primary concern for urban areas (Straubinger et al., 2020). The continual rise in vehicle numbers has resulted in the persistent traffic management issue. An escalation in infrastructure development is a potential remedy, although it is expensive in terms of time and labor. Countries worldwide are eager to develop effective systems for traffic management using Information and Communication Technology (ICT) (Nath & Liu, 2017). Recent improvements in Wireless Sensor Networks (WSN) and economical, low-power detectors have bolstered efforts to develop an intelligent traffic control system (Mazunga & Nechibvute, 2021). Authorities are attempting to leverage contemporary computing, networking, and communication technology to create solutions that enhance the efficiency of existing roads and traffic situations. The emergence of the Internet of Things (IoT) (Rahman & Asyhari, 2019) and the widespread availability of Cloud assets are facilitating the development of methods to automate transport networks and optimize the use of existing assets.

The urban environment and civilization have led to innovative city ideas globally. Numerous issues arise with global revolutions leading to urban expansion and technological advancements, notably highlighted by heightened traffic congestion accompanying modern advances. Congestion of traffic has been observed in multiple cities (Zhao & Hu, 2019). The rising rush hour traffic not only impairs urban mobility but also intensifies fossil fuel consumption's environmental impact. A comprehensive examination of Smart City (SC) efforts includes retail and delivery solutions enhanced by Machine Learning (ML) (Oladipo et al., 2021), hence essential in transforming urban mobility. Investigating the complex interactions between humans and other beings in urban environments reveals numerous opportunities for fostering productive and environmentally friendly urban development.

Related Works

Contemporary society is characterized by swift urbanization and the resultant urban difficulties. This results in heightened demand for people's mobility and transit services, necessitating significant expenditures in the transportation system. Road traffic is a fundamental component of urban infrastructure, facilitating economic expansion while significantly influencing environmental and social quality of life. It precipitates considerable environmental and social problems, including air quality, social inclusion, land utilization, noise pollution, climate change, traffic safety, and more. Energy use in transport is anticipated to rise substantially by 2030. The massive increase in demand for urban mobility is the principal cause of traffic congestion, which is rapidly becoming a prominent characteristic of nearly every metropolitan economic center (Ceder, 2021).

Emerging cities globally are encountering challenges such as heightened congestion in urban locales, rising road fatality rates, scarcity of parking spaces—particularly in areas lacking organized parking systems—insufficient public transportation, vehicular emissions, and inefficiencies in systems for traffic management. Numerous techniques exist in metropolitan environments for enhancing traffic operations, including infrastructural enhancements and public transportation upgrades. The research recognizes that a different amalgamation of these actions will be essential to satisfy the transportation requirements of all individuals without a significant rise in motorized traffic (Hawkins & Nurul Habib, 2019). Reducing the volume of automobiles on urban highways has become a goal in SC design. Numerous intelligent modes of transportation have arisen, ranging from park management platforms to sophisticated traffic control solutions. Traffic control agencies can employ ML-driven technologies to regulate traffic flow. This research examines the potential of various solutions and their capacity to assist.

Proposed Smart City Traffic and Congestion Management System

Actor-network theory (ANT) has highlighted the complex interrelations among human and non-human actors and the extensive use of technological technologies. ANT asserts that combining human and non-human elements is essential in determining the functional characteristics of socio-technical systems. ANT involves analyzing the various actors engaged in SC efforts, including urban planning, advanced ML computations, and developing drones for delivery. The comprehensive approach improves the analysis of the participants in the broader framework of alliance formation, interest negotiation, and aggregate impact on urban mobility, alleviating congestion in traffic (Fig. 1).

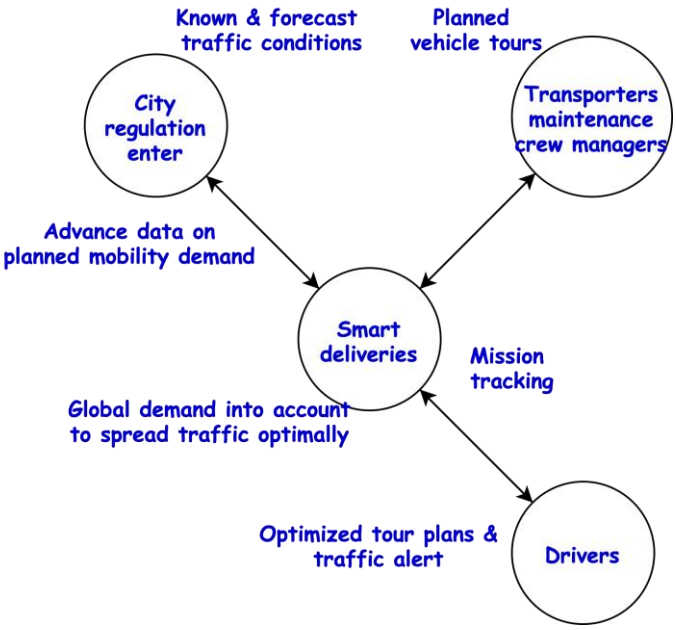


Fig. 1: Smart deliveries model

Rorty introduced pragmatism to enhance the ANT by emphasizing the role of action and circumstance in shaping development and executing urban activities. The framework analyzes the efficacy and relationship of the initiative as essential within the contextual circumstance and activity. The innovative city program pragmatically examines the development inside an urban context, defining the situational environment and its evolving aspirations. This approach is essential for reviewing the real-world applications and consequences of integrating the shop and delivery concept, emphasizing adaptive and context-sensitive strategies.

Intelligent machines inspire concepts for SC: ML can analyze vast amounts of data from several sources, facilitating the identification of discoveries that enhance the effectiveness and efficiency of municipal activities while reducing associated expenses. ML-powered SC solutions can learn from citizens' interactions with their areas. It is plausible to assert that the quality of ML algorithms will be enhanced daily. Al can investigate the behaviors of urban dwellers and improve urban governance and planning. It discloses previously unknown information, allowing the local government to proactively anticipate and address residents' needs.

Theoretical Guidelines: This study employed a strategy based on mixed methods, incorporating quantitative and qualitative methods. ANT and pragmatism constituted the theoretical framework's foundation. ANT offered comprehensive recognition and evaluation of actor networks in opposition to pragmatics, which drove the contextual evolution of SC efforts.

Data Acquisition: Contemporary applications and decisions predominantly rely on real-time data-driven methodologies. The research gathered data from several sources, including interviews, states, and media information. The semi-structured interviews included a questionnaire administered to various campaign participants, such as municipal planners, technological specialists, and inhabitants. The publications and media content regarding brilliant city efforts and urban mobility patterns offer an extensive analysis of the actor networks. The study enlisted 300 subjects, of whom only 250 consented to the interview, while some resigned midway, resulting in their removal from participation. The study employed 50 studies and 10 news pieces obtained from various media organizations with the approval of their management.

Data Processing and Evaluation: The study employed a thematic approach to coding the interview transcriptions, enabling the recognition of essential actor networks and their interactions. Data analysis facilitated extracting information regarding SC projects and city mobility from publications and media articles.

Results

The algorithm is executed within the suggested platform. It encompasses several preset classes that offer a simulation setting for the IoT, integrating the advantages of cloud-based computing. It is a Java-based simulator toolkit executed

with Eclipse and NetBeans Integrated Development Environment (IDE). The research will utilize the Eclipse IDE. To execute iFogSim on Eclipse, the researcher must first download and set up the Eclipse IDE. Upon a successful setup of the Eclipse IDE, get the newest pack, unzip it, and import it into Eclipse. Regarding the suggested work, the research has developed the classes and represented the approach in Java code.

The research has utilized Weka, a renowned open-source platform, to implement machine learning methods. The mean waiting time has diminished for each road across all time frames. The extent of dropping the mean wait differs by road; the overarching pattern across the whole collection is a decline in average wait times.



Fig. 2: Result analysis

The traffic estimate relies on the suggested method, and Fig. 2 demonstrates the accuracy of selecting features in conjunction with the chosen method. The graph compares actual and projected traffic figures based on car count. The graph suggests that the projected activity count differs from the actual count; over an extended period, the fluctuations in traffic levels remain consistent for both projected and exact numbers. The research has examined how the suggested intelligent traffic control system proves advantageous by decreasing the typical waiting time on a particular road and accurately predicting shifting traffic volumes. The subsequent graphs examine the incident warning system and compare the estimated and actual number of incidents on a specific highway across various periods. The predicted incidents consistently exceed the exact number of accidents, as seen by the numbers. This indicates that the algorithm successfully identified actual accidents while simultaneously misclassifying other events with attributes similar to disasters. This leads to a rise in the total amount of incidents relative to those that occurred.

Conclusion

Integrating the buy-and-deliver proposal will shape future attempts to adopt the creation of SC, propelled by the integration of ML technology. The integration will profoundly transform urban mobility, tackling the challenges of escalating urbanization, including traffic congestion. The study findings demonstrate the complex network of players that can be integrated into the organization of the specific intervention, along with the potential intervention locations. The study includes some restrictions that hinder data usage. The study included oral and quantitative techniques influenced by the specific participants involved, thereby introducing biases in the information provided.

The research analysis inadequately integrated the cultural and social components, particularly regarding their impact on the acceptance and success of urban planning programs. This element creates a need for future studies, particularly on the cultural aspects that affect the acceptability and execution of ML-driven solutions. The research concentrated on the shop's incorporation's diverse, readily attainable advantages. It presented a proposal involving ML for future

study to investigate the long-term viability of various programs, focusing on scaling, allocation of resources, and ecological effects.

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