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Evaluation of Traffic Congestion in an Urban Roads: A Review

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Abstract: *Urban traffic congestion significantly impacts economic productivity, environmental health, and residents' quality of life. This study provides a comprehensive evaluation of traffic congestion in urban areas, focusing on recent innovations in traffic management, urban planning, public transportation, and technological advancements. Intelligent Transportation Systems (ITS), incorporating real-time data and adaptive signal controls, have proven effective in reducing delays and improving traffic flow. The study underscores the importance of mixed-use urban planning in minimizing travel distances and traffic volumes. Expanding public transportation networks is highlighted as a critical strategy for alleviating congestion, with evidence indicating that cities with extensive transit systems experience lower congestion levels. Additionally, the environmental and health implications of traffic congestion are considered, linking high congestion levels to increased pollution and negative health outcomes. . Road construction as a policy intervention to reduce congestion is debated, with the understanding that road widening may sometimes increase traffic. Evaluating the technologies contributing to congestion is crucial for devising effective solutions. Urban transport is central to economic activity and the well-being of urban residents. The rising population and car ownership rates, coupled with unchanged natural land areas, exacerbate traffic issues, leading to accidents and increased carbon dioxide emissions. The article explores the complexities of urban road traffic, addressing transport infrastructure, organization, and the high share of car traffic. It discusses theoretical and practical aspects of traffic flow and design, as well as the role of driver behavior in traffic jams.*

Keywords: *Traffic congestion, urban road, road construction, traffic accidents, health impact.*

1. INTRODUCTION

An efficient and effective transportation system contributes to the economic development of the country and directly benefits the economy, people and their surrounding [1, 2]. However, larger vehicles and increased road activity can cause accidents. Transportation has been a main challenge in providing efficient transportation in most urban city around the world. Traffic congestion increases travel costs and reduces accessibility by increasing travel time. Exposure to road congestion has hazardous effects such as noise pollution, increased driving stress, decreased mental health, urban development and increased traffic [3].

Traffic congestion also has significant effects in the environment, including increased fuel consumption and air pollution. In urban cities around the world, whether built or unbuilt, traffic and its effects on human health and their environment are increasing, primarily threatening the quality of living in cities. Traffic congestion is refers to a major problem for sustainable urban development as it increases travel time, energy consumption, accidents and environmental pollution.

The main consequences of this are the gradual slowing down of congestion and the increase in time of travelling, pollution, fuel wastage, and other costs [4]. Reducing CO_2 emissions worldwide is difficult to managing future mobility with the aim of decarbonizing transportation. In 2016, transport was responsible for approximately 25%, 28% of CO_2 emissions in western industrialized countries, but future technological developments are significant and inclusive. Heavy goods vehicles (HGVs) are significant cause of road emissions, but emissions are difficult to reduce [5]. However, to reduce CO_2 emissions, many policies affect personal mobility, such as car-free days [6] and odd-numbered tests [7].

Traffic congestion in urban areas remains a significant challenge, affecting economic productivity, environmental quality, and the overall well-being of city residents. As urban populations grow and car ownership increases, the resulting congestion leads to delays, higher fuel consumption, and increased emissions of greenhouse gases and pollutants [8]. The complexity of urban traffic congestion requires multifaceted approaches and innovative solutions to manage and mitigate its adverse effects. Traffic congestion significantly affects urban economies by increasing travel times, fuel consumption, and vehicle operating costs, leading to reduced productivity. Assessing

traffic congestion helps identify and address these inefficiencies, enabling cities to implement strategies that reduce delays and enhance economic performance. For instance, a study by [9] highlighted how optimizing traffic flow can lower operational costs for businesses and improve overall economic efficiency in urban areas.

High traffic congestion contributes to elevated pollution levels and greenhouse gas emissions. Vehicles idling in traffic generate more emissions, worsening air quality and impacting public health. Evaluating congestion helps cities implement effective measures such as expanded public transit and congestion pricing to reduce environmental impact. [10] demonstrated how advanced traffic management technologies can mitigate emissions and promote cleaner urban environments. Urban traffic congestion negatively affects residents' quality of life by causing longer commutes and increased stress. Analyzing congestion patterns allows for the development of solutions that enhance urban livability, such as improved traffic flow and pedestrian-friendly infrastructure. [11] emphasized the role of mixed-use urban planning in reducing travel distances and improving overall quality of life in cities.

Understanding traffic congestion is vital for effective infrastructure planning and investment. Evaluations provide data that help prioritize projects and allocate resources efficiently. [12] discussed how comprehensive public transportation systems can reduce congestion and guide infrastructure investments for improved urban mobility. Recent advancements in technology, such as Intelligent Transportation Systems (ITS) and real-time traffic monitoring, offer valuable insights into traffic congestion. Integrating these technologies into traffic management systems enhances the ability to address congestion issues effectively [13]. Explored how smart traffic signals improve traffic flow and reduce congestion in urban areas.

Congestion impacts public health and safety by increasing traffic accidents and degrading air quality. Evaluations help identify safety risks and environmental concerns, leading to improved policies and interventions. [14] highlighted the link between congestion, pollution, and health outcomes, stressing the need for effective congestion management to protect public health. Effective policy development relies on a thorough understanding of traffic congestion. Evaluations provide data necessary for crafting targeted policies such as congestion pricing and improved transit options. [15] demonstrated how congestion pricing can reduce traffic volumes and improve urban transportation systems.

In summary, evaluating traffic congestion is crucial for addressing economic, environmental, and social challenges. It facilitates the development of effective solutions to improve urban transportation systems, enhance quality of life, and ensure sustainable city growth.

2. LITERATURE REVIEW

2.1 Transit-Oriented Developments Impacts

Effect of (TOD) reforms are willing to minimize the number and average queue of vehicle length and promote sustainability by enhancing convenient transportation options for workplaces and other trips (e.g., public transportation, walking, and cycling). Promoting pedestrian accessibility environment and transportation services. Literature reviews has been carried out on TOD fields to find out maybe TOD lives up to these ideals. A review of TOD investigation and effects studies includes a report by [16] which confirms the following hypothesis: TOD housing designs more cars than good growth in four major cities studied with much less traffic. The study found that during the peak period (which usually refers to the construction of roads) residential buildings occupy about half of the traffic in a building. [17] switching to TOD reduced Motor Vehicles Traveled (VMT) by an estimate of 15%, or approximately 3,500 miles in a year; this affected the (Texas Department of Transportation) revenue from vehicle fuel taxes. The estimated results also shows that these families are changing their choices by using more highways.

[18] discovered that residents in transit-oriented developments (TOD) tend to walk more and drive less, opting for various modes of transportation. Their findings indicate that TOD residents typically walk short distances from all types of transportation, suggesting that their activities are generally situated closer to their homes [18]. Similarly, [19] used long-term data to examine how uneven changes in the built environment affect transportation routes relative to highways. They estimated a transportation factor of 3.04, meaning that for every mile of public transportation lost, vehicle miles traveled (VMT) decreases by three miles. The direct impact of TOD is cause by the high rate in vehicle use and is related with the decrease in household (VMT) change of interest, research shows that (TOD) can provide economic benefits to consumers and transportation.

2.2 Analysis of Roadside Friction

Intelligent Transportation Systems (ITS) have emerged as a promising solution to urban traffic congestion. These systems leverage real-time data and adaptive signal controls to optimize traffic flow and reduce delays. Studies have shown that ITS can significantly enhance the efficiency of urban transportation networks by predicting traffic patterns and adjusting signal timings accordingly [20].This dynamic approach to traffic management represents a significant advancement over traditional fixed-schedule traffic signals.

Urban planning also plays a crucial role in addressing traffic congestion. The development of mixed-use areas, where residential, commercial, and recreational spaces are integrated, can reduce travel distances and lower the volume of traffic on major roads [21]. By promoting compact and walkable communities, urban planning strategies can help minimize the need for long commutes and reliance on private vehicles.

Expanding public transportation networks is another vital strategy for mitigating urban traffic congestion. Cities with comprehensive and reliable public transit systems tend to experience lower levels of congestion. Research indicates that investment in public transportation infrastructure not only eases traffic flow but also contributes to reduced environmental pollution and improved public health outcomes [22].

Technological advancements have further enhanced the evaluation and management of traffic congestion. For instance, the use of drones for real-time traffic monitoring provides accurate data and broad coverage, enabling more effective traffic management strategies [23]. These technological tools offer new perspectives and solutions for urban traffic challenges.

Moreover, traffic congestion has significant environmental and health impacts. High levels of congestion are associated with increased emissions of pollutants, which can lead to respiratory problems and other health issues for urban residents [24]. Addressing congestion is therefore essential not only for improving traffic flow but also for enhancing the overall quality of life in urban areas.

Case studies such as the implementation of congestion pricing in New York City illustrate the practical applications of innovative congestion management strategies. This approach has been shown to reduce traffic volume, decrease emissions, and improve public transportation services [25]. Such measures demonstrate the potential benefits of adopting comprehensive and integrated strategies to tackle urban traffic congestion.

[26] conducted an in-depth study on the impact of road friction on traffic, examining aspects such as speed and capacity. His research, which included both macro and micro-level analyses, led to several significant conclusions. Introduced the Free Re-Import Certificate (FRIC) concept to consolidate all external frictions. Given that friction coefficients vary across different units, he proposed a ranking system to express them uniformly using the FRIC unit code [26].

[27] investigated side frictions, including on-street parking, city buses stopping randomly, vehicle entry and exit, and U-turns. His research found that these frictions had a more significant impact than initially estimated by the High Capacity Manual (HCM) in Indonesia. Munawar's new model aims to improve the calculation of speed and capacity for urban roads affected by internal friction, seeking to enhance the Indonesian HCM's efficiency in assessing these factors [27].

[28] developed a simulation model to analyze the effect of bus stops on traffic. This model accounts for various traffic dynamics, such as different speeds, acceleration, deceleration, and overtaking, and simulates non-lane-based heterogeneous traffic on roads of various lengths and widths, including station interactions. Their analysis highlights the importance of quantitatively assessing both individual and combined friction factors, which is beneficial for urban planners and engineers in mitigating these impacts when integrating street furniture within cities [28].

[29] showed that when pedestrian volume reaches 1,360 people per hour, urban road capacity decreases by nearly 50%. Their mathematical model also indicated that a pedestrian crossing volume of about 100 people per hour would result in a 3.52% reduction in capacity [29].

Impact of Bus Stops on Road Traffic

[30] explored how bus stops and stations influence urban rail systems, finding that reducing the number of bus stops could significantly impact route capacity. They developed a model to assess route capacity and bus arrival times at bus stops. Similarly [30]. [31] reviewed recent studies on the outcomes of bus stops on urban infrastructure. They highlighted gaps in the research, recommended further studies, especially considering the varied contexts in which previous studies were conducted [31].

2.3 Causes of Traffic Congestion

Traffic congestion in urban and regional areas can arise from different factors, including excessive demand, traffic signals, events, work zones, weather conditions, and special events. Rail traffic congestion can be classified into two types based on different principles: (i) recurrent congestion and (ii) Episodic congestion [32].

(i) Recurrent congestion: This type of congestion typically occurs in major cities during peak hours, when commuters face daily delays. According to the Federal Highway Administration (FHWA), around half of all traffic accidents are related to repetitive movements [32]. The primary cause of recurrent congestion is bottlenecks or blockages during peak flow hours, often occurring where the number of lanes converges, such as on roadways, bridges, or tunnels that exceed their capacity [31-32]. Congestion happens when demand surpasses the road's capacity, which is influenced by factors like the number and width of lanes, the length of intersections, and the methods used for installation.

Inadequate Infrastructure: This is a major cause of congestion, particularly in densely populated areas. As populations grow, the number of vehicles increases, intensifying the problem. Congestion occurs when existing infrastructure cannot handle the increased traffic volumes [32]. Variations in daily traffic demand can lead to higher traffic levels on certain days, and when these demands exceed infrastructure capacity, delays result [32]. Additionally, inadequate traffic controls, such as poorly timed or designed traffic lights, stop signs, and railroad crossings, can disrupt normal traffic flow, causing accidents and longer travel times.

(ii) Episodic congestion: This type of congestion is often triggered by unexpected events like traffic accidents, construction zones, adverse weather conditions, or special events [32]. Episodic congestion can create new traffic issues during off-peak hours and exacerbate delays. Some common causes of episodic congestion include: Traffic Accidents: Accidents, such as collisions, explosions, and road debris, frequently disrupt common traffic flow by blocking lanes and reducing overall road capacity.

Work Zones: Construction work often alters the road environment, leading to lane reductions, temporary closures, and changes in lane width, all of which contribute to congestion.

Weather: Adverse weather conditions, such as storms, rain, or snow, can significantly impact traffic congestion flow and safety. Approximately 28% of traffic accidents and 19% of fatal accidents are attributed to poor weather conditions. These conditions also necessitate adjustments in traffic controls and can affect highway functionality.

Special Events: Events like sports matches, concerts, and other large gatherings can cause sudden surges in traffic demand, overwhelming the components and resulting in congestion. These events often produce traffic patterns that significantly deviate from the usual daily flows

2.4 Existing Methods for Measuring Congestion

To evaluate congestion levels, researchers have devised various measurement approaches, each utilizing distinct performance models. These approaches can be classified into five primary types: (i) speed measurement, (ii) travel time analysis, (iii) delay assessment, (iv) level of service (LoS) evaluation, and (v) congestion index calculation.

2.5 Assessment of Traffic Speed analysis

The pattern is to examine whether the reduction in traffic will lead to better driving behavior of the remaining drivers. Consequently, we investigated the driving behavior of drivers who continued to work because there was a decreasing in traffic during the intervention period. In the analysis, we know that we needed to account for negative self-selection, as at least part of the improvement in driving behavior appeared to be due to particularly negative drivers choosing not to work. [32] reviewed that the fixed impact test is the same not only in parameter selection but also in cases where the selection process involves time differences, and the explanation is the same. Consequently, some studies have adopted models that explain self-selection.

Also, doing the same random-effects model requires further consideration, particularly if the selection indicator is not independent of time enough to explain the difference. If we assume that both poor driving and self-employment result from an individual's unique, well-functioning poor work schedule and poor job performance, model effects may result in inconsistent estimates [32].

Table 1: Summary of recent studies on urban traffic congestion (2022-2024)

Study	Focus Area	Key Findings
Zhang *et al.* (2022)	Intelligent Transportation Systems (ITS)	ITS improves traffic flow through real-time data and adaptive signal controls.
Kim *et al.* (2022)	Drone technology for traffic monitoring	Drones enhance traffic monitoring accuracy and coverage.
Chen and Wang (2023)	Mixed-use urban planning	Mixed-use development reduces travel distances and traffic volumes.
Martinez and Sanchez (2023)	Public transportation expansion	Comprehensive transit systems reduce urban traffic congestion.
Lee *et al.* (2022)	Congestion Pricing	Congestion pricing reduces traffic volumes and emissions.
Gupta and Verma (2023)	Economic and environmental impacts	High congestion linked to increased pollution and negative health outcomes.
Wang *et al.* (2024)	Impact of smart traffic signals	Smart signals reduce wait times and improve overall traffic flow.
Singh and Patel (2023)	Effects of ride-sharing services	Ride-sharing reduces individual car usage and overall traffic congestion.

3. METHODOLOGY

This study employed a comprehensive literature review methodology to evaluate traffic congestion in urban roads. A targeted literature search was conducted using Google Scholar, Science Direct, and Research Gate to gather relevant research on urban traffic assessment from various countries. The literature review focused on data published between 2000 and 2021. The research strategy included search terms such as "transportation in the region," "economic impact of transport," "urban population and transport," "bus improvements and their effect on road and metro service," among others.

The literature review encompassed a diverse range of sources, including multiple academic articles, transportation research reports, and empirical evidence. This comprehensive approach ensured a robust understanding of the causes and solutions for mitigating traffic congestion. The study utilized effective communication methods to analyze the economic influence on transportation, the impact of roadside friction, the consequences of bus stops and bus traffic, and the causes of road accidents.

A systematic review process was employed to identify, screen, and select relevant studies. Data extraction involved summarizing key findings from each study, focusing on methods of measuring traffic congestion, impacts on urban roads, and proposed solutions. The research adhered to ethical principles, ensuring appropriate credit and acknowledgment of sources.

Responsible use of information and data was emphasized, maintaining the privacy and confidentiality of individuals involved in the studies reviewed. An unbiased and careful analysis was conducted to accurately reflect the findings on traffic measurements and their implications for urban roadways. The review synthesized research from various sources to identify common themes, challenges, and effective strategies related to urban traffic congestion.

The synthesis aimed to provide a comprehensive overview of current methods for measuring traffic congestion and assessing its impact on urban roads. This

methodological approach allowed for a thorough evaluation of existing literature on urban traffic congestion, providing valuable insights into the multifaceted nature of the issue and potential solutions for mitigating its adverse effects.

4. RESULTS AND DISCUSSION

Urban traffic congestion poses a significant challenge, affecting economic productivity, environmental health, and the quality of life for residents. As urban populations and car ownership rates rise, congestion leads to delays, increased fuel consumption, and higher emissions of greenhouse gases and pollutants. Addressing this issue requires multifaceted approaches and innovative solutions.

One promising solution is the implementation of Intelligent Transportation Systems (ITS). These systems utilize real-time data and adaptive signal controls to optimize traffic flow and reduce delays. Research has shown that ITS can significantly improve the efficiency of urban transportation networks by predicting traffic patterns and adjusting signal timings accordingly. This represents a significant advancement over traditional fixed-schedule traffic signals.

Urban planning also plays a crucial role in mitigating traffic congestion. The development of mixed-use areas, which integrate residential, commercial, and recreational spaces, can reduce travel distances and decrease traffic volumes on major roads. By promoting compact and walkable communities, these planning strategies can help reduce reliance on private vehicles and the need for long commutes.

Expanding public transportation networks is another critical strategy for reducing urban traffic congestion. Evidence shows that cities with comprehensive and reliable public transit systems experience lower levels of congestion. Investing in public transportation infrastructure not only eases traffic flow but also reduces environmental pollution and improves public health outcomes.

Technological advancements have further enhanced the evaluation and management of traffic congestion. For example, the use of drones for real-time traffic monitoring provides accurate data and broad coverage, enabling more effective traffic management strategies. These technological tools offer new perspectives and solutions for urban traffic challenges.

Moreover, traffic congestion has significant environmental and health impacts. High levels of congestion are associated with increased emissions of pollutants, which can lead to respiratory problems and other health issues for urban residents. Thus, addressing congestion is essential for improving both traffic flow and overall quality of life in urban areas.

Case studies, such as the implementation of congestion pricing in New York City, illustrate the practical applications of innovative congestion management strategies. This approach has been shown to reduce traffic volume, decrease emissions, and improve public transportation services. Such measures demonstrate the potential benefits of adopting comprehensive and integrated strategies to tackle urban traffic congestion. Examined the impact of road friction on traffic, introducing the Free Re-Import Certificate (FRIC) to standardize friction coefficients. Studied side frictions such as on-street parking and random bus stops, finding that these significantly impact traffic speed and capacity. Developed a simulation model to analyze the effect of bus stops on traffic, emphasizing the need for quantitative assessments to aid urban planners. Showed that pedestrian volume can drastically reduce urban road capacity. These studies underscore the importance of accurately predicting traffic potential to make informed decisions and mitigate congestion effectively.

5. CONCLUSION

In conclusion, managing urban traffic congestion requires a multi-pronged approach, incorporating advanced technologies, thoughtful urban planning, and robust public transportation systems. Evaluating the technologies and strategies contributing to congestion is crucial for devising effective solutions that enhance urban mobility and quality of life. The evaluation of urban traffic congestion reveals that it remains a significant challenge with far-reaching impacts on economic productivity, environmental health, and residents' quality of life. The increasing urban population and car ownership exacerbate congestion, leading to delays, higher fuel consumption, and elevated emissions of pollutants. Innovative solutions and comprehensive strategies are essential to address these challenges effectively. Intelligent Transportation Systems (ITS) offer promising advancements in traffic management by utilizing real-time data and adaptive signal controls to optimize traffic flow. Mixed-use urban planning reduces travel distances and traffic volumes, promoting compact and walkable communities. Expanding public transportation networks is crucial, as cities with reliable transit systems experience lower congestion levels. Technological tools like drones for real-time traffic monitoring provide accurate data for better traffic management. Addressing congestion is imperative for improving both traffic flow and the overall quality of urban life, as evidenced by case studies like congestion pricing in New York City. In recent years, especially since the 1990s, the improvement of roads and the need for transportation have led to serious accidents, collisions, delays and environmental problems, especially in new cities. It not only affects automobile and public transport riders, but also creates many negative effects on society, incorporation to reducing the economy. Worryingly, today's presentation is on the rise and shows no signs of abating, causing a nightmare that is destroying urban life. Planning research into urban congestion charging is a project involving the interests of government, the public and business. Payment method; It should include the payment purpose, payment model, payment location and payment method. All content must be factual and scientifically based on societal and commercial conditions. For this reason, public transportation must be established as a prerequisite. First of all, public transportation must be adequate to meet people's transportation, convenience and comfort needs. Second, public transport should be given some control in advance, such as waiving transport costs, creating transit lanes, and

changing parts of public transport achievement to attract more people to use public transport instead of cars.

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