An Analysis of Congestion Patterns on the Tuaran Bypass and Sulaman KKIP Road Networks in Kota Kinabalu, Sabah

A. Paramasivam [1]* and E. Aruchunan[2]

[1*]Department of Commerce, Politeknik Kota Kinabalu
No. 4, Jalan Politeknik, KKIP Barat Kota Kinabalu Industrial Park,
88460 Kota Kinabalu Sabah, Malaysia

[2]Deparment of Decision Science, Faculty of Business and Economics, Universiti Malaya,
50603 Kuala Lumpur, Wilayah Persekutuan Kuala Lumpur,

* Corresponding author e-mail address: anbukkarasu@polikk.edu.my

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Abstract

This study examines the recurring and non-recurring congestion patterns on the Tuaran Bypass and Sulaman KKIP road networks in Kota Kinabalu, Sabah. The research provides valuable insights into the factors contributing to congestion in the area. A quantitative survey research design was used to collect data through an online survey administered between January and February 2023. A survey instrument adapted from relevant literature was used to collect demographic information about respondents and identify patterns of traffic congestion on both road networks. A total of 1,483, completed responses were obtained and analysed using descriptive statistics. The findings indicate that recurring congestion, primarily influenced by poor roadway conditions, lack of lanes, bottlenecks, and inefficient traffic management, accounts for 52.40% of the congestion. Non-recurring congestion, attributed to poor weather conditions, new development projects, festivals, and accidents, contributes to 47.60% of the congestion. The analysis further highlights the most congested roads during peak hours, with the Sulaman > KKIP Sepanggar > UMS route being the most problematic, followed by the Jalan Tuaran Bypass route. These routes experience heavy traffic due to their significance as major arteries connecting key areas, as well as the presence of construction work, narrow road width, and limited public transportation options. Addressing congestion in the Tuaran Bypass and Sulaman KKIP road networks requires prioritizing improvements in roadway conditions, increasing the number of lanes, optimizing traffic management, enhancing signaling systems, and effectively managing weather-related disruptions and new development projects. By implementing targeted strategies, it is possible to alleviate recurring congestion and mitigate non-recurring congestion, ultimately improving traffic flow and mobility in the area.

Keywords: Congestion Patterns, Recurring Congestion; Non-Recurring Congestion; Roadway Conditions; Traffic Management

1.0 Introduction

Kota Kinabalu, known colloquially as KK, stands as Sabah's largest urban hub and takes the sixth spot among Malaysia's most populous centers. Boasting a population of 617,972, within the city limits and an approximate 900,000 residents in the broader urban expanse, Kota Kinabalu assumes a prominent role as Sabah's capital and a flourishing nexus for industrial and commercial progress, firmly establishing its status as the preeminent city for industrial development in the region (Kota Kinabalu, Sabah & Laquo;

Authentic Borneo, 2015). This area is stretching beyond the confines of the city, predominantly towards the southern region, lies an expansive area that includes the districts of Tuaran, positioned approximately 34 km northward (The Booming of Greater Kota Kinabalu, 2014). Essential for transportation, the Tuaran Bypass and Sulaman KKIP Road Networks serve as vital conduits, fostering connectivity among Tuaran, Tamparuli, Kota Belud, and the central metropolis of Kota Kinabalu. These well-established road networks assume a pivotal role in seamlessly integrating these surrounding areas with the bustling core of Kota Kinabalu, guaranteeing smooth and efficient transportation for both residents and visitors. Nevertheless, the continuous urbanization in the suburban regions encircling Kota Kinabalu, encompassing Kota Belud, Tamparuli, Tuaran, and Menggatal, has resulted in notable traffic congestion along the Tuaran Bypass and Sulaman KKIP Road Networks, critical conduits connecting to the heart of Kota Kinabalu (Besar et al., 2020; Daily express, 2019). The increasing volume of vehicles on these roadways, coupled with their insufficient capacity to accommodate the surging traffic, has given rise to recurrent and protracted traffic gridlocks. This situation presents significant challenges and time limitations for commuters navigating the city, impeding daily routines and stalling the local economy's progress. The Central Business District in the city centre attracts a substantial influx of vehicles, further exacerbating the difficulties faced by commuters traveling from outside the city to reach their workplaces.

Gaining a comprehensive understanding of the repetitive and occasional traffic congestion patterns observed on the Tuaran Bypass and Sulaman KKIP Road Networks is of most importance in effectively managing traffic and urban planning in Kota Kinabalu, Sabah. Conducting a thorough analysis of these congestion patterns will yield valuable insights that can guide the formulation of efficient solutions, optimizing traffic flow and fostering sustainable development. By pinpointing the root causes of congestion, the government can make well-informed decisions to enhance transportation infrastructure and implement strategic measures aimed at mitigating traffic-related challenges in Kota Kinabalu. The presence of repetitive and intermittent congestion patterns significantly affects the daily lives of commuters and poses obstacles to the growth of the local economy (Kien Hua & Abdullah, 2017). Hence, conducting a comprehensive analysis of these congestion patterns becomes imperative to identify effective solutions for traffic management and urban planning in Kota Kinabalu, Sabah.

This study aims to achieve two primary objectives. The first objective is to systematically identify and analyses patterns of traffic congestion on the KKIP Sulaman and Tuaran Bypass Road Networks. By conducting a comprehensive examination of recurring and non-recurring congestion, this research seeks to uncover the underlying patterns and characteristics of congestion in these road networks. The second objective of the research is to identify the road networks that experience the most congestion during peak hours. Through quantitative analysis and evaluation of congestion levels across different segments of the KKIP Sulaman and Tuaran Bypass roads,

the research aims to identify the specific areas with the most severe congestion. The findings of this study will contribute to the development of effective traffic management strategies, assisting urban planners and decision-makers in mitigating congestion issues and enhancing the overall efficiency of transportation systems in the study area.

2.0 Literature Survey

Traffic congestion has emerged as a significant and daily problem in urban areas worldwide. As cities continue to expand, the influx of residents results in a surge of cars on the roads. Insufficient public transportation options and limited road infrastructure further exacerbate the issue. The World Bank's Malaysia Economic Monitor (2015) revealed that working class Malaysians waste approximately 1 million hours annually due to traffic congestion, amounting to an opportunity cost of RM 10-20 billion. This cost encompasses the value of lost productive time that could have been utilized for work, social activities, or other endeavors. Malaysia faces substantial economic consequences due to traffic congestion, primarily in terms of lost productivity, followed by wasted fuel expenses and environmental harm caused by exhaust emissions. Literature offers various definitions of traffic congestion, commonly characterized as a condition impeding traffic flow due to an excess of vehicles or reduced road capacity.

The Federal Highway Administration (2020) describes it as an abundance of vehicles resulting in slower speeds, occasionally significantly slower than normal, often accompanied by stopped or stop-and-go traffic. In essence, traffic congestion obstructs the movement of vehicles on roads or road networks, stemming from an overabundance of vehicles, diminished road capacity, or a combination thereof. Its repercussions include reduced speeds, longer travel durations, increased fuel consumption, and adverse environmental effects such as heightened air pollution and greenhouse gas emissions. Effectively addressing traffic congestion necessitates improvements in public transportation, enhanced road infrastructure, and efficient traffic management strategies, thereby fostering sustainable and efficient urban environments. There are a number of factors that contribute to traffic congestion, which can be broadly categorized into two types, recurring and non-recurring (Jha & Albert, 2021). According to (Pishue, 2022) recurring congestion accounts for nearly one-third of all traffic delays nationwide and is the leading cause of congestion in 14 states, including densely populated states such as California, Texas, Florida, and New York. Non-recurring congestion accounts for two-thirds of all traffic delays nationwide, and it is the leading cause of congestion in 37 states including Washington. Recurring congestion occurs frequently and is usually caused by inadequate roadway capacity, insufficient traffic control devices, or excessive traffic demand during peak travel times, such as rush hours. Whereas non-recurring congestion occurs on a non-routine basis, typically due to unexpected events such as crashes, weather, or special events (Jha & Albert, 2021; Mathew 2019).

Recurrent congestion is usually more severe and longer-lasting than non-recurrent congestion because it is caused by underlying infrastructure and demand issues. Non-recurrent congestion is usually more short-term and can be addressed more quickly due to its isolated nature (Rahman et al., 2021). The study by Jha & Albert (2021) found that non-recurring congestion accounts for more delay than recurring congestion when aggregated across all national roadways. This is because recurring congestion is typically caused by predictable events, such as traffic during rush hour, while non-recurring congestion is caused by unexpected events, such as accidents or weather events. As such, non-recurring congestion can cause significant delays that would not be present in recurring congestion. In the United States, approximately 45% of congestion is caused by recurring sources (bottlenecks and suboptimal signal timing), and the remaining 55% by non-recurring sources. This emphasizes the significance of addressing both recurring and non-recurring sources of traffic congestion in order to reduce delays and improve traffic flow. The understanding regarding the recurring and non-recurring congestion patterns on road networks, hindering effective traffic management and urban planning efforts. To better manage traffic and improve urban planning, a thorough analysis of congestion patterns is necessary (FHWA Operations - Reducing Recurring Congestion, 2021). Factors contributing to recurring and non-recurring traffic congestion are summarized in Table 1.

Table 1: Factors Contributing to Recurring and Non-Recurring Traffic Congestion

Type of congestion	**Factors**	**Explanation**
Recurring traffic congestion	Capacity constraints or bottlenecks	This refers to the maximum amount of traffic that can be handled by a given highway section. several factors affect capacity, including the number and width of lanes and shoulders, merge areas at interchanges, and roadway alignment (grades and curves). It is also possible to consider toll booths a special case of bottlenecks since they restrict the physical flow of traffic. The behavior of the drivers also plays a significant role in determining capacity. The result is an increase in the amount of traffic that can be handled.
	Signalization or traffic control devices	Intermittent disruption of traffic flow by control devices such as railroad grade crossings and poorly timed signals also contribute to congestion and travel time variability.

	Work zones	Construction activities on the roadway result in physical changes to the highway environment. These changes may include a reduction in the number or width of travel lanes. They may also include lane "shifts," lane diversions, the reduction or elimination of shoulders, and even temporary roadway closures. Delays caused by work zones have been cited by travelers as one of the most frustrating conditions they encounter on trips.
Non-recurring traffic congestion	**Factor**	**Explanation**
	Traffic incidents	Traffic incidents are events that disrupt the normal flow of traffic. They can be caused by a variety of factors, including vehicular crashes, breakdowns, debris in travel lanes, and events that occur on the shoulder or roadside. Even incidents off of the roadway can be considered traffic incidents if they affect travel in the travel lanes. Traffic incidents can have a significant impact on traffic flow, leading to delays, congestion, and increased emissions.
	Weather	Environmental conditions, such as reduced visibility from precipitation, bright sunlight, fog, or smoke, as well as wet, snowy, or icy road surfaces, cause drivers to lower speeds and increase headways, impacting traffic flow.
	Special events	This is because special events attract people from outside the area, who are unfamiliar with the traffic patterns, and the influx of people can cause traffic to become congested. Traffic patterns may also be different due to the specific type of event, such as sporting events or concerts, and the associated travel habits of those attending.

Sources: Traffic Congestion and Reliability: Trends and Advanced Strategies for Congestion Mitigation: Chapter 2, 2020

3.0 Methodology

This study employed a quantitative survey research design to investigate the recurring and non-recurring traffic congestion patterns on the Tuaran Bypass and Sulaman KKIP road networks in Kota Kinabalu, Sabah. The survey-descriptive research approach was utilized, focusing on describing the characteristics of traffic congestion phenomena rather than exploring the reasons behind them. The survey instrument, adapted from relevant literature such as Jha & Albert (2021) and the City of Tempe Traffic Congestion Survey (2016), consisted of two sections. The first section gathered demographic information from the respondents, while the second section aimed to identify the type of traffic congestion experienced by the participants.

Data collection took place through an online survey conducted from January 10 to February 8, 2023. The target participants were commuters using the Tuaran Bypass and Sulaman KKIP road networks. The survey was hosted on an online survey platform and utilized a 5-point Likert scale questionnaire. A total of 1,483, completed responses were received and considered for analysis.

The collected data was securely stored and managed on the online platform for future analysis. Descriptive statistics, implemented using Excel and SPSS version 27, were employed to analyze the data and provide insights into the research questions. Descriptive analysis was conducted to gain a comprehensive understanding of the recurring and non-recurring traffic congestion patterns, factors influencing congestion, and demographic characteristics of the respondents. This methodology employed a quantitative survey research design, utilizing an online survey instrument, statistical analysis, and descriptive statistics to investigate the traffic congestion patterns on the specified road networks in Kota Kinabalu, Sabah.

4.0 Results and Discussion

In this section, the findings gathered from the survey are discussed. As a result of the survey responses, this section provides valuable insight into the analysis of recurring and non-recurring congestion patterns on the Tuaran Bypass and Sulaman KKIP road networks in Kota Kinabalu, Sabah. The study findings are organized into four subsections. In the first subsection, a description of the survey participants based on their demographic characteristics is provided. Subsequently, the second subsection, the findings concerning situation of congestion in both road networks is presented. The third subsection the recurring and non-recurring patterns of congestion on both networks of roads are examined. In the last subsection the results related to the most congested roads are discussed.

4.1 Demographic Finding

Based on the survey results in Table 2, the demographic information of respondents is tabulated. The survey participants consist of 795 (53.6%) males and 688 (46.4%) females, indicating that there were more male respondents than females. Based on the analysis of the age groups of the

respondents it was observed that a significant portion, specifically 30.4%, fell within the age range of 32 to 38 years old. Following closely, 27.0% of commuters belonged to the age group of 39 to 45 years. Additionally, 13.7% of respondents were in the age bracket of 25 to 31 years, while 14.2% fell within the 46 to 52 years age range. Furthermore, commuters aged 53 to 59 years constituted 9.4% of the respondents, and those aged 60 and above made up 2.4% of the participants.

In terms of occupation, the majority of respondents, comprising 846 (57.0%), were employed in the public sector, while 371 (25.0%) worked in the private sector. 103 (6.9%) of the respondents were self-employed, and 44 (3.0%) were retired. However, a smaller percentage of the sample consisted of students, part-timers, and riders (such as those on Grab or Maxim).

Furthermore, the survey encompassed gathering data on the average monthly vehicle expenses of the respondents. Out of the total participants, 432 individuals (29.1%) reported spending between RM201 and RM300 per month on their vehicles. Similarly, 469 respondents (31.6%) indicated monthly expenditures ranging from RM301 to RM400. Moreover, 265 participants (17.9%) reported their vehicle expenses falling within the range of RM401 to RM500 per month, while 197 respondents (13.3%) stated that their monthly vehicle expenses exceeded RM500. A smaller portion of respondents, specifically 120 individuals (8.1%), expressed that their monthly vehicle expenses were below RM200.

To summarize, the analysis revealed that the surveyed population was predominantly male, with a significant proportion employed in the public sector. The age groups of 32-38 and 39-45 years were the most prevalent among the respondents. Furthermore, the majority of participants allocated a moderate portion of their monthly budget towards vehicle-related expenses. These findings provide valuable insights into the demographic characteristics and average expenditure patterns of the surveyed population, allowing for a better understanding of the surveyed population.

Table 2: Demographic Information of Respondents

General Information		**Frequency**	**Percentage (%)**
Gender	Male	795	53.6%
	Female	688	46.4%
	Total	1483	100%
Age Group	18 – 24 years	45	3.0%
	25 – 31 years	203	13.7%
	32 – 38 years	451	30.4%
	39 – 45 years	400	27.0%
	46 – 52 years	210	14.2%
	53 – 59 years	139	9.4%
	60 years and above	35	2.4%
	Total	1483	100%

Occupation	Students	24	1.6%
	Unemployed	9	0.6%
	Self-employed	103	6.9%
	Rider (Grab, Maxim, Shoppe Express and others)	12	0.8%
	Part-timer	12	0.8%
	Private sector	371	25%
	Public sector	846	57%
	Retired	44	3%
	Others	62	4.2%
	Total	1483	100%
Monthly expenditure on vehicles	Below RM200	120	8.1%
	RM 201 – RM 300	432	29.1%
	RM 301 – RM 400	469	31.6%
	RM 401 – RM 500	265	17.9%
	Above RM 501	197	13.3%
	Total	1483	100%

4.2 Finding of Congestion Situation

Based on the data on peak-hour congestion, it clearly showed that the majority of traffic occurs during the morning and evening, with 875 (59.0%) respondents indicating that they experienced traffic during both times of the day. This is likely due to the heavy volume of commuters traveling to and from work during these hours. Surprisingly, only a small number of respondents 27 (1.8%) and 39 (2.6%), respectively reported experiencing traffic during the afternoon and evening hours. The fact that 473 (31.9%) respondents reported experiencing traffic congestion "all day" highlights the ongoing nature of the traffic problem, which could be due to several factors, including road design, a lack of public transportation options, and population growth in the area.

Table 3: Congestion Situation

Traffic Congestion Data		**Frequency**	**Percentage (%)**
How often does traffic delay your trip to work?	Never	6	0.4%
	Everyday	1342	90.5%
	A few times a week	111	7.5%
	A few times a month	24	1.6%
	Total	1483	100%
The peak period of Traffic congestion	Morning	69	4.7%
	Afternoon	27	1.8%
	Evening	39	2.6%
	Morning & Evening	875	59.0%
	All day	473	31.9%
	Total	1483	100%

4.3 Finding of Recurring and Non-Recurring Congestion Patterns

According to the findings presented in Table 4, the survey results reveal the presence of both recurring and non-recurring congestion patterns on the Tuaran Bypass and Sulaman KKIP roads in Kota Kinabalu, Sabah. Each type of congestion was assessed by calculating the mean values for various contributing factors.

In the case of recurring congestion, the analysis indicated that poor roadway condition (4.81) and lack of lanes (4.65) had the highest mean values, signifying their significant impact. Other notable factors contributing to recurring congestion were bottlenecks/poor geometry (4.54), inefficient traffic management (4.49), and a deficient signaling system (4.18). On the other hand, factors such as excessive number of vehicles (4.02), inefficient public transport service (4.03), population growth (3.88), and economic development/urbanization (4.09) had relatively lower mean values. The overall mean value for recurring congestion was determined to be 4.30.
Regarding non-recurring congestion, poor weather conditions (such as rain and floods) had a notable mean value of 4.10, followed by new development projects (road construction) with a mean value of 4.21. Festivals, seasonal events, and school holidays had a relatively lower mean value of 3.90, while accidents had the lowest mean value of 3.41. The overall mean value for non-recurring congestion was 3.91.

Based on these findings, it can be concluded that 52.40% of the congestion in both road networks is attributed to recurring congestion, while 47.60% is attributed to non-recurring congestion. This analysis provides insights into congestion patterns in the Tuaran Bypass and Sulaman KKIP road networks, emphasising the significance of addressing factors related to road infrastructure, traffic management, and the impact of population growth and economic development. Efforts to improve roadway conditions, increase the number of lanes, optimize traffic management, and enhance signalling systems could help reduce recurring congestion. Similarly, addressing factors such as weather-related disruptions and effectively managing new development projects can help mitigate non-recurring congestion.

Table 4: Traffic Congestion Patterns

No	Factors	Mean	Percentage
	RECURRING CONGESTION		
1	Excessive No. of vehicle	4.02	**52.40%**
2	Inefficient public transport service	4.03	
3	Inefficient traffic management	4.49	
4	Poor roadway condition	4.81	
5	Lack of number of lanes	4.65	
6	Poor signaling system	4.18	
7	Bottlenecks /poor geometry	4.54	
8	Population growth	3.88	
9	Economic development/urbanization	4.09	
Sum of the Mean		**4.30**	

	NON-RECURRING CONGESTION		
1	Accident	3.41	**47.60%**
2	Poor weather such as rain and floods	4.10	
3	Festival seasonal and school holidays	3.90	
4	New development project (Road construction)	4.21	
Sum of the Mean		**3.91**	

4.4 Finding of the Most Congested Roads

Table 5 shows the most congested roads during peak hours based on survey results. The most congested road network during peak hours is the Sulaman > KKIP Sepanggar > UMS route with 576 (38.8%), followed by the 3/A1/AH150 (Jalan Tuaran Bypass) route with 376 (25.4%). The Sulaman > Telipok > 3/A1/AH150 (Jalan Tuaran Bypass) route has 163 (10.9%), while 368 (24.8%) respondents reported that all road networks face heavy congestion. According to the data, the Sulaman > KKIP Sepanggar > UMS route is the most problematic during rush hour and requires immediate attention to improve traffic flow. In conclusion, the high volume of traffic is caused by the fact that this route is a major artery connecting the city center with the University of Malaysia Sabah (UMS). The narrow road width and construction work on the roads make it difficult for traffic to flow smoothly, and the lack of public transportation options forces people to drive, which only adds to congestion.

Table 5: The Most Congested Road Networks

Traffic Congestion Data		**Frequency**	**Percentage (%)**
The Most Congested Road Networks at Peak Hours	Via Route 3/A1/AH150 (Jalan Tuaran Bypas)	376	25.4%
	Via Route Sulaman > Telipok > 3/A1/AH150 (Jalan Tuaran Bypas)	163	10.9%
	Via Route Sulaman > KKIP Sepanggar > UMS	577	38.9%
	Above all Road Netwok	368	24.8%

In comparing the findings of the present study on the Tuaran Bypass and Sulaman KKIP road networks with the nationwide study conducted by Jha and Albert (2021), notable differences in the proportion of recurring and non-recurring congestion sources can be observed. The current study reveals that 52.40% of the congestion in both road networks is attributed to recurring congestion, while 47.60% is attributed to non-recurring congestion. On the other hand, Jha and Albert (2021) reported that at a nationwide level, recurring congestion accounted for approximately 45% of the total congestion, with the remaining 55% being attributed to non-recurring sources.

The variations in these findings may stem from several factors, including regional differences in traffic patterns, road infrastructure, and levels of economic development. The Tuaran Bypass and Sulaman KKIP road networks studied in the present research may have unique characteristics that contribute to a higher proportion of recurring congestion compared to the national average. Factors such as poor roadway conditions, bottlenecks, and suboptimal signal timing, which are typical sources of recurring congestion, may be more prevalent or have a more significant impact in the specific study area.

The disparity between the two studies highlights the importance of conducting localized assessments to understand the specific dynamics and factors influencing congestion in a particular region. While the nationwide study provides valuable insights into congestion patterns at a broader scale, it is crucial to recognize the contextual variations that exist between regions and transportation networks.

To effectively address congestion in the Tuaran Bypass and Sulaman KKIP road networks, strategies should be tailored to target the specific recurring congestion sources identified in this study, such as improving roadway conditions, increasing the number of lanes, optimizing traffic management, and enhancing signaling systems. Simultaneously, efforts to mitigate non-recurring congestion, including effectively managing weather-related disruptions and new development projects, should also be prioritized.

This study contributes to the existing body of knowledge on congestion and provides local policymakers and transportation authorities with valuable information to make informed decisions regarding infrastructure improvements, traffic management strategies, and urban development planning in the Tuaran Bypass and Sulaman KKIP road networks. Further research and monitoring of congestion patterns in the area are recommended to evaluate the effectiveness of implemented measures and adapt strategies as needed.

5.0 Conclusion

In conclusion, the study on recurring and non-recurring congestion patterns on the Tuaran Bypass and Sulaman KKIP road networks in Kota Kinabalu, Sabah provides valuable insights into the factors contributing to congestion in the area. The findings reveal that recurring congestion, primarily influenced by poor roadway conditions, lack of lanes, bottlenecks, and inefficient traffic management, accounts for 52.40% of the congestion. Non-recurring congestion, attributed to poor weather conditions, new development projects, festivals, and accidents, contributes to 47.60% of the congestion. Furthermore, the analysis highlights the most congested roads during peak hours, with the Sulaman > KKIP Sepanggar > UMS route being the most problematic, followed by the Jalan Tuaran Bypass route. The heavy traffic on these routes is a result of their significance as major arteries connecting key areas and the presence of construction work, narrow road width, and limited public transportation options.

To address congestion, it is crucial to prioritize improvements in roadway conditions, increase the number of lanes, optimize traffic management, enhance signaling systems, and effectively manage weather-related disruptions and new development projects. By implementing targeted strategies, it is possible to alleviate recurring congestion and mitigate non-recurring congestion, ultimately improving traffic flow and mobility in the Tuaran Bypass and Sulaman KKIP road networks. Moving forward, future research on recurring and non-recurring congestion patterns should consider conducting longitudinal studies to track congestion over time, comparing congestion patterns across different regions, integrating multiple data sources to capture a comprehensive understanding of congestion, exploring the impact of emerging technologies on congestion, examining the relationship between congestion and socioeconomic factors, evaluating the effectiveness of congestion mitigation strategies, and investigating the integration of sustainability and resilience principles in congestion management. By focusing on these areas, we can enhance our understanding of congestion dynamics and develop effective strategies to alleviate traffic congestion and improve transportation systems.

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Conflicts Of Interest
The manuscript has not been published elsewhere and is not under consideration by other journals. All authors have approved the review, agree with its Submission, and declare no conflict of interest in the manuscript.

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