International Journal for Multidisciplinary Research (IJFMR)
E-ISSN: 2582-2160 ● Website: www.ijfmr.com ● Email: editor@ijfmr.com

A Review on Causes of Traffic Congestion and Management Techniques in Urban Transportation Systems

Rishabh[1], Ravish Rathee[2]

[1]Student, Civil Engineering Department, UIET (MDU Rohtak)
[2]Assistant Professor, Civil Engineering Department, UIET (MDU Rohtak)

Abstract

Rapid urbanisation, population growth and an increase in private vehicle ownership created a persistent issue in many cities as the transport need is increasing in such a way that it is surpassing the capacity of present road networks [1]. Congestion not only impacts travel time or traffic flow but also increases fuel consumption, economic losses and the degradation of the environment [4]. The objective of this review paper is to examine the distinct traffic congestion management techniques discussed in earlier studies and to study the major causes of congestion in traffic. A systematic literature review is carried out to analyse the previous studies on the causes of congestion and its mitigation strategies. Google Scholar, Science Direct, Scopus, ASCE Library and other academic databases are used to collect relevant research publications. Approximately 20 research publications published between 1999 and 2026 are evaluated to find out the major causes of traffic congestion (consolidated in Table 1) and the benefits of different congestion management techniques. Incidents in traffic, population growth, outdated transportation Infrastructure, using private vehicles and inefficient traffic management systems are the common factors of congestion which are observed during the evaluation. In this study, different congestion management techniques like parking management, intelligent traffic control technology, managed lane services, vehicle limits, and signal optimisation are also evaluated. Simulation demonstrated that artificial intelligence-based approaches can increase traffic flow efficiency by around 30% as compared to conventional methods [18]. The findings suggest that the updated infrastructure, advanced traffic management technologies and intervention of the government are important for the proper traffic congestion management. In total, an integrated traffic management strategy will improve the traffic flow and promote sustainable transport systems [7,11,13].

Keywords: Traffic congestion; Urban transportation; Congestion management techniques; Traffic flow; Intelligent transportation systems; Sustainable mobility; Urban traffic dynamics

1. Introduction

Urban transportation systems have a significant impact on economic activities and mobility within cities. The demand for travel on the current road networks has expanded dramatically due to fast population growth, greater motorisation, and urban expansion. Congestion arises when the demand for travel exceeds the capacity of the roads, which lowers the effectiveness of transportation networks [1,2]. Mobility, accessibility, and overall transportation performance are all negatively impacted by traffic

congestion, which has become a recurring problem for many urban areas worldwide. The degree of congestion in urban settings is frequently determined by the interplay between the quantity of cars and the restricted capacity of road infrastructure [1].

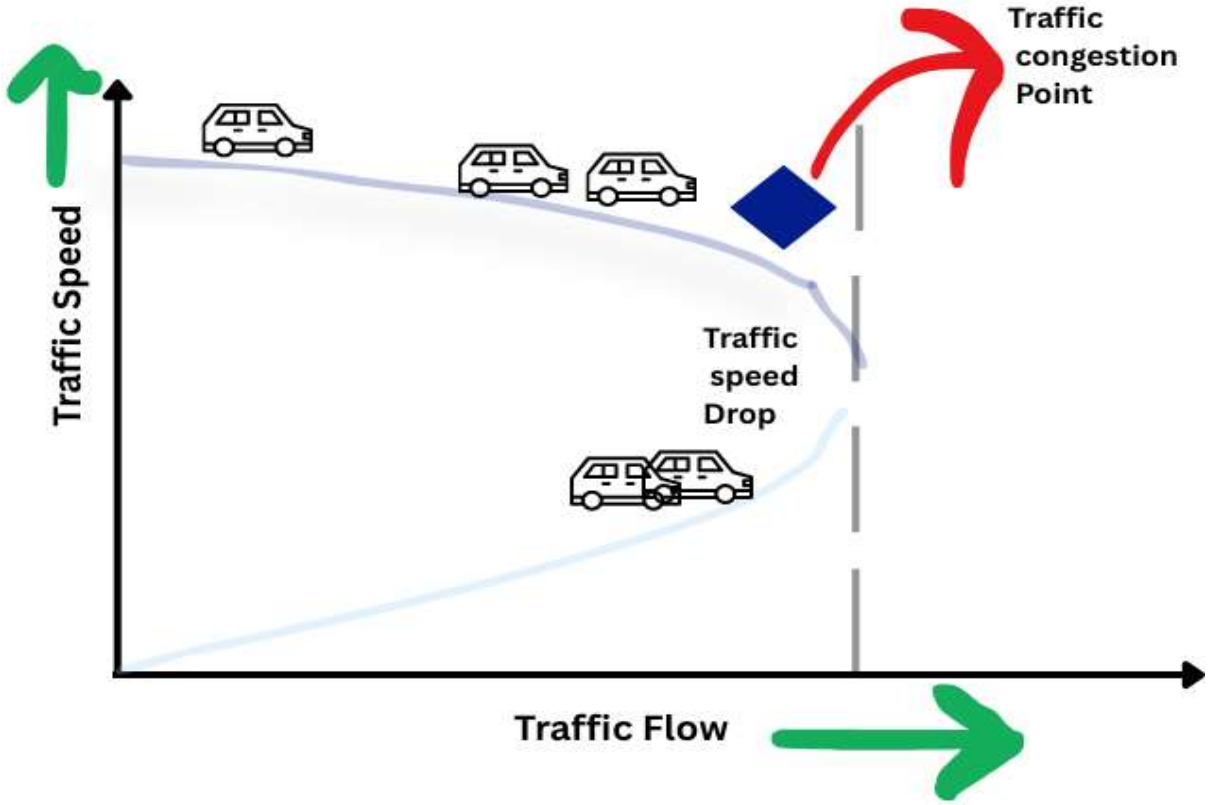
One major problem with transportation systems is traffic congestion. Traffic congestion increases the demand for limited road space [3].

Recurring congestion results from the mismatch between infrastructure capacity and demand as the number of cars rises, especially during periods of high travel demand.

Traffic congestion is one of the many significant global problems that emerge in all major cities as a result of rapid urbanisation and continually has negative repercussions on society. Longer travel times, higher fuel usage, and increased vehicle emissions are all consequences of congestion, which contributes to both economic losses and environmental pollution [2,4].

The flow and speed of traffic are also impacted by traffic congestion. Figure 1 shows the connection between traffic flow vs traffic speed and congestion. Vehicle stop-and-go motions and erratic traffic flow patterns are common in congested areas, which drastically lower average vehicle speed and lengthen travel times [4].

Figure 1. Effect of congestion on traffic flow and speed



Source: ECMT, 1999; Hon, 2005, p.14 [20]

Furthermore, ongoing traffic congestion has an impact on urban productivity, the effectiveness of freight transportation, and the general standard of living in cities in addition to daily commuters. Thus, to enhance traffic flow, maximise road capacity, and support sustainable urban transportation systems, efficient congestion management techniques are required.

This review's goals are to assess different traffic congestion management strategies put out in recent literature and analyse the main causes of urban traffic congestion.

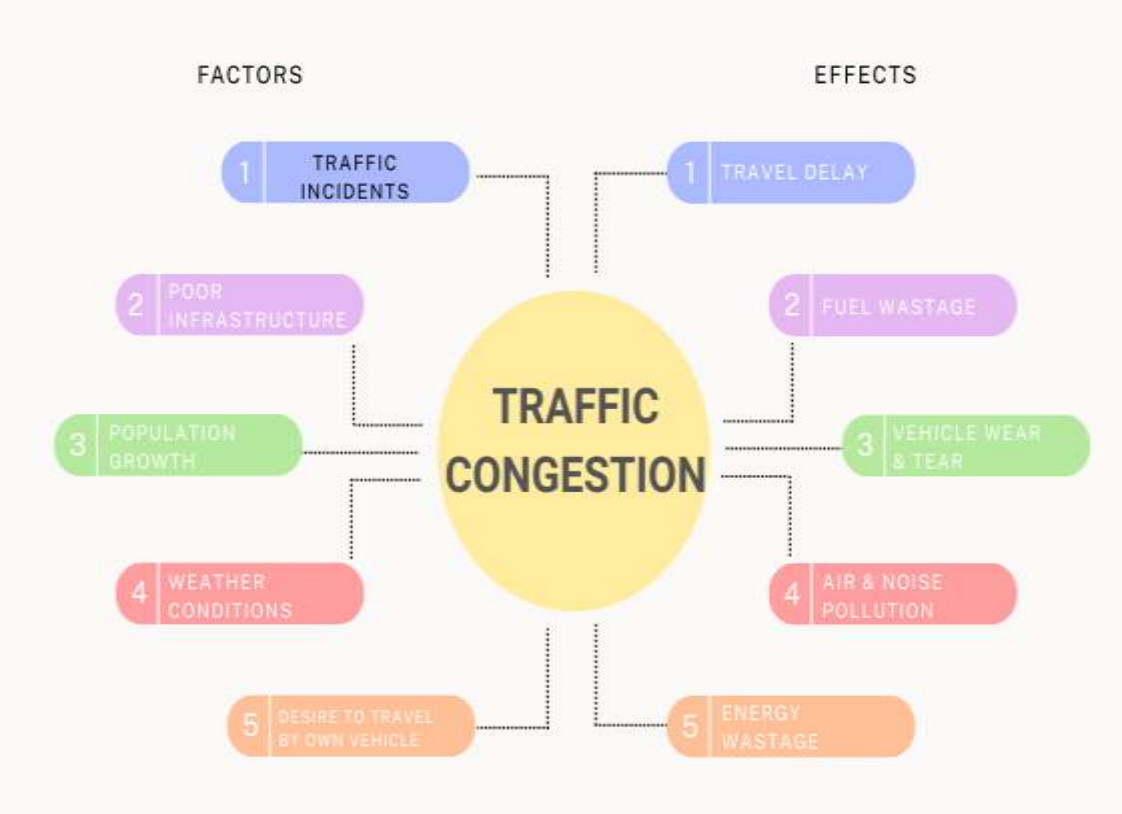
2. Causes of Traffic Congestion

Traffic congestion occurs due to many reasons [3]. The major factors and effects of traffic congestion are summarised in Figure 2.

Table 1: Causes and Effects of Traffic Congestion

Sr.No.	Causes of traffic congestion	Effects of Traffic Congestion
1	Increase in Population	Travel Delay
2	Economic Growth	Fuel Wastage
3	Poor Transportation Infrastructure	Air Pollution
4	Lack of Public Transport	Noise Pollution
5	Desire to travel by private vehicle	Economical Loss
6	Improper traffic control	Road Rage
7	Weather Conditions	Commuter Stress
8	Emergency Situations	Environmental Damage
9	Construction Activities	Vehicle Depreciation
10	Traffic Incidents	Health Issues
11	Commuter behaviour, etc.	Reduction in Mobility, etc.

Figure 2. Causes & effects of traffic congestion



Source: Prepared by Rishabh through literature review

3. Traffic Demand Management Measures

Various traffic demand management measures affect traffic flow and mitigate congestion.

3.1 Access management

It guarantees a suitable configuration of traffic flow and road access that limits or regulates vehicle entry into forbidden or restricted areas. By reducing pointless entry and departure locations, access management aids in controlling the relationship between main roadways and nearby land uses. It enhances traffic flow efficiency, lessens vehicle conflicts, and helps urban transportation systems manage congestion by regulating vehicle movement in sensitive or busy regions.

3.2 Parking Management

In order to stop cars from being parked alongside roads, parking management makes sure that there are sufficient and thoughtfully designed parking spaces. In order to encourage cars to use designated parking locations, it also entails the implementation of reasonable and well-organised parking fees. In addition to offering safe parking for cars, adequate parking facilities also lessen roadside traffic and enhance traffic flow in cities.

3.3 Imposing a Fine

It guarantees that those who break the regulations will be fined [5]. One key tactic for upholding discipline on city roadways is the imposition of fines for breaking traffic laws. Signal jumping, unauthorised parking, and other traffic infractions that cause congestion are discouraged by strict enforcement of penalties.

4. Congestion Management Techniques

Several techniques have been studied and the potential benefits of congestion management techniques are illustrated in Figure 3 while classification are illustrated in Figure 4.

4.1 Isolated Intersection Optimisation for Congestion Control

The primary bottlenecks in cities are signalised crossings. Vehicles and other road users experience delays at these crossroads due to poorly built traffic signals [6].

4.2 Elevated Railway Tracks

Elevated railway tracks play an important role in reducing traffic congestion. For example, elevated railway crossings have been implemented in Rohtak city to reduce delays caused by railway crossings.

4.3 Restriction of big vehicles in the city

In metropolitan settings, limiting heavy vehicles like trucks and large commercial vehicles during rush hour is an efficient way to control traffic. These cars take up more space on the road and frequently travel at slower speeds, which can impede traffic flow and exacerbate congestion. Traffic authorities can enhance road capacity use and minimise traffic delays by restricting the entry of heavy trucks into city centres during peak hours. In order to sustain the delivery of goods without impairing urban traffic flow, heavy vehicles are permitted to run at nighttime or off-peak hours, but such limits are typically put in place during peak hours.

4.4 Managed lane services

Managed lane services are an effective traffic management strategy used to improve traffic flow and reduce congestion on busy urban roads. One common example is the implementation of bus-only lanes, which are reserved exclusively for public transport vehicles. These lanes improve public transportation mobility and encourage commuters to use public transport. Promoting bus transportation through dedicated lanes can reduce the number of private vehicles on the road and contribute to overall congestion reduction in urban areas [7].

4.5 Queue Warning

The queue warning system is a significant addition to the speed harmonisation system. This technology, which is integrated with the active management gantries, shows congestion ahead with a congestion pictogram on either side of the speed harmonisation gantry. This congestion pictogram is shown on an overhead DMS in various systems. The goal of this warning system is to lessen the likelihood of secondary incidents brought on by either recurrent or nonrecurring traffic [7].

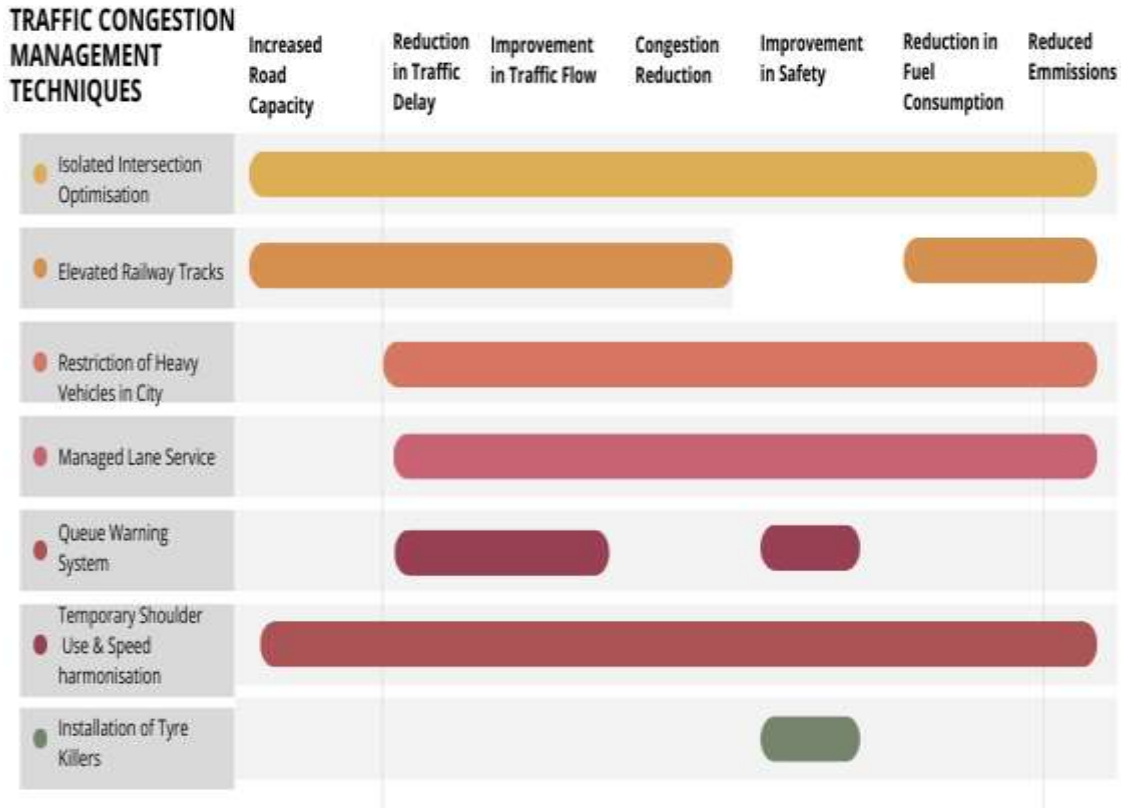
4.6 Temporary Shoulder Use and Speed Harmonisation

Temporary Shoulder Use and Speed Harmonisation increase the road capacity. It is one of the active traffic management strategies, reducing congestion by allowing vehicles to use the shoulder as a traffic lane and simultaneously directing vehicle speeds by digital signs [7].

4.7 Tyre Killer

Tyre killers are the traffic control devices that restrict the entry of vehicles moving in the wrong direction or lane. They are made up of sharp metal spikes and placed on roads in such a way that allows the safe movement of vehicles in the allowed direction, and affect vehicles moving in the wrong direction by puncturing their tyres.

Figure 3. Benefits of traffic congestion management techniques



Source: Prepared by the authors through literature review

Figure 4. Classification of traffic congestion management techniques

Source: Prepared by Rishabh through literature review

5. Literature Review

Prior research has been done to find out the causes, effects and management techniques of traffic congestion in urban transportation systems. These studies give important information about the causes of jams in traffic and the outcomes of various mitigation strategies. From these reviewed studies, it can be stated that a type of congestion management technique must be used to minimise the conflicts in urban traffic.

5.1 Congestion Causes

It is noticeable that the travel demand is increasing while the capacity of the roads remains the same. Serdar Colak, A. Lima, and Marta C. Gonzalez (2016) suggest that the imbalance between demand and capacity is causing congestion. Their study points to a critical issue that the jams in traffic can last the whole day rather than just peak hours in major cities with high density. On a similar side, Huang and Loo (2022) linked rapid urbanisation, an increase in car ownership and restricted road expansion with congestion as these factors are increasing the traffic density.

The patterns of congestion in urban traffic are not similar. In the same context, Lampo, Borge-Holthoefer, Gomez and Sole-Ribalta (2021) give an important analysis that congestion hotspots move from city centres to outer growing areas as the city expands. Also, congestion patterns are found to be different on weekends and weekdays [16].

The reasons for congestion turn out to be urbanisation and vehicle ownership, which directly increase the demand while the infrastructure remains the same. It is interesting that the geography of the area also affects congestion patterns. Therefore, during the planning stage of the transportation system, the growing demand of the area must be considered to reduce the infrastructure causes of congestion.

5.2 Congestion Effects

Congestion disturbs the overall mobility of the transport system. Different studies show that it not only affects transportation but also triggers stress and pollution levels. Ankit Choudhary and Sharad Gokhale (2016) correlated frequent stop-and-go driving due to congestion with increased fuel consumption and

emissions. This automatically escalates the degradation of the environment and the expenses of running a motor vehicle. Mahbub, Zhao, Assanis, and Malikopoulos (2019) also agreed with the above analysis as their simulation found that inefficient flows of traffic at an intersection raise the spirit consumption. It is just not limited to the delays or more fuel usage; for example, Parkavi and Parthiban (2025) showed that traffic during peak hours goes to the level of service E and F in their study of a major intersection in Chennai. It points out a traffic system which is running beyond its maximum handling capacity. Hence, it is evaluated that congestion is not just reducing mobility or increasing automotive fuel consumption but also affecting mentally, economically, environmentally and administratively.

5.3 Congestion Management Techniques

Effective management cannot be done without proper monitoring of traffic. Saurabh Thakur (2016) identifies this technical requirement and evaluates the hardware necessity for real-time traffic monitoring and locating congestion hotspots with the help of sensors and CCTV cameras. He demonstrated that authorities can work efficiently with these techniques instead of just guessing. But Tasnim Afrin and Noriyuki Yodo (2020) debated that only hardware is not a primary solution and suggest integrating it with an intelligent transport system. Traffic monitoring can be done at every place, and the same with the mitigation techniques, but it is not economical and feasible. This is the point where Serok, Havlin, and Blumenfeld-Lieberthal's (2022) research adds value in traffic management by detecting and prioritising the congestion bottlenecks. While Saurabh Thakur (2016) and Tasnim Afrin and Noriyuki Yodo (2020) provide an overview of traffic conditions, Serok, Havlin, and Blumenfeld-Lieberthal (2022) sorted the bottlenecks for efficient implementation of congestion mitigation strategies.

Recent studies are more attracted to artificial intelligence and technology. Yahya H. Taher and associates (2025) elaborated on the use of artificial intelligence and machine learning in the estimation of traffic and management. They argued that intelligent algorithms can identify patterns much better than humans. This benefit is also supported by Elbasha and Abdellatif in 2025. They made a simulation which interpreted that an artificial intelligence-based approach can increase the traffic flow efficiency by 30%, as compared to conventional fixed time signals. Guo, Wang, Chan, and Askary (2019) also discussed technology and suggested that adaptive traffic signal systems can react to real-time traffic circumstances and drastically cut down queue lengths and vehicle waiting times at the intersection. Mahbub, Zhao, Assanis, and Malikopoulos (2019) also demonstrated an ideal control framework that enables cars to manoeuvre through junctions without stopping too frequently. As the simulation is done on ideal conditions, its results may vary in the real world.

Hussain et al. (2026) observed that demand management techniques, traffic signal optimisation and infrastructure upgradation can lessen traffic in quickly expanding metropolitan areas effectively. Despite focus on the technology, Hussain et al. (2026), Federal Highway Administration and the American Association of State Highway and Transportation Officials argue that no single technique is sufficient, but a combination of techniques is required for long-term congestion control.

From the above discussion, it is clear that a number of factors, such as rapid urban growth, increasing car ownership and poor transportation infrastructure, contribute to traffic congestion. Different studies have suggested several approaches to reduce traffic, which include an intelligent traffic management system plus infrastructure development. Table 2 also provides an overview of a few studies on traffic congestion and management strategies. To efficiently control the congestion, it is preferred to integrate several mitigation strategies rather than using only one approach.

Table 2: Summary of Previous Studies on Traffic Congestion and Management Techniques

Sr. No.	Author(s)	Year	Study Focus	Methodology	Key Findings
1	Serdar Colak, A. Lima and Marta C. Gonzalez	2016	Analysis of congestion patterns in urban areas	Large-scale mobility data analysis	The primary cause of congestion is an imbalance between the demand for travel and the capacity of the roads.
2	Tasnim Afrin and Noriyuki Yodo	2020	Review of traffic congestion measurement techniques	Literature review	Traffic congestion monitoring and management can be enhanced by intelligent transportation systems.
3	Ankit Choudhary and Sharad Gokhale	2016	Environmental impacts of traffic congestion	Real-world traffic emission analysis	Due to continuous stop-and-go traffic, congestion raises fuel consumption and vehicle emissions.
4	Saurabh Thakur	2016	Automated traffic monitoring technologies	Review of traffic sensors and measurement techniques	Monitoring traffic flow and congestion levels is made easier by technologies like cameras and loop detectors.
5	Yahya H. Taher et al.	2025	Computational intelligence models for congestion control	Review of AI-based traffic models	Congestion prediction and signal control can be enhanced using artificial intelligence methods.
6	American Association of State Highway and Transportation Officials	2007	Congestion management strategies	Policy and infrastructure analysis	Shoulder use, queue warning systems, and managed lanes can all increase the effectiveness of traffic flow.
7	F. Bolte	2006	Traffic management policies	Policy analysis	Congestion in urban transportation systems can be lessened by effective traffic control regulations.
8	A. Pilz	2006	Operation of traffic control centres	Case study	Modern traffic control facilities enhance traffic management coordination and monitoring.

9	Federal Highway Administration	1999	Innovative traffic control technologies	Technology review	Road safety is increased, and congestion is lessened with the use of intelligent traffic control systems.
10	Federal Highway Administration	2006	Travel demand management strategies	Policy and planning review	Congestion is lessened by demand management techniques like carpooling and encouraging public transportation.
11	Serok, Havlin & Blumenfeld-Lieberthal	2022	Identification of urban congestion bottlenecks	Network traffic data analysis	Prioritising infrastructure upgrades to lessen traffic congestion is made easier by identifying significant bottlenecks in road networks.
12	Huang & Loo	2022	Urban congestion patterns in metropolitan cities	Policy and thematic analysis	Urban traffic congestion is mostly caused by rapid urban expansion and rising car ownership.
13	Guo, Wang, Chan & Askary	2019	Intelligent traffic signal control systems	Reinforcement learning based traffic model	Intersection congestion and vehicle waiting times can be decreased with AI-powered adaptive signal control.
14	Mahbub, Zhao, Assanis & Malikopoulos	2019	Coordination of connected and automated vehicles at intersections	Optimal control and simulation modeling	Both travel time and fuel consumption can be decreased by coordinated vehicle movement through intersections.
15	Lampo, Borge-Holthoefer, Gómez & Solé-Ribalta	2021	Spatial distribution of congestion in urban networks	Network analysis of traffic data	As cities grow, congestion hotspots move from city cores to nearby arterial corridors.
16	Elbasha & Abdellatif	2025	AI-based smart traffic management system	Image processing and AI traffic monitoring	Traffic flow and congestion can be greatly enhanced by AI-based traffic monitoring systems.

17	Parkavi & Parthiban	2025	Urban traffic congestion analysis in Vellore city	Traffic volume and peak-hour analysis	Planning improvements and recognising patterns of congestion are made easier with data-driven traffic monitoring.
18	Parkavi & Parthiban	2025	Congestion analysis at urban intersections	Level of Service (LOS) evaluation	During peak hours, many metropolitan crossings operate at LOS E or F, signifying extreme congestion.
19	Hussain et al.	2026	Evaluation of congestion mitigation strategies	Multi-criteria decision-making (Entropy-TOPSIS)	Among the best ways to reduce traffic are infrastructure upgrades and signal improvements.
20	Glasgow Urban Traffic Data Study	2025	Large-scale urban traffic dataset analysis	Big data traffic monitoring	Predictive traffic models can be improved, and congestion patterns can be found with the use of high-resolution traffic statistics.

6. Research methodology

A systematic literature analysis is done on the earlier published studies of traffic congestion and its management strategies in urban transportation systems. In this review, research on the reasons behind traffic jams and the efficacy of various congestion management strategies is examined and summarised.

Google Scholar, Science Direct, Scopus, ASCE Library and other academic databases were used to collect relevant research publications by using keywords like traffic congestion, congestion management strategies, traffic flow management, urban transportation systems and intelligent transportation systems. These keywords were used both separately and in combination.

After selecting the topic, different studies were collected on traffic congestion and management techniques. Then we sorted the papers on the basis of their methodology, inclusion of technologies and relevance to management techniques and causes of congestion. Approximately twenty research and review articles published between 1999 and 2026 were chosen for this review to synthesise.

The sorted papers were thoroughly examined by us to determine the common causes of monitoring strategies, traffic congestion and its mitigation techniques. The results from these studies are compared and compiled in a table to understand the causes of congestion and management techniques with their potential efficacy in urban transportation systems.

7. Discussion / Comparative Analysis

In this review, the effects suggest that traffic congestion is a complicated problem as the travel demand is surpassing the road capacity [1]. The infrastructure and behavioural constraints both impact congestion.

The efficiency of the many congestion management techniques studied in this literature depends on the features of the urban transportation system.

Transportation capacity can be boosted by infrastructure-based management techniques like road widening and elevated rail tracks, as they help in reducing traffic congestion. These strategies are good for places with high traffic demand, but they take a long time to improve infrastructure and require a big financial commitment. While there are some operational approaches like managed lane services and signal optimisation, which increase the effectiveness of current infrastructure without requiring significant physical expansion.

The main goal of traffic demand management techniques is to reduce the number of vehicles on the road network by applying severe vehicle limitations and public transportation. In crowded urban areas with little road space, these actions can specifically improve traffic conditions. As also discussed by Aniello Lampo (2021), with the growth of the city, congestion hotspots move from city centres to suburban areas. Therefore, techniques must be implemented by considering these outer areas.

Transportation authorities can successfully apply traffic management measures and identify congestion in advance because of growing technology. Intelligent technologies provide greater flexibility and improve traffic management capabilities as compared to conventional traffic control techniques. The use of technology helps improve the traffic flow efficiency by 30% [18], but it is limited to ideal conditions. Therefore, this literature insists that a single congestion management technique cannot help totally to get rid of traffic congestion [7, 11, 13]. To accomplish long-lasting congestion reduction in the urban transportation system, a combination of technology, traffic management strategies and infrastructural upgrades is required.

8. Research Gap

A lot of research has been done on causes of traffic congestion and mitigation, but most of the studies concentrate on developed nations and major economic cities. Congestion control techniques appropriate for rapidly expanding cities in emerging countries have not received much attention. Furthermore, more research is needed to fully understand how intelligent transportation systems can be integrated with conventional traffic management techniques. Furthermore, only a small number of studies have looked at congestion management techniques designed especially for medium-sized cities in developing nations. As a result, a thorough analysis that finds workable solutions that may be implemented quickly in urbanising cities and outlines congestion management strategies is required.

9. Conclusion

Globally, traffic congestion has grown to be a major problem for metropolitan transportation systems. In many cities, the issue of traffic congestion is getting worse due to factors like rapid population growth, rising car ownership, and inadequate road infrastructure. In addition to decreasing travel efficiency, congestion raises fuel consumption, pollutes the environment, and causes financial losses.

This review analysed several congestion management strategies put out in earlier research and looked at the main causes of traffic congestion. This literature highlighted a number of congestion management techniques, such as intelligent transportation systems, managed lane services [11], improved public transportation, and traffic signal optimisation [6,15], which can help reduce congestion.

The success of these strategies is dependent on traffic patterns (like congestion differs on weekends and weekdays [16] and it moves out to the suburbs of growing metropolises [17]), infrastructure and the

implementation of policies. As a result, urban transportation planners prefer the integration of congestion management techniques that blend traffic management technologies with infrastructure development.
To meet the growing demand for urban mobility while reducing traffic congestion and environmental effects, future research should focus on creating more effective traffic prediction models, like the coordination of autonomous and linked vehicles [19], and sustainable transportation policies. The urban transportation planning should concentrate on integrating intelligent transportation systems, data-driven traffic monitoring and sustainable mobility solutions to efficiently reduce congestion in fast-expanding urban areas.

10. References/Bibliography

1. Çolak, S., Lima, A., & González, M. C. (2016). Understanding congested travel in urban areas. Nature Communications, 7. https://doi.org/10.1038/ncomms10793
2. Afrin, T., & Yodo, N. (2020). A Survey of Road Traffic Congestion Measures towards a Sustainable and Resilient Transportation System. *Sustainability*, *12*(11), 4660. https://doi.org/10.3390/su12114660
3. Talukdar, M. H. (2013). Framework for traffic congestion management. *Economia. Seria Management*, *16*(1), 54-64.
4. Choudhary, A., & Gokhale, S. (2016). Urban real-world driving traffic emissions during interruption and congestion. Transportation Research Part D: Transport and Environment, 43, 59–70. https://doi.org/10.1016/j.trd.2015.12.006
5. Thakur, S. (2016). A Review of Traffic Congestion Problem and Various Automated Traffic Measurement Sensors and Techniques. Indian Journal of Science and Technology, 9(1), 1–16. https://doi.org/10.17485/ijst/2016/v9i47/106902
6. Taher, Y. H., Mandeep, J. S., Marhoon, H. A., Al-Jamimi, H. A., Luqman, H., Azzedin, F., Abdullah, M., Al-Ahmadi, H. M., & Yaseen, Z. M. (2025). Traffic Congestion Estimation and Control: A Comprehensive Review of the Applied Computational Intelligence Models. In Archives of Computational Methods in Engineering. Springer Science and Business Media B.V. https://doi.org/10.1007/s11831-025-10311-x
7. American Association of State Highway and Transportation Officials National Cooperative Highway Research Program The Next Step in Congestion Management. (2007). www.international.fhwa.dot.gov
8. F. Bolte. “Transport Policy Objectives: Traffic Management as Suitable Tool,” Federal Highway Research Institute (BASt), Bergisch-Gladbach, Germany, Presentation to Planning for Congestion Management Scan Team,June 2006.
9. A. Pilz. “Presentation of the Traffic Centre Hessen.” Hessian Ministry of Economy and Transport, Frankfurt, Germany, Presentation to PCM Scan Team, June 2006.
10. “Creative ways to beat congestion.” BBC News World Edition, November 2004, BBC News Web site, http://news.bbc.co.uk/2/hi/uk_news/magazine/4044803.stm.
11. S. Tignor, L. Brown, J. Butner, R. Cunard, S. Davis, H. Hawkins, E. Fischer, M. Kehrli, P. Rusche, and W.Wainwright. Innovative Traffic Control Technology and Practice in Europe. Federal Highway Administration,Washington, DC, August 1999.
12. D. Differt, W. Berman, K. Aufschneider, P. DeCorla-Souza, A.Flemer, L. Hoang, R. Hull, E. Schreffler, G. Zammit.Managing Travel Demand: Applying European Perspectives to U.S. Practice.

Federal Highway Administration, Washington, DC, May 2006.
13. Hussain, D., Jamal, A., Farooq, A., Almoshaogeh, M., Alharbi, F., & Farooq, D. (2026). Evaluation of traffic congestion mitigation techniques using an entropy-TOPSIS integrated method. Scientific Reports. https://doi.org/10.1038/s41598-026-35814-w
14. Li, Y., Zhao, Q., & Wang, M. (2025). High-resolution traffic flow data from the urban traffic control system in Glasgow. Scientific Data , 12(1). https://doi.org/10.1038/s41597-025-04494-y
15. Guo, M., Wang, P., Chan, C. Y., & Askary, S. (2019, October). A reinforcement learning approach for intelligent traffic signal control at urban intersections. In 2019 IEEE Intelligent Transportation Systems Conference (ITSC) (pp. 4242-4247). IEEE.
16. Parkavi, S., & Parthiban, A. (2025). Assessing urban traffic congestion for sustainable transportation in Chennai, India: a case study of Kathipara and T. Nagar intersections. Frontiers in Sustainable Cities, 7. https://doi.org/10.3389/frsc.2025.1684489
17. Lampo, A., Borge-Holthoefer, J., Gómez, S., & Solé-Ribalta, A. (2021). Emergence of spatial transitions in urban congestion dynamics. https://doi.org/10.1007/s41109-021-00383-6
18. Elbasha, A. M., & M. Abdellatif, M. (2025). AIoT-Based Smart Traffic Management System. 69–77. https://doi.org/10.5121/csit.2024.150204
19. Mahbub, A. M. I., Zhao, L., Assanis, D., & Malikopoulos, A. A. (2019). Energy-Optimal Coordination of Connected and Automated Vehicles at Multiple Intersections. https://doi.org/10.23919/ACC.2019.8814877
20. European Conference of Ministers of Transport, ECMT (1999), Report of the Hundred and Tenth Round Table on Transport Economics held in Paris on 12 -13" March 1998 on Centre,The following topic: Traffic Congestion in Europe, Paris: Economic Research European Conference of Ministers of Transport.