Journal of Advanced College of Engineering and Management

A Multi-Faceted Approach to Urban Congestion in Developing Nations: Theory, Practice, and the Kathmandu Experience

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DOI: 10.3126/jacem.v11i1.84536

Abstract

Urban traffic congestion poses a critical barrier to sustainable development in rapidly urbanizing regions, particularly in the Global South. This review examines the theoretical foundations of congestion, outlining core metrics and classical models, and assesses a range of mitigation strategies implemented in developing countries. Drawing on international case studies including Delhi, Dhaka, Lagos, and Nairobi, the article analyzes the effectiveness of infrastructure expansion, traffic management innovations, and public transport reforms. Kathmandu Valley serves as a focal case, exemplifying how rampant motorization, inadequate infrastructure, and fragmented governance contribute to chronic congestion. Despite some efforts in signal optimization and public transport modernization, systemic challenges persist. Comparative insights reveal that enduring congestion mitigation requires a multimodal, data-driven approach that encompasses intelligent traffic systems, public transit investment, and institutional reform. The paper concludes with tailored policy recommendations for Kathmandu, emphasizing the need for coherent, scalable, and locally responsive mobility strategies.

Keywords*—Urban Congestion, Developing Countries, Kathmandu Valley, Public Transport, Intelligent Traffic Management, Institutional Reform, Multimodal Mobility*

1. INTRODUCTION

Urban congestion arises when travel demand exceeds the capacity of transportation infrastructure, resulting in reduced speeds, longer travel times, and vehicle queuing [1]. While congestion affects cities globally, it is especially acute in low- and middle-income countries (LMICs), where urbanization frequently outpaces infrastructure development [2]. Congestion stems from both recurrent patterns, such as peak-hour traffic, and non-recurrent incidents like road accidents and construction [3]. Localized urban factors, including land use patterns, street connectivity, intersection layout, and public transport accessibility, significantly influence congestion dynamics [4].

Emerging tools, including real-time bottleneck identification using spatiotemporal data, have shown promise in addressing these challenges [5]. In LMICs, the impacts of congestion are particularly severe: it undermines economic productivity, impedes access to services, and disproportionately burdens marginalized populations [6]. Moreover, increased vehicular emissions contribute to environmental degradation and adverse health outcomes—issues compounded by weak traffic management and limited investment capacity [7], [8]. Tackling these multifaceted challenges requires integrated, data-driven, and equity-focused planning strategies [2].

The intensification of global trade and foreign investment has further accelerated urbanization in many developing countries. Cities that have evolved into regional economic hubs, such as Shanghai and Dubai, attract multinational enterprises, migrant workers, and infrastructure development, all of which heighten travel demand. Without proportional investment in public transport or congestion management, this growth can overwhelm existing road systems and exacerbate traffic congestion (see Figure 1).

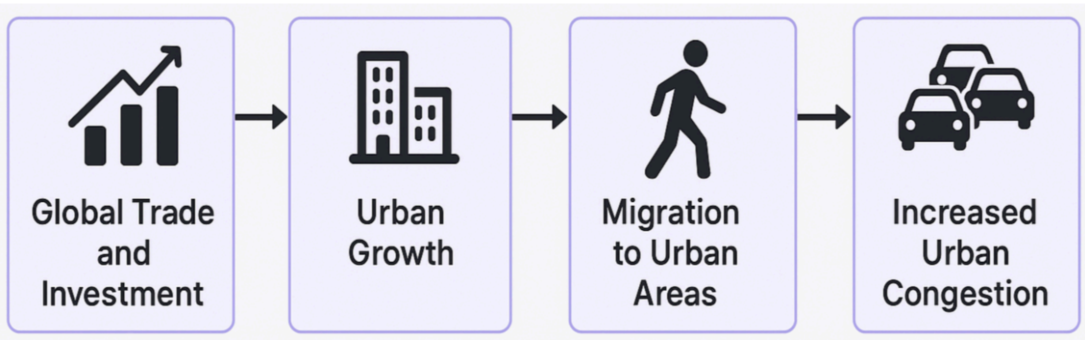

Figure 1: Link between global trade, urban growth, and increased urban congestion

Globally, urban congestion imposes significant economic and environmental costs, particularly in Southeast Asian cities like Jakarta and Manila. These cities experience daily delays that translate into billions of dollars in lost productivity [9]. In Manila, commuters lose over 70 minutes daily due to traffic [10]. Congestion also worsens fuel consumption and air pollution, elevating rates of respiratory illness and premature mortality [7], [10]. The recent surge in e-commerce has exacerbated last mile inefficiencies, with delivery vehicles losing up to 200 hours annually to traffic delays [10]. These patterns contribute to rising greenhouse gas emissions and increase vulnerability to climate change [11].

In response, cities have deployed congestion pricing, expanded transit systems, and improved urban freight logistics, all with measurable success [8], [12]. Without timely intervention, LMICs risk escalating environmental, fiscal, and social consequences [9]. Despite growing theoretical consensus around integrated planning and intelligent traffic systems, practical implementation in many LMIC cities remains limited. Common barriers include fragmented governance, poor data availability, limited financial resources, and resistance to policy innovations such as congestion pricing [13]–[15]. Informal transport systems, inadequate public transit, and institutional overlap further constrain reform of this sector [14], [16].

Kathmandu exemplifies these dynamics. Over the past decade, vehicle ownership in the valley has risen by more than 300%, overwhelming an already constrained and deteriorating road network [17]. Weak traffic control, institutional fragmentation, and minimal investment in public transit have resulted in chronic congestion, significant economic loss, and severe air pollution [18], [19]. While Kathmandu's traffic index remains lower than some larger global cities, recent data show that LMIC cities, including Lagos, Dhaka, Nairobi, and Delhi, experience disproportionately high congestion levels (see Figure 2). Although cities like Los Angeles and San Francisco face high congestion, LMICs typically lack the infrastructure and institutional capacity to manage the issue effectively. Kathmandu's current trajectory indicates a rising risk of system-wide mobility failure unless bold, coordinated interventions are enacted.

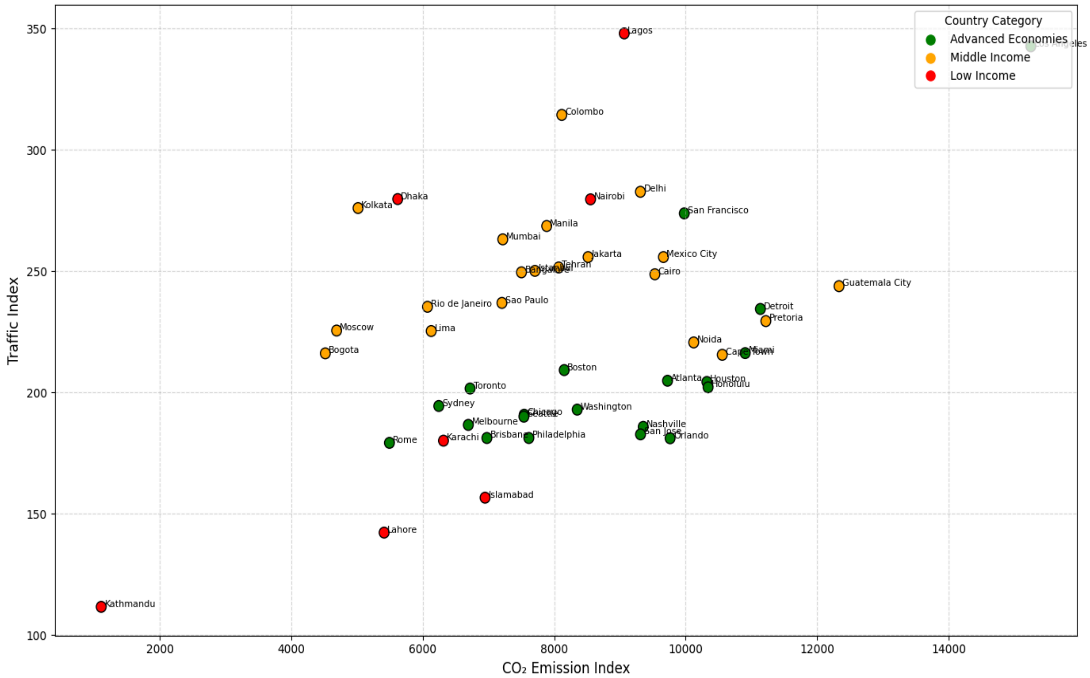

Figure 2: Traffic and CO2 Emission Indices Across Cities by Economic Category, Data from: [20]

This paper examines the theoretical foundations of congestion, reviews global mitigation practices, and assesses the current challenges of Kathmandu. Drawing comparative insights from cities of developing countries, it proposes an integrated, locally adaptive strategy for congestion management, emphasizing institutional reform, multimodal planning, and data-driven governance.

2. THEORETICAL FOUNDATIONS OF URBAN CONGESTION

A. Definitions and Key Metrics

Urban congestion refers to a condition in which transportation demand persistently exceeds infrastructure capacity, resulting in slower speeds, longer travel times, and increased queueing. Although typically associated with road networks, congestion also affects public transit systems and pedestrian infrastructure, especially in compact urban environments. To evaluate and compare the severity of congestion, several key metrics are widely used in transportation research and practice. Together, these metrics form a robust analytical framework to diagnose congestion, guide infrastructure planning, and evaluate mitigation outcomes.

- Travel Time Index (TTI): This metric captures the ratio of travel time during peak hours to that under free-flow conditions. It is defined as:

$$TTI = \frac{T_{peak}}{T_{free-flow}}$$

  A TTI of 1.5 means that peak-hour travel takes 50% longer than under free-flow conditions [21].
- Volume-to-Capacity Ratio (V/C): This measures roadway saturation, with values approaching or exceeding 1.0 indicating severe congestion, where V is the actual traffic volume and C is the road's design capacity [22].
- Level of Service (LOS): A qualitative classification ranging from A (free flow) to F (gridlock), LOS reflects user comfort and operating efficiency.
- Additional indices such as the Roadway Congestion Index (RCI), Lane-Mile Duration Index (LMDI), and Speed Reduction Index provide further granularity, accounting for spatial extent, delay duration, and travel time deviation from optimal conditions [23].

Together, these metrics form a robust analytical framework to diagnose congestion, guide infrastructure planning, and evaluate mitigation outcomes.

B. Classic Theories and Models

The study of congestion is grounded in both microscopic and macroscopic traffic flow theories, which model vehicle behavior at different levels of aggregation.

Microscopic Models: Microscopic models focus on individual driver behavior, particularly how drivers adjust speed and spacing in response to the vehicle ahead. Car-following models—such as those by Pipes, General Motors, and Newell—simulate acceleration and deceleration dynamics based on reaction time and desired headway [24]. For example, Newell's model assumes that each vehicle maintains a minimum gap and adjusts speed based on the leader's motion [24]. These models are critical for traffic simulation tools and are widely used in signal timing and safety studies.

Queuing Theory: Queuing theory treats congestion as a service delay problem, analyzing vehicle arrivals and departures at bottlenecks such as intersections or toll plazas. It is particularly useful for estimating delays, queue lengths, and optimal signal timings under varying demand scenarios [25].

Macroscopic Models: Macroscopic models view traffic as continuous flow, analogous to fluid dynamics, characterized by aggregate variables such as density, speed, and flow rate. The fundamental diagram of traffic flow illustrates the nonlinear relationship between these parameters and is foundational in large-scale traffic modeling [26].

Microscopic and macroscopic models are often interrelated: driver behaviors modeled at the micro level underpin aggregate flow patterns observed in macro models [26], [27]. Together, these theoretical approaches enable practitioners to simulate, analyze, and predict traffic behavior in various scenarios, forming both infrastructure design and operational control strategies.

3. REVIEW OF CONGESTION REMEDIAL MEASURES

A. Infrastructure-Based Interventions

Infrastructure expansion is one of the most commonly adopted responses to congestion in developing countries. Projects such as road widening, flyover construction, and ring road development aim to increase capacity and reduce bottlenecks. While these measures offer initial relief, their long-term effectiveness is often limited.

Road widening is frequently undermined by rapid urbanization, informal street encroachment, and illegal parking, which quickly consume added capacity [28]. Flyovers can reduce intersection delays by separating traffic streams, but without integrated planning, they may simply shift congestion downstream [29]. Ring roads, like those in Tripoli and Nairobi, aim to divert through-traffic from central areas but depend heavily on land use regulation and enforcement against informal development along new corridors.

Despite large capital investments, infrastructure-based solutions alone often fail to resolve congestion due to poor maintenance, weak enforcement, and limited integration with public transit and travel demand management [30]. In many cases, added capacity induces more travel demand, a phenomenon known as "induced traffic," which can reintroduce congestion over time. As a result, infrastructure investments must be part of broader, multimodal urban mobility strategies..

B. Urban Planning Integration

Integrating land use planning with transportation systems is increasingly recognized as essential for sustainable congestion management. Transit-oriented development (TOD), characterized by high-density, mixed-use urban forms around public transit nodes, can reduce trip lengths and encourage modal shift away from private vehicles [2].

Cities adopting integrated planning approaches promote pedestrian-friendly environments and prioritize access to public transit. The use of geospatial tools and real-time data supports proactive identification of congestion hotspots and facilitates decentralized traffic interventions [5]. However, in rapidly expanding cities, implementation is hindered by fragmented governance, limited technical capacity, and poor data availability [6]. Addressing these challenges requires collaborative governance frameworks, investments in local planning expertise, and planning models tailored to local socioeconomic contexts.

C. Traffic Management and Control

Traffic control measures remain foundational in cities with constrained infrastructure and budgets. Conventional tools, such as signal optimization, roundabouts, and lane management, can significantly reduce delays when strategically deployed. Coordinated signal timing along major corridors enhances traffic flow and reduces emissions. Roundabouts improve safety and throughput, particularly in moderate-density areas with high turning volumes [31]. Dedicated lanes for buses or high-occupancy vehicles (HOVs) help prioritize efficient modes and incentivize shared travel.

The adoption of Intelligent Transportation Systems (ITS) is expanding, even in low-resource settings. Cities like Dhaka, Nairobi, and Bangalore have introduced adaptive signal control, real-time surveillance, and mobile data collection using GPS and CCTV technologies [32], [33]. These systems have shown to reduce delays and increase average vehicle speeds. Nonetheless, implementation remains uneven. Funding constraints, limited technical capacity, and fragmented institutional authority often hinder scaling ITS solutions [28]. Effective traffic management also requires public awareness, enforcement, and inter-agency coordination.

D. Public Transport Enhancement

Expanding and modernizing public transport is central to long-term congestion mitigation. Bus Rapid Transit (BRT) systems, used in cities such as Bogota, Jakarta, Dar es Salaam, and Lagos, offer higher capacity and faster service through dedicated lanes and limited stops [28], [34]. These systems have reduced travel times and improved access to jobs and services, though challenges like overcrowding and inconsistent service quality persist [35].

Rail-based transit (e.g., metro or light rail) provides higher capacity but is often prohibitively expensive for many developing cities. As a result, optimizing existing bus systems, through rationalized routing, improved frequency, and fare integration, remains a practical strategy. As shown in Figure 3, the line capacity of metro systems can reach up to 50,000 passengers per hour per direction (PPHPD), significantly surpassing other modes such as Bus Rapid Transit (15,000 PPHPD) and conventional buses (4,000 PPHPD). Intermediate options like trackless trams and light rail transit offer moderate capacities of 20,000 and 13,000 PPHPD respectively, providing a trade-off between scalability and infrastructure cost. To determine which system is most appropriate for a given urban context, cities must first evaluate current and projected travel demand. Based on these forecasts, a comprehensive cost-benefit analysis should be conducted to identify the most feasible and sustainable mass transit solution.

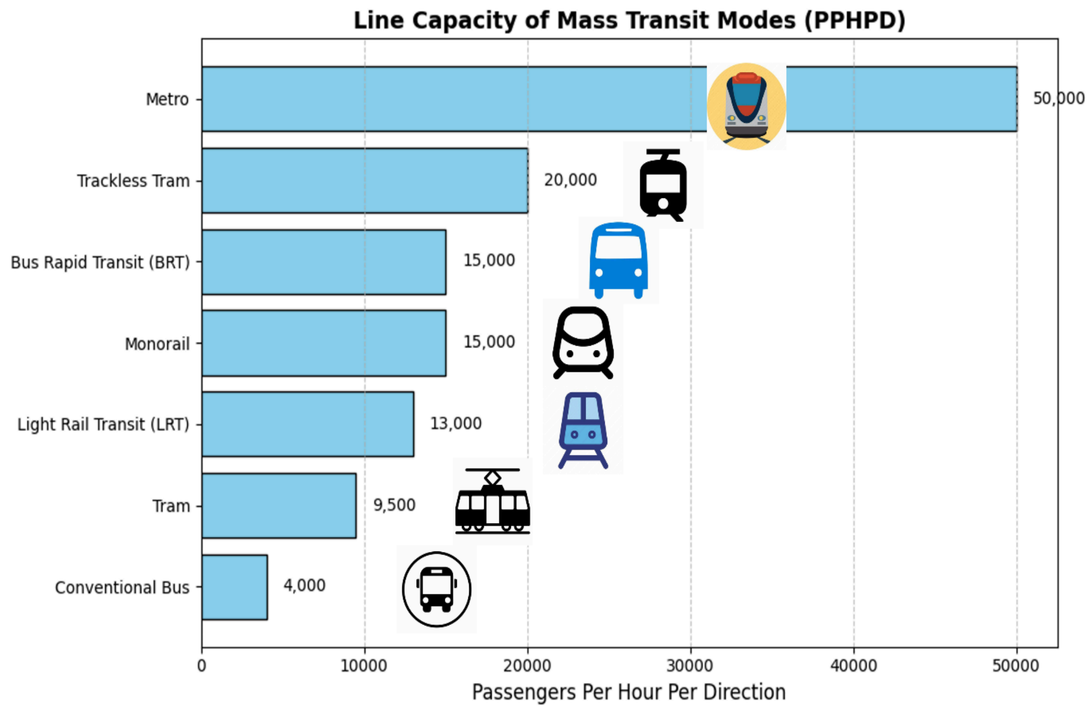

Figure 3: Line capacity (PPHPD) of transit modes

Non-motorized transport (NMT) infrastructure, such as sidewalks, bike lanes, and pedestrian crossings, is equally important. Well-integrated NMT networks support first- and last-mile connectivity, reduce car dependency, and improve health outcomes. Investment in walkability and cycling must be prioritized alongside public transport to ensure inclusive, sustainable mobility.

E. Technology-Driven Approaches

Technology is playing an increasingly transformative role in congestion management. Geographic Information Systems (GIS) allow cities to map congestion hotspots, model traffic patterns, and develop real-time interventions [36], [37]. Cloud-based GIS platforms also facilitate public access to traffic information and support participatory planning. Artificial Intelligence (AI) and Machine Learning (ML) techniques are used to predict congestion, optimize traffic signal timing, and allocate resources dynamically. These technologies process vast datasets from sensors, GPS devices, and mobile apps to deliver adaptive control strategies [38].

Crowd-sourced platforms, such as Waze or Google Maps, allow users to share real-time updates, enabling more responsive route planning. Smart card systems in public transit offer not only efficient fare collection but also valuable data on travel behavior, which can be used to refine service planning [37]. Despite their promise, these solutions face constraints in funding, data governance, and technical capacity. Pilot programs in cities in Asia and Africa show that incremental, locally adapted deployments of technology can yield significant results, particularly when combined with broader mobility reforms.

4. GLOBAL BEST PRACTICES IN URBAN CONGESTION MANAGEMENT

Urban congestion management in low- and middle-income countries has evolved through a combination of smart technologies, sustainable infrastructure investments, and strategic planning. Cities across Asia, Africa, and beyond have piloted diverse initiatives many of which offer valuable lessons for Kathmandu.

A. Technology and Innovation

Cities like Yogyakarta (Indonesia) and Bandar Seri Begawan (Brunei) have leveraged smart technologies to improve urban mobility. Yogyakarta introduced an air-conditioned urban bus fleet with smart card ticketing and integrated it with airport train systems, promoting modal shift from private vehicles. Bandar Seri Begawan has advanced a multi-modal transportation master plan featuring walking, biking, trams, and light rail systems. Singapore is a global leader in traffic innovation. Its electronic road pricing (ERP) and vehicle quota system reduced road traffic by 40%, increased public transport share by 20%, and significantly improved air quality [13], [39]. Real-time traffic monitoring and adaptive signal control further support efficient traffic management.

B. Public Transport Infrastructure Investment

Large-scale investments in public transport have played a central role in managing congestion across major Asian cities. In Bangkok, the expansion of the BTS Skytrain and MRT networks has helped reduce car dependency while improving overall accessibility. Jakarta has implemented the TransJakarta Bus Rapid Transit (BRT) system and is also investing in monorail and metro projects to provide high-capacity transit alternatives. Similarly, both Ho Chi Minh City and Hanoi are constructing metro and BRT lines to shift commuters away from motorcycles. Notably, Hanoi has set an ambitious goal of achieving a 65% public transport modal share by 2030. These investments have contributed to increased ridership, shorter travel times, and enhanced air quality, although challenges persist in achieving seamless multimodal integration and improving last-mile connectivity [13].

C. Transit-Oriented Development and Land Use Integration

Transit-Oriented Development (TOD) policies aim to reduce commute distances and encourage sustainable travel. Cities like Manila (Philippines) and Kuala Lumpur

(Malaysia) promote high-density, mixed-use development along transit corridors [13]. This has supported greater public transport use and reduced reliance on private vehicles.

D. Congestion Pricing and Demand Management

Congestion pricing has shown strong results in cities such as Singapore, Stockholm, and London. These programs have reduced traffic volumes by 16–45%, boosted public transport ridership, and significantly lowered emissions [13], [40]. Importantly, revenue from congestion charges is often reinvested into public transit and pedestrian infrastructure, creating a positive feedback loop. However, successful implementation requires strong political will, public support, and robust enforcement mechanisms.

E. Integrated Multimodal Planning

Several cities have adopted holistic mobility plans that integrate multiple transport modes to address urban congestion more effectively. Seoul (South Korea) has implemented an integrated fare system that connects buses, metro services, and shared mobility options, promoting seamless travel across the network [41]. In Curitiba (Brazil), a structured Bus Rapid Transit (BRT) system is strategically aligned with land use zoning to guide urban growth and enhance accessibility [42]. Bogota (Colombia) complements its BRT infrastructure with protected bicycle lanes and enforces a car-free day policy to encourage modal shifts [43]. These examples illustrate that congestion cannot be resolved through infrastructure expansion alone. Instead, integrated planning reinforced by institutional reforms, public engagement, and data-informed decision-making forms the foundation for sustainable and long-term mobility improvements.

5. INSTITUTIONAL AND POLICY FRAMEWORK FOR CONGESTION MANAGEMENT IN KATHMANDU

A. Current Scenario

Kathmandu, or the Kathmandu Valley, comprises 18 municipalities across three districts: Kathmandu, Bhaktapur, and Lalitpur. Kathmandu faces a severe and worsening congestion crisis driven by rapid population growth and an unchecked increase in vehicle ownership. With a population nearing 3 million, and more than 1.8 million registered vehicles—growing by 80,000 to 100,000 annually—the city's road infrastructure is under immense strain [44], [45]. Daily traffic often exceeds the capacity of Kathmandu's narrow and aging road network, with average cross-city journeys frequently taking over an hour [17], [46]. According to studies by the Japan International Cooperation Agency (JICA), as of December 2011–January 2012, traffic volumes at 19 of 30 surveyed sites in Kathmandu Valley had already exceeded capacity, with six out of ten intersections fully saturated; furthermore, most traffic signals were either non-functional or manually operated, and pedestrian infrastructure remained critically inadequate [47], [48]. However, in recent years, a significant number of traffic signals have been installed, albeit in isolation. Notably, Lalitpur Metropolitan City has recently implemented ITS-based signals at five intersections.

The economic cost of congestion is staggering, estimated at NPR 116 billion (around USD 880 million) annually, accounting for lost productivity, fuel wastage, health costs, and accidents [49]. Fuel inefficiency due to idling and start-stop traffic further compounds fiscal losses. Environmental impacts are equally severe. Kathmandu has seen a 28% increase in transport-related carbon emissions, and PM2.5 levels are more than seven times WHO-recommended limits [50], [51]. Respiratory illnesses and noise pollution have also intensified, while traffic-related accidents average nearly 40 per day. Road crashes represent a critical concern in Kathmandu Valley, accounting for up to 60.5% of Nepal's total crashes and imposing an annual economic burden exceeding NRs. 1.8 billion, underscoring the urgent need for targeted safety interventions [52].

Nepal's vehicle fleet grew to 5.2 million by 2022, with a disproportionate concentration in the Kathmandu Valley. Although the national motorization index remains moderate (125 vehicles per 1,000 people), its rate of increase is among the highest in Asia, second only to China [53]. The transport sector accounts for 44% of Nepal's fuel combustion emissions, with 99% of that from road transport [54]. While Nepal's electricity grid is now largely powered by hydropower (25 kg CO_2/MWh), the shift toward electric vehicles (EVs) has been slow [55]. Despite national EV targets, such as reaching 90% of new private vehicle sales by 2030, electrification alone will not solve congestion. Without investments in public transport, modal integration, and urban planning, Kathmandu risks cleaner but equally gridlocked streets. According to the data obtained from the Department of Transport Management (DoTM), private two-wheelers have consistently made up over 80% of new vehicle registrations since 2005/06. Meanwhile, the share of public transport vehicles declined from 5.22% in 2003/04 to just 1.19% in 2021/22. This imbalance is shown in Figure 4. This over-reliance on private vehicles, particularly motorbikes, has led to worsening congestion, air pollution, and fuel dependency. To move toward equitable and sustainable mobility, Nepal must urgently reverse this trend by reinvesting in public transport infrastructure.

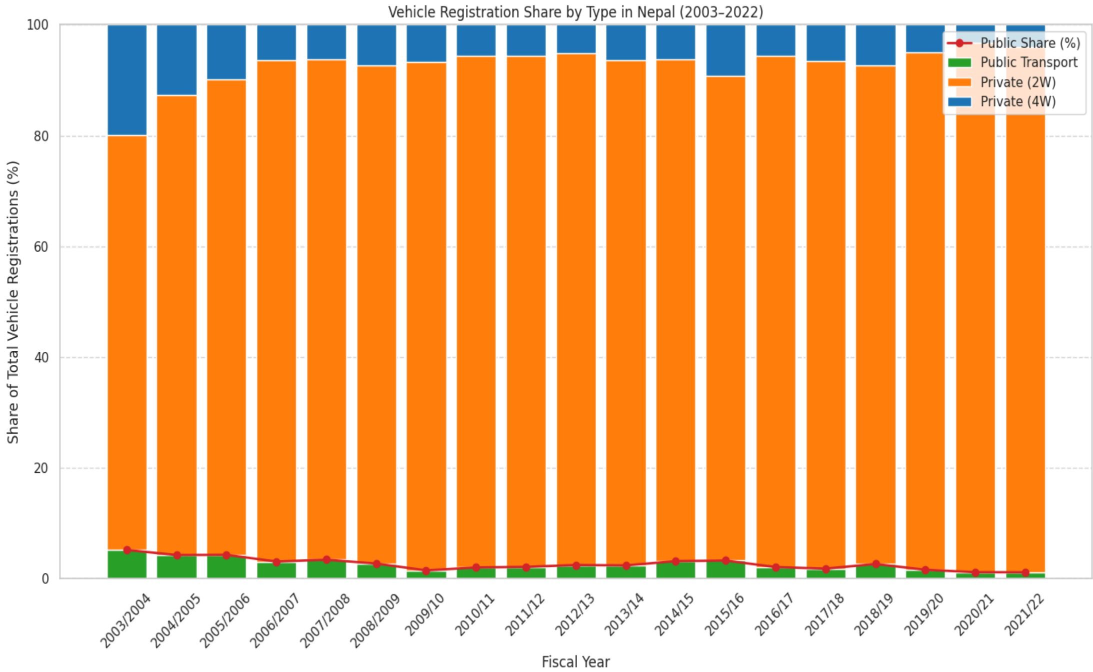

Figure 4: Vehicle registration share by type in Nepal (2003–2022). Source: Department of Transport Management

B. Recent Interventions for Congestion Mitigation in Kathmandu

Kathmandu has undertaken several interventions to mitigate growing traffic congestion, focusing on road capacity expansion, traffic signal upgrades, intersection-level redesigns, pedestrian improvements, and limited public transport reforms.

Road Infrastructure Projects

The expansion of the 27-kilometer Ring Road is the city's flagship infrastructure project, designed to divert through-traffic away from the congested urban core. The first phase, widening the Koteshwor–Kalanki section to eight lanes, was completed in 2018. However, the absence of dedicated pedestrian, cycling, and public transport facilities has significantly limited its effectiveness. The second phase, extending from Kalanki to Maharajgunj, has been delayed by utility relocation, land acquisition, and funding hurdles, leaving key segments unmanaged, congested, and pollution-prone [56], [57].

Complementary infrastructure interventions, such as intersection reconfiguration at New Baneshwor and Lainchaur led by JICA in coordination with the Department of Roads, have helped address localized congestion issues to some extent [58]. However, these isolated improvements often shift congestion to upstream or downstream intersections and fail to offer long-term systemic solutions. Hence, a comprehensive, network-wide planning approach is essential.

Another intervention is the recently inaugurated overpass at Gwarko in Lalitpur [59], constructed to alleviate chronic traffic congestion along the Koteshwor–Gwarko–Kalanki corridor, one of the busiest routes in the Kathmandu Valley. Initiated in February 2022 under an EPC (Engineering, Procurement, and Construction) contract, the project faced several delays due to design modifications and intermittent construction halts. Despite the setbacks, officials anticipate that the four-lane overpass will reduce bottlenecks at the intersection. However, to evaluate its effectiveness fully, it is crucial to monitor traffic performance at neighboring intersections post-construction to ensure the intervention does not simply displace congestion. Although the plan to construct underpasses or overpasses at Satdobato and Ekantakuna was conceived in 2019, it has not progressed due to a lack of budget assurance and limited experience in managing urban traffic in work zones, as highlighted by the challenges faced during the Gwarko flyover project. Similarly, the Department of Roads has conducted a feasibility study for an underpass at the New Baneshwor intersection, but this project has also seen no signs of initiation, again due to budget constraints.

While several intersection-level interventions, such as the installation of median blocks and traffic islands, have been implemented across the valley in a piecemeal manner, their impact has been limited. Many intersections continue to suffer from significant congestion due to poor geometric design, particularly the lack of dedicated right-turn lanes. This often forces right-turning vehicles to encroach into opposing traffic lanes, causing further disruption to traffic flow and undermining the effectiveness of these localized improvements.

Traffic Signal Management

A major initiative in traffic signal modernization began in 2003 through Japanese grant aid, which enabled the installation of traffic lights at nine intersections. Since then, additional signals have been installed with funding from the Department of Roads (DoR) and private sector contributions. Currently, traffic signals are operational at 39 intersections, most of which are controlled centrally by the Kathmandu Valley Traffic Police Office (KVTPO). However, inefficiencies remain prevalent as signal timing relies heavily on real-time manual inputs from traffic police rather than data-driven traffic analysis. This has led to frequent mismatches between signal phases and actual traffic conditions, thereby reducing system effectiveness.

In 2015, the Kathmandu Sustainable Urban Transport Project (KSUTP) developed plans to review and upgrade 22 intersections and install traffic lights at 44 new locations. Unfortunately, these efforts stalled due to unsuccessful bidding and lack of funding. Similarly, the Department of Roads initiated the Kathmandu Valley Traffic Signal Project, which has completed its initial study phase, but subsequent implementation remains stalled.

Lalitpur Metropolitan City has more recently taken the lead in technological upgrades by installing smart, ITS-based signal systems at five key intersections [63]. Despite these initiatives, most signalized intersections in the Kathmandu Valley remain manually operated and are often turned off during peak hours, requiring direct management by traffic police. These signals are typically isolated and installed by different agencies, including local bodies, using basic preset time-based systems. However, due to highly variable traffic volumes and complexity, preset signals are generally ineffective. Recent studies suggest that selective synchronization and adaptive signal timing can reduce peak-hour delays by up to 40%, while also lowering fuel consumption and emissions [60]–[62]. Given these insights, a centrally coordinated system governed by a modern traffic control center using the latest Intelligent Transport Systems (ITS) technologies is of utmost importance for the effective implementation of smart traffic management in the Kathmandu Valley.

A promising pilot initiative under JICA's 2023 Project for the Introduction of Urban Transport Management in the Kathmandu Valley involved comprehensive upgrades at the New Baneshwor intersection. Improvements included dedicated right-turn lanes, median installations, and signal optimization based on real-time congestion lengths. This intervention demonstrated a substantial reduction in congestion and offers a replicable model for future intersection design.

Pedestrian Infrastructure Improvements

Pedestrian infrastructure has also seen incremental improvements. Push-button pedestrian signals have been installed at 36 intersections [64], [65], and both Kathmandu and Lalitpur Metropolitan Cities have engaged in the construction and rehabilitation of existing footpaths. Although expanding footpath width remains constrained by urban space limitations and roadside encroachments, efforts to improve surface quality, ensure continuity, and enhance maintenance have improved pedestrian safety and convenience.

The Department of Roads has also begun integrating basic pedestrian facilities into new road projects. Moreover, despite limited maintenance budgets, the rehabilitation of footpaths is increasingly prioritized alongside carriageway upgrades, marking a gradual but important shift toward more inclusive, pedestrian-friendly urban transport planning.

Public Transport Reforms and Pilots

On the public transport front, reforms include expanding the Sajha Yatayat fleet, introducing electric buses, and modernizing vehicle amenities. However, the absence of a dedicated mass transit system, such as Bus Rapid Transit (BRT) or metro, continues to hinder a significant modal shift from private vehicles [65]. Although various studies, including one conducted as far back as 2012, have recommended mass transit development, implementation remains elusive.

In response to inefficiencies in the public transport system, the Government of Nepal launched the Express Bus Service along the Suryabinayak–Ratnapark corridor. Following a feasibility study by a PMO-formed task force in April 2023, the Department of Roads was assigned to design a dedicated lane, and the Department of Transport Management coordinated with bus operators. Launched on September 20, 2023, the system introduced red-painted, peak-hour dedicated lanes (9–11 AM and 4–6 PM), aiming to reduce travel times from 90 to 45 minutes and offer a safer, more efficient, and environmentally friendly transit alternative. However, due to weak enforcement and other technical reasons, the exclusive lanes were used by other private vehicles undermining their effectiveness. Flexible use of these lanes by private vehicles has reduced the system's reliability. Despite these challenges, the initiative represents a significant step toward modernizing Kathmandu's transit system by piloting public transport prioritization and learning from real-world implementation.

C. Institutional and Policy Landscape

Kathmandu's efforts to mitigate traffic congestion are heavily shaped by its fragmented institutional framework. Governance responsibilities are dispersed across a wide array of agencies, including the Ministry of Physical Infrastructure and Transport, the Department of Roads, Kathmandu and Lalitpur Metropolitan Cities, the Kathmandu Valley Development Authority, the Ministry of Urban Development, the Department of Urban Development and Building Construction, and the Metropolitan Traffic Police Division. This overlap in jurisdiction has resulted in duplicated efforts, inconsistent execution, and frequent delays in implementing key initiatives such as signal upgrades, road expansion, and public transport reforms [48], [67].

Decentralization has allowed Kathmandu Metropolitan City (KMC) and Lalitpur Metropolitan City to assume greater responsibility in managing local traffic systems. Both municipalities have installed push-button pedestrian signals, implemented one-way street conversions, and prioritized pedestrian safety in recent years [64], [68]. Local authorities argue that municipal control enhances responsiveness and adaptability to urban mobility needs. However, their effectiveness is frequently constrained by limited financial autonomy and weak alignment with national-level policies. In response to the growing need for coordinated governance, the Federal Capital City Public Transportation Authority (FCCPTA) was recently established. The Authority is chaired by the Mayor of KMC, with the Mayor of Lalitpur Metropolitan City serving as Vice Chairman, reflecting an encouraging shift toward inter-municipal collaboration and integrated planning.

Despite these institutional developments, enforcement remains a persistent weakness. Although some improvements in traffic rule compliance have been observed, widespread violations, including unauthorized parking, frequent VIP convoy disruptions, and general non-compliance, continue to undermine traffic flow. Signal failures frequently force traffic police to revert to manual control, negating the benefits of automation. Moreover, the absence of sustained public awareness campaigns and limited enforcement capacity further reduce the system's overall effectiveness [64], [68].

Coordination challenges among agencies, exacerbated by siloed decision-making and undefined mandates, have delayed key infrastructure and policy initiatives. Nevertheless, recent collaborative dialogues between the Ministry of Urban Development and municipal officials indicate growing recognition of the need for integrated mobility planning. These dialogues have explored innovative solutions such as urban cable car systems, podways, and grade-separated intersections, highlighting a willingness to think beyond conventional road infrastructure [64], [68].

On the policy front, significant reforms are underway. New frameworks propose nationwide modernization of traffic signals, stricter enforcement mechanisms, and the establishment of a dedicated Road Safety Fund, to be managed by the National Road Safety Council. This fund aims to support accident response and emergency medical treatment [44], [69]. These policy shifts signal a broader movement toward more structured, accountable, and technology-enabled urban transport governance.

One of the most promising policy advancements is the enactment of the Urban Area Public Transport (Management) Authority Act in 2022. The FCCPTA legal framework was introduced by the Government of Nepal to facilitate the creation of dedicated public transport authorities responsible for regulating and managing services in urban areas. The Act aims to promote a safe, accessible, reliable, and user-focused transport system by encouraging integrated network planning and enhancing inter-agency coordination. Under the Act, a Public Transport Authority can be formed to cover one or more municipalities and is to be chaired by the mayor of the largest municipality in the service area. In the case of the federal capital, the Federal Capital Urban Area Public Transport Council, led by the Mayor of Kathmandu, has been entrusted with the oversight and operation of the Authority, under provincial government supervision.

The Authority is mandated to lead on key areas including urban transport policy formulation, route and fare determination, network and infrastructure planning (such as designated bus stops and passenger amenities), and the promotion of environment-friendly transport systems. Emphasis is also placed on integrating modern technologies, such as cashless fare collection systems and real-time passenger information platforms, to improve operational efficiency and transparency. However, despite the strength of the legal framework, implementation has been weak. Institutional setup has been delayed, jurisdictional roles between federal, provincial, and municipal governments remain unclear, and no dedicated funding mechanisms have been established. As a result, many planned improvements, such as integrated fare systems and route rationalization, have not materialized. Public transport in Kathmandu remains fragmented, informal, and poorly regulated, limiting its contribution to congestion mitigation and sustainable mobility.

Despite growing acknowledgment of the need for non-motorized and sustainable mobility, their integration into road design remains limited and subordinate to vehicular priorities [66]. Broader congestion mitigation measures such as congestion pricing, parking reform, and vehicle restrictions are still pending. The persistence of fragmented systems, project delays, and chronic underinvestment underscores the pressing need for a coordinated, multimodal, and data-driven urban transport strategy for the Kathmandu Valley.

6. COMPARATIVE PERSPECTIVES

Urban congestion is a shared challenge for rapidly growing cities across Asia and Africa. Kathmandu's experience, marked by surging vehicle ownership, limited infrastructure, and fragmented governance, mirrors patterns observed in cities such as Delhi, Dhaka, Lagos, and Nairobi. A comparative lens offers critical insight into how cities with similar constraints are responding to congestion.

Kathmandu's population density has increased by over 150% since 2000, one of the fastest rates in Asia. Yet its built-up area per capita remains among the lowest compared to cities of similar size [70]. The city's urban form, with high block density and minimal road coverage, amplifies congestion. Over 60% of Nepal's vehicles are registered in Kathmandu Valley, and roughly 80% of them are two-wheelers [17]. While two-thirds of all trips are currently made by walking, cycling, or public transport, private vehicle use is rising rapidly, echoing trends in Dhaka and Nairobi. The impacts are far-reaching. Kathmandu loses nearly USD 880 million annually due to congestion, mainly from lost productivity, fuel waste, and health impacts [45], [49]. Vehicular emissions are a leading contributor to air pollution, driving up respiratory and cardiovascular illnesses. Similar challenges are evident in Delhi and Dhaka, where traffic congestion is tightly linked to deteriorating public health. Lagos, ranked among the world's most congested cities, reports average commutes of up to five hours per day [71].

Institutional fragmentation is another shared barrier. In Kathmandu, overlapping responsibilities between ministries, municipalities, federal units, and traffic police have slowed implementation of traffic reforms. Delhi and Dhaka experience similar governance bottlenecks. Meanwhile, Lagos and Nairobi grapple with underfunded agencies and regulatory challenges, limiting their ability to coordinate complex transport initiatives. These issues are reflected in the poor transport system of Kathmandu.

Despite facing similar constraints such as limited infrastructure, rapid urbanization, and institutional challenges, cities have pursued diverse strategies to tackle congestion. Delhi has made substantial investments in metro rail, Bus Rapid Transit (BRT) systems, and digital ticketing platforms, with pilot programs in congestion pricing and adaptive signal control systems showing promising early results. Dhaka, while still in the implementation phase, has launched metro and BRT projects and recently begun testing pedestrianized zones and digital fare systems; however, weak enforcement continues to hinder progress. In Lagos, authorities have focused on expanding ferry networks and upgrading jetties, aiming to triple the number of waterway commuters by 2027, a multimodal strategy supported by international funding that offers a replicable model for other coastal cities. Meanwhile, Nairobi has introduced BRT corridors and promoted non-motorized transport through new cycling infrastructure and smart traffic signal systems, although outcomes so far have been mixed.

Elsewhere, Jakarta and Manila have introduced odd-even vehicle restrictions, mass transit investments, and dedicated bike lanes to manage congestion. These examples show that even under similar constraints, cities can innovate across different modes, governance tools, and funding mechanisms. Kathmandu stands to benefit by synthesizing these approaches, adapting what works to its own urban context, institutional capacity, and socio-political realities.

7. DISCUSSION

Global best practices for urban congestion management consistently highlight three interdependent pillars: technology and innovation, sustainable infrastructure investment, and integrated urban planning. Cities such as Singapore, Delhi, and Bogota´ demonstrate that success stems from a multimodal approach that includes intelligent transport systems (ITS), expanded public transit networks, and land use integration [20], [70], [72].

By contrast, Kathmandu's congestion response remains heavily infrastructure-centric. The focus has largely been on road widening and infrastructure construction, with limited investment in intelligent traffic management, public transport expansion, or land use coordination. Manual traffic control still dominates, despite clear evidence that ITS can reduce delays and emissions [17], [45]. Moreover, fragmented governance continues to delay project execution. Responsibilities are spread across multiple ministries, municipal bodies, federal units and enforcement agencies, leading to inefficiencies and conflicting priorities [64]. A lack of real-time data, inadequate coordination, and limited institutional capacity further hinder effective traffic planning. These systemic issues mirror challenges observed in cities like Dhaka and Lagos, where structural inefficiencies obstruct even well-intentioned reforms [71].

To overcome these gaps, Kathmandu must adopt a holistic and phased mitigation framework, as illustrated in Figure 5. Under the first pillar, Technology and Innovation, the city should expand adaptive traffic signal systems, deploy smart traffic monitoring, and integrate crowd-sourced data platforms to improve situational awareness and enforcement. These tools can enhance the efficiency of existing infrastructure and reduce reliance on manual traffic policing. The second pillar, Sustainable Infrastructure Investment, calls for substantial upgrades to the public transit system (bus based or rail based), including fleet electrification, route rationalization, and improved last-mile connectivity. Investments in non-motorized infrastructure such as sidewalks and bicycle lanes should be prioritized to reduce dependency on private vehicles and support inclusive mobility. The third pillar, Urban Planning and Management, requires long-term land use reform, including transit-oriented development, zoning incentives, and demand-side strategies such as congestion pricing and parking regulation. These tools have proven effective in cities like Singapore and Stockholm, where modal shift and emission reductions were achieved through policy alignment and public engagement.

Institutional reform will be essential. A dedicated metropolitan mobility authority could streamline responsibilities, improve inter-agency coordination, and align capital projects with policy goals. Further, the adoption of digital infrastructure and open-data platforms would enable evidence-based policymaking and foster public trust through transparency.

In sum, Kathmandu's current approach is insufficient to address the scale and complexity of its congestion challenge. Without a pivot toward integrated, technology-enabled, and equity-focused strategies, the city risks locking itself into a future of chronic mobility dysfunction. Learning from global experiences and adapting them to the local context offers a path forward toward a more livable, resilient, and sustainable urban future.

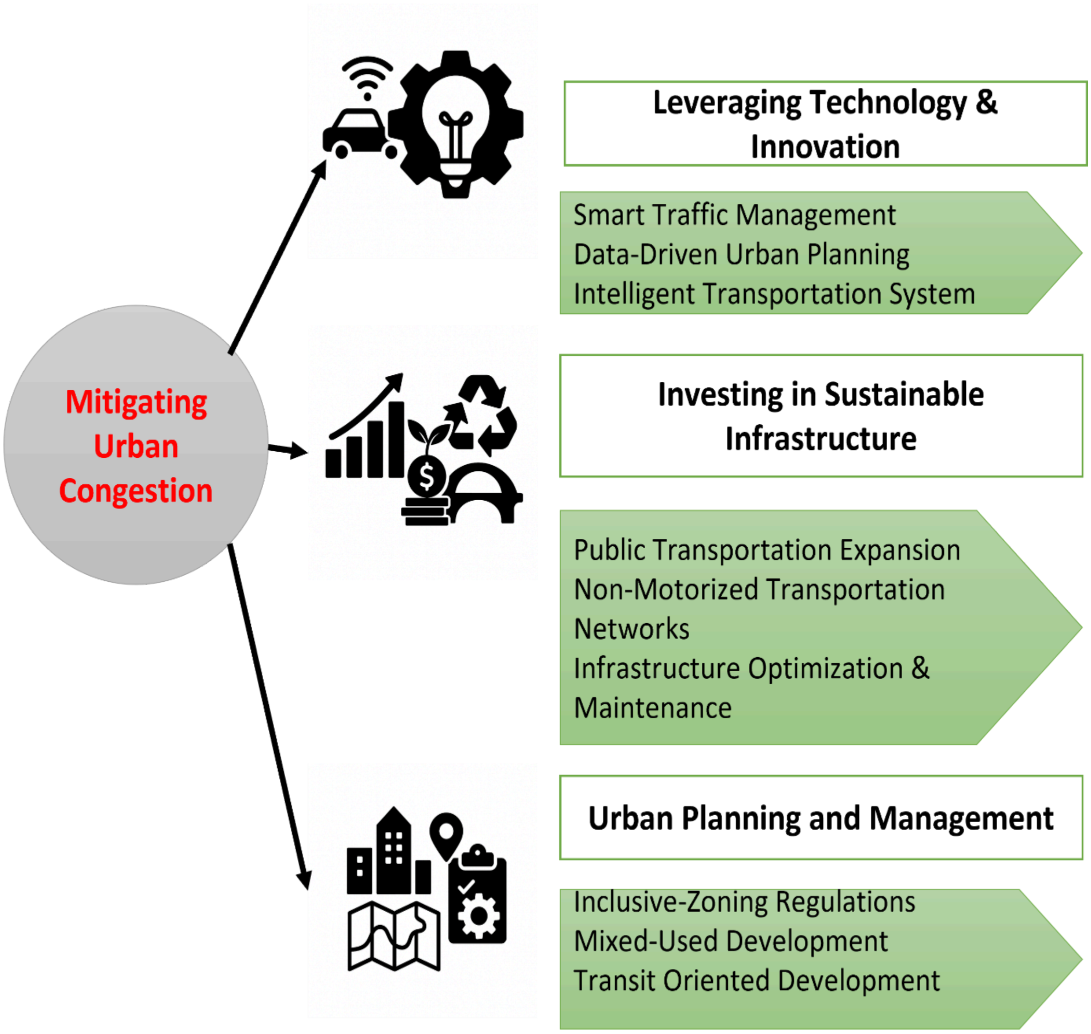

Figure 5: Key strategies for mitigating urban congestion

8. CONCLUSION

Urban traffic congestion remains one of the most urgent and complex challenges facing rapidly growing cities in the Global South. This study examined the theoretical foundations of congestion, reviewed a wide range of international mitigation strategies, and critically assessed Kathmandu's evolving efforts within a comparative framework. Despite several interventions, including road widening, intersection upgrades, and limited improvements in public transport, Kathmandu's approach has remained largely fragmented and infrastructure-heavy. These efforts have not adequately addressed the systemic drivers of congestion: poor land use coordination, lack of sustainable transport infrastructure, declining public transit use, weak institutional collaboration, and the absence of intelligent traffic systems.

Comparative lessons from cities like Delhi, Bogota, Dhaka, and Lagos reveal that sustainable congestion reduction depends on a balanced, multimodal strategy. This includes investments in high-capacity public transport, smart traffic technologies, demand side policies such as congestion pricing, and the promotion of walking and cycling infrastructure. Importantly, successful cities have also strengthened institutional capacity and adopted data-driven governance frameworks. Kathmandu must now pivot from reactive, piecemeal solutions toward a holistic mobility strategy. This includes creating a unified urban transport authority, leveraging real-time data for traffic management, and accelerating the transition to clean and efficient public transit. Electrification, while important, must be embedded within a broader effort to reduce car dependency and promote equitable access to mobility.

The city's window for action is narrowing. With continued population growth and vehicle proliferation, inaction will deepen congestion-related economic losses, public health risks, and environmental degradation. However, by adapting global best practices to local realities, and ensuring that reforms are inclusive, scalable, and evidence-based, Kathmandu can still chart a path toward a more resilient and sustainable urban future.

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