International
Journal
Of Advanced Research in Engineering & Management (IJAREM)
ISSN: 2456-2033 || PP. 16-21

Sustainable of Transportation Systems in Developing Countries: A Case Study Nepal

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Abstract: Sustainable transportation is a critical component of urban development, economic growth, and environmental protection in developing countries like Nepal. With rapid urbanization, increasing vehicle ownership, and deteriorating air quality, Nepal faces significant challenges in establishing an efficient and eco-friendly transport system. This paper examines the current state of transportation in Nepal, identifies key challenges, and explores sustainable solutions such as mass transit systems, non-motorized transport (NMT), electric mobility, and policy reforms. By analyzing successful case studies from other developing nations, this research provides recommendations for Nepal to transition toward a sustainable transportation future. The study draws on academic literature, government reports, and international best practices to propose actionable strategies for policymakers.

Keywords: Sustainable transport, Nepal, electric vehicles, public transit, non-motorized transport, urban mobility, policy reforms.

1. Introduction

Transportation is a cornerstone of economic growth, social integration, and national development. In developing countries like Nepal, however, the sector is fraught with systemic challenges. The Kathmandu Valley home to over 4 million people exemplifies these issues. Chronic traffic congestion, unplanned urban sprawl, and one of the highest concentrations of air pollutants in South Asia characterize the current transportation landscape. According to the Ministry of Population and Environment (MoPE, 2021), particulate matter (PM2.5) levels in Kathmandu frequently exceed World Health Organization (WHO) air quality standards, posing severe health and environmental risks. The root causes of Nepal's transport-related problems can be visualized through a systemic lens, as shown in Figure 1. Rapid urbanization, inadequate infrastructure, and fossil fuel dependency form an interrelated triad that undermines sustainable mobility. Urban expansion has outpaced infrastructure development, leading to vehicle overcrowding and increased travel times. Simultaneously, road networks—narrow, poorly maintained, and insufficiently planned fail to accommodate the growing volume of private and commercial vehicles. Compounding these issues is Nepal's overreliance on imported fossil fuels, which not only intensifies carbon emissions and environmental degradation but also exposes the economy to international price volatility (ADB, 2019).Figure 1 illustrates how rapid urbanization (left branch) leads to increased vehicular density, placing severe strain on existing infrastructure. The inadequate infrastructure (right branch) is unable to accommodate rising traffic demands. Meanwhile, the roots symbolize the systemic dependence on fossil fuels, which feed into both upper branches creating a self-reinforcing loop of pollution, congestion, and energy inefficiency.

Amid these challenges, sustainable transportation emerges not merely as an environmental imperative but as an economic and social necessity. Defined as a system that promotes accessibility, affordability, and low-carbon mobility while minimizing energy consumption (Litman, 2022), sustainable transportation aligns with global climate commitments and domestic development goals. For Nepal, adopting sustainable transport strategies is essential to reducing fuel imports, improving urban air quality, and ensuring inclusive access to mobility.

This research investigates a range of strategies to transition Nepal toward a more sustainable transportation paradigm. It focuses on four key pillars: (1) strengthening public transit systems, (2) promoting electric vehicles (EVs), (3) developing cycling and pedestrian infrastructure, and (4) enacting supportive policy and regulatory frameworks. These interventions are examined in light of international best practices and contextualized within Nepal's unique geographical, socio-economic, and institutional landscape.

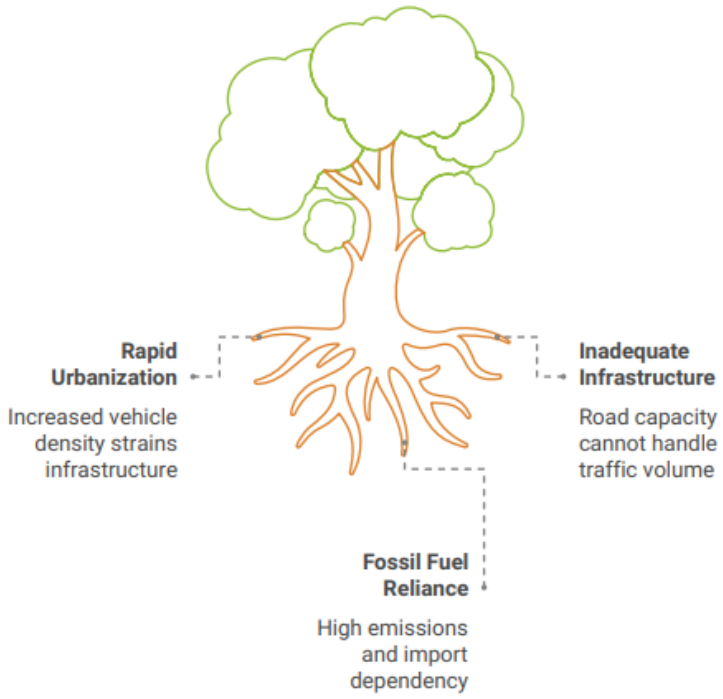

Figure 1: Need for the Sustainable Urban Transportation System

2. Current Transportation Scenario in Nepal

2.1 Urban Mobility Challenges

Nepal's transportation sector faces a multitude of structural and environmental challenges, particularly in its urban centers. Rapid motorization, combined with inadequate infrastructure, has placed immense pressure on the country's road networks. In Kathmandu, for instance, the existing road system originally designed to serve a much smaller population—is now severely congested due to the exponential rise in private vehicle ownership (DoTM, 2022). This congestion not only hampers mobility but also contributes significantly to air pollution. Vehicular emissions are responsible for over 30% of the city's PM2.5 levels, positioning Kathmandu among the most polluted cities in the world (IQAir, 2023). Public transportation remains highly inefficient, largely dominated by informal systems such as microbuses and tempos, which are often overcrowded, unreliable, and raise serious safety concerns (Thapa et al., 2020). Furthermore, the city's infrastructure does little to support non-motorized transport; only 5% of roads are equipped with sidewalks, and cycling remains perilous due to the absence of dedicated bike lanes (KUKL, 2021). These challenges underscore the urgent need for a comprehensive, sustainable overhaul of Nepal's urban transportation planning.

2.2 Energy Consumption and Emissions

Nepal's heavy reliance on imported petroleum poses significant economic and environmental challenges. The country imports 100% of its petroleum products, allocating nearly 15% of its Gross Domestic Product (GDP) to fuel expenditures—a substantial burden on the national economy (NRB, 2022). The transportation sector is the largest consumer of energy, accounting for approximately 35% of Nepal's total energy use, and is a major contributor to environmental degradation, responsible for 25% of the nation's greenhouse gas (GHG) emissions (MoPE, 2021). Alarming projections indicate that, in the absence of decisive policy interventions and sustainable transport solutions, emissions from this sector could triple by 2030, significantly undermining Nepal's climate commitments and environmental health (ICIMOD, 2020). This trajectory underscores the urgent need for a strategic transition toward cleaner, more efficient, and locally sustainable modes of transportation.

3. Sustainable Transportation Solutions for Nepal

3.1 Mass Transit Systems

Implementing modern mass transit solutions is essential for addressing Kathmandu's growing urban mobility crisis. One of the most promising strategies is the introduction of a Bus Rapid Transit (BRT) system. International examples, such as Bogotá's Trans Milenio, have demonstrated that BRT systems can significantly reduce traffic congestion and improve commute times in rapidly developing cities (Hidalgo & Graftieaux, 2018). In Kathmandu, the proposed BRT along the Ring Road has the potential to cut travel times by up to 40% if effectively planned and executed (DoTM, 2023). Complementing this, long-term urban mobility planning must also consider the development of a metro rail system. Cities like Delhi and Dhaka have successfully integrated metro systems to support high-capacity, sustainable transportation, serving as valuable models for Kathmandu's future (ADB, 2022). In the short to medium term, upgrading existing public bus services is crucial. Transitioning to electric or hybrid bus fleets, similar to Shenzhen's fully electric bus system, could reduce vehicular emissions by as much as 50%, while enhancing service quality and reliability (ITDP, 2021). Together, these integrated transport strategies offer a pathway toward a cleaner, more efficient, and resilient urban transport network for Kathmandu.

3.2 Promotion of Electric Vehicles (EVs)

Nepal's abundant renewable energy resources, particularly hydropower, position the country uniquely for a sustainable transition to electric mobility. With an estimated 4,000 MW of untapped hydropower potential, the adoption of electric vehicles (EVs) offers a clean, domestically powered alternative to fossil fuel dependency (NEA, 2023). Recognizing this opportunity, the government has introduced a range of incentives, including tax exemptions and subsidies, which have led to a remarkable 300% increase in EV adoption since 2019 (DoTM, 2023). To maximize the benefits of this transition, priority should be given to electric three-wheelers, such as Safa tempos, and electric bicycles, which are ideal for last-mile connectivity in dense urban areas. These modes not only reduce emissions and operating costs but also enhance accessibility and mobility for a wider segment of the population. Embracing electric mobility at both macro and micro levels will be instrumental in building a cleaner, more resilient transport system for Nepal.

3.3 Non-Motorized Transport (NMT)

Creating pedestrian-friendly and cyclist-oriented infrastructure is vital for promoting sustainable urban mobility in Nepal's cities. Enhancing walkability through wider sidewalks, designated pedestrian zones—such as the successful Thamel Car-Free Day—and safe, well-marked crossings can significantly encourage walking as a viable mode of transport (UN-Habitat, 2022). In parallel, developing comprehensive cycling networks is essential to reduce dependence on private vehicles. Dedicated bike lanes, modeled after the world-class infrastructure in Copenhagen, along with affordable bike-sharing programs similar to those in Pune, India, offer practical and inclusive solutions to urban congestion and pollution (C40 Cities, 2021). Prioritizing non-motorized transport infrastructure not only improves public health and environmental quality but also fosters more livable, accessible, and resilient cities.

3.4 Policy and Institutional Reforms

A holistic approach to sustainable urban mobility in Nepal requires integration of transportation planning with broader urban development strategies. Transit-Oriented Development (TOD) is a key urban planning tool that promotes high-density, mixed-use neighborhoods centered around efficient public transport hubs. By prioritizing pedestrian access, reducing commute distances, and limiting urban sprawl, TOD can enhance land use efficiency and reduce the environmental footprint of cities (ITDP, 2020). In tandem with planning reforms, the enforcement of strict vehicular emission standards is critical to addressing Nepal's growing air pollution crisis. Adopting and implementing Euro-6 emission norms, coupled with mandatory and regular vehicle inspections, can significantly curb harmful pollutants from the transport sector (MoPE, 2022). However, infrastructure and policy alone are not sufficient without public engagement. Raising awareness through targeted media campaigns and educational initiatives can drive behavioral change, encouraging citizens to adopt cleaner transport options and support sustainable policies. Such public awareness efforts, as emphasized by the World Bank (2021), are essential in cultivating long-term commitment to environmental stewardship and fostering a culture of sustainable urban living. Together, these strategies form a comprehensive framework for creating cleaner, more equitable, and resilient cities in Nepal. Figure 2 shows the policy reformation to achieve sustainable urban transportation in Nepal.

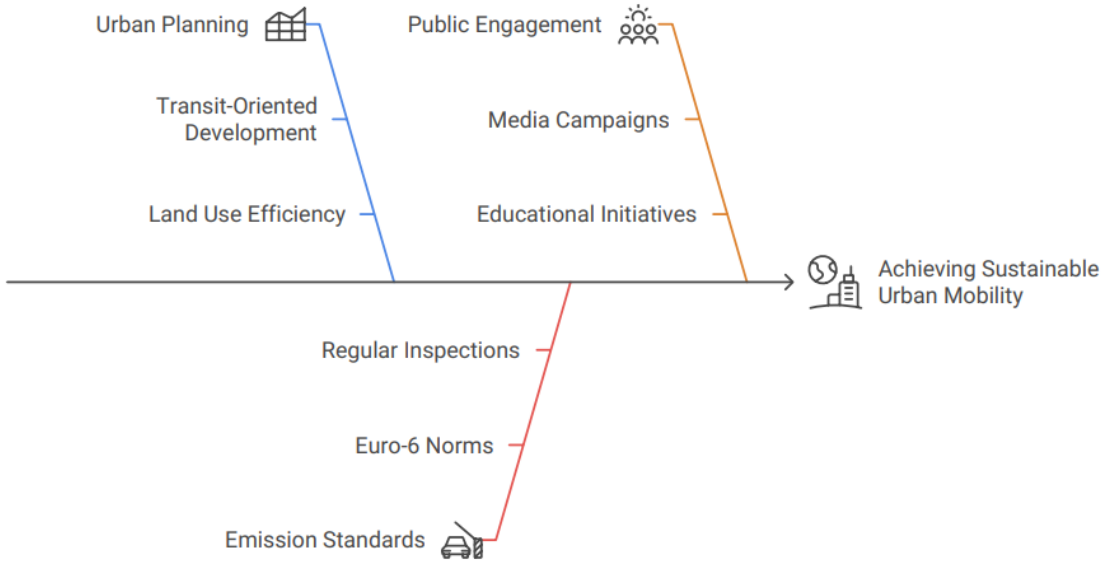

Figure 2: Enhancing Sustainable Urban Mobility in Nepal

4. Case Studies from Developing Countries

4.1 India: Delhi Metro – A Model of Urban Transit Transformation

The Delhi Metro stands as one of the most successful examples of sustainable urban transportation in the Global South. Since its inception, it has played a transformative role in reducing both congestion and air pollution in India's capital city. According to the Delhi Metro Rail Corporation (DMRC, 2022), the system has led to a 30% decrease in traffic congestion by offering a reliable, efficient, and high-capacity alternative to private vehicles. In addition, Delhi Metro operations have contributed to a 20% reduction in vehicular emissions, thus playing a crucial role in combating the city's severe air pollution. The metro system's integration with buses, pedestrian pathways, and last-mile connectivity options further enhances its accessibility. Moreover, Delhi Metro has received international recognition for its green practices, including the use of solar power and energy-efficient technologies, making it a benchmark for developing urban transit infrastructure in South Asia.

4.2 Bangladesh: Dhaka BRT – Enhancing Bus Efficiency through Dedicated Infrastructure

Dhaka, one of the most densely populated cities in the world, has begun to address its public transport inefficiencies through the development of a Bus Rapid Transit (BRT) system. With dedicated bus lanes and upgraded bus services, the Dhaka BRT project has significantly improved the city's transportation efficiency. According to the Bangladesh Road Transport Authority (BRTA, 2023), the introduction of the BRT system has increased bus operational efficiency by 50%, reducing travel times and improving reliability. The BRT corridors are designed to provide uninterrupted flow for buses, thus avoiding the delays caused by mixed traffic congestion. This has not only enhanced commuter experience but also attracted a greater share of public transport ridership. The success of the Dhaka BRT showcases how strategic investment in dedicated transport infrastructure can bring about substantial improvements in mobility, particularly in rapidly urbanizing environments.

4.3 Rwanda: Electric Motorbikes – A Leap Toward Green Mobility

Rwanda has emerged as a leader in sustainable mobility in Africa by championing the adoption of electric motorbikes (e-motos). In an effort to combat urban air pollution and reduce dependency on imported fuels, the Rwandan government has deployed over 10,000 electric motorbikes across the country. This initiative, led by the Ministry of Infrastructure (MININFRA, 2023), has resulted in a 15% reduction in greenhouse gas emissions in urban transport. These e-motos are particularly effective in Kigali and other cities, where motorcycles are a dominant form of personal and commercial transport. In addition to environmental benefits, the program has generated green jobs in manufacturing, charging infrastructure, and maintenance services.

Rwanda's e-mobility transition offers a scalable, cost-effective model for other developing nations aiming to reduce emissions while addressing last-mile transport needs.

5. Recommendations for Nepal

To achieve a cleaner, more efficient, and inclusive urban mobility future, Nepal must urgently formulate and implement a comprehensive National Sustainable Transport Policy. This policy should set clear and measurable targets for electric vehicle (EV) adoption and public transit development, providing a strategic framework to guide investment and regulatory action. A key priority must be the development of mass rapid transit systems, including the rollout of Bus Rapid Transit (BRT) and long-term planning for metro rail networks, particularly in Kathmandu and other rapidly urbanizing cities. To support the shift toward electric mobility, it is essential to expand EV charging infrastructure across the country, ensuring accessibility and convenience for all users. Equally important is the promotion of active transport modes such as walking and cycling through pedestrian-friendly urban design, dedicated cycle lanes, and safe public spaces. Finally, strengthening the governance and institutional capacity of public transport authorities will be critical to ensure service efficiency, accountability, and long-term sustainability. Together, these integrated strategies can position Nepal on a path toward resilient, low-carbon, and people-centered urban transportation.

6. Conclusion

Sustainable transportation is not just an option but a necessity for Nepal's long-term economic growth, environmental preservation, and societal well-being. As the country grapples with rising urban congestion, severe air pollution, and heavy dependence on imported fossil fuels, the need for transformative change in the transport sector has never been more urgent. By adopting integrated mass transit systems such as Bus Rapid Transit (BRT) and metro networks, promoting electric mobility powered by Nepal's abundant hydropower resources, and investing in pedestrian- and cyclist-friendly infrastructure, Nepal can significantly enhance urban mobility while reducing greenhouse gas emissions and improving public health.

Moreover, sustainable transportation creates inclusive opportunities by making cities more accessible for all, including women, children, the elderly, and people with disabilities. It also supports green economic development by generating jobs in clean energy, public transport, and urban planning sectors. For these benefits to be fully realized, it is imperative that policymakers embed sustainable transport at the core of national and local development agendas. This includes implementing a robust National Sustainable Transport Policy, expanding EV infrastructure, improving public transport governance, and fostering public awareness. With visionary planning, political commitment, and coordinated action, Nepal can build a resilient, low-carbon, and equitable transport system that not only meets present challenges but also secures a sustainable future for generations to come.

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