DESIGNING A MODIFIED SUSTAINABLE TRANSPORT FRAMEWORK FOR DELHI

A Thesis Submitted
In Partial Fulfilment of the Requirements
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DOCTOR OF PHILOSOPHY
in
DESIGN
by

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-Utkarsh Chaudhari

CANDIDATE'S DECLARATION

I, **Utkarsh Chaudhari**, hereby certify that the work presented in this thesis, entitled " **Designing a Modified Sustainable Transport Framework for Delhi**," submitted in partial fulfilment of the requirements for the award of the **Degree of Doctor of Philosophy** in **Design at Delhi Technological University**, is an original and authentic record of my research. This work was carried out under the supervision of **Prof. Ranganath M. Singari** and **Dr. S.L. Bhandarkar** during the period from **January 2022 to December 2025.**

I further declare that the content of this thesis has not been submitted for the award of any other degree at this or any other institution.

Candidate's Signature

This is to certify that the student has incorporated all the corrections suggested by the examiners in the thesis, and the statement made by the candidate is correct to the best of our knowledge.

Signature of Supervisor (s) **Signature of External Examiner**

CERTIFICATE BY THE SUPERVISOR(S)

This is to certify that **Utkarsh Chaudhari** (2K21/PHDDES/502) has conducted the research work presented in this thesis, entitled "**Designing a Modified Sustainable Transport Framework for Delhi**," for the award of the **Doctor of Philosophy** from the Department of Design, Delhi Technological University, Delhi, under our supervision. The thesis embodies the results of original research, and the studies have been carried out independently by the candidate. The contents of this thesis have not been submitted as the basis for the award of any other degree to the candidate or to any other individual from this or any other University/Institution.

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ABSTRACT

The transport system in Delhi has suffered excessive pressure as a result of the fast urbanisation and motorisation that have resulted in congestion, air pollution, safety issues, social disparities and governance issues. Despite the fact that several policies and plans are associated with transport, they are not connected to such principles as holistic sustainability and global development agendas. The current doctoral study fills this research gap by developing a Modified Sustainable Transport Framework (MSTF) and an Assistive Decision-Support System (DSS) particular to the case of Delhi, and directly aligned to the United Nations Sustainable Development Goals (SDGs).

The research is based on a rigorous multi-method research design coordinated around four objectives, which are:

1. Understanding the transport system of Delhi.
2. Identifying major areas of improvement in line with the SDGs.
3. Reformatting the current planning framework to develop an effective, sustainable transport system.
4. Developing an assistive system to actualise the principles of sustainability.

The literature review, together with policies and best practices worldwide, provided a holistic description of the transport system, drawing on empirical fieldwork and secondary data analysis. The reason is that fourteen national- and locally based structures that transport were analysed, and the Delhi Master Plan 2041 (MPD-2041) was chosen to be evaluated.

According to SDG-based indicators designed as the 5P framework (People, Planet, Prosperity, Peace, and Partnership), a systematic evaluation of 33 transport and urban planners was conducted using a Likert-scale assessment. The gaps were quantitatively analysed using mean scores and percentage agreement and were found to be critical, particularly in the domains of governance integration, multimodal coordination, non-motorised transport infrastructure, inclusiveness, and collaborating with stakeholders.

PITS-G has been designed to address the identified gaps and introduce quantifiable SDG-based performance indicators. The research also conceptualises an Assistive Decision-Support System to balance planning and implementation, comprising a unit mobility data platform, a dashboard for the policymaker, and assistive tools for the commuter. The usefulness of the framework and the strength of the system were justified by two contrasting case studies, Connaught Place and Dwarka Sector 21, where sustainability performance improved, with the greatest change in the Peace and Partnership dimension.

It strengthens the relationship between the global sustainability goals and local transport planning, providing a viable understanding for policymakers, planners, and researchers on the path to achieving inclusive, resilient, and climate-responsive urban mobility systems in Delhi.

LIST OF PUBLICATIONS:

Journal Articles

1. Chaudhari, U., Singari, R. M., & Bhandarkar, S. L. (n.d.). *Designing inclusive and sustainable transport in Delhi: Patterns, challenges, and policy reflections.* **International Development Planning Review (IDPR)**. https://doi.org/10.13140/RG.2.2.34203.73761

2. Chaudhari, U., Singari, R. M., & Bhandarkar, S. L. (n.d.). *Assessing Delhi's transportation system for sustainable development: A framework-based analysis aligned with the SDGs.* **International Development Planning Review (IDPR)**. https://doi.org/10.13140/RG.2.2.27492.85126

Conference Presentations

1. Chaudhari, U., Singari, R. M., & Bhandarkar, S. L. (2024, January 28). *Analysing the relationship between sustainable public transportation and Delhi's urban environment: A comprehensive overview.* Paper presented at the **International Journal of Advance Research and Innovation (ICARI-24) Conference**, Delhi State Centre, Institution of Engineers (India), New Delhi.

2. Chaudhari, U., Singari, R. M., & Bhandarkar, S. L. (2024, January 28). *Design and development of a drowsiness alert system while driving.* Paper presented at the **International Journal of Advance Research and Innovation (ICARI-24) Conference**, Delhi State Centre, Institution of Engineers (India), New Delhi

3. Chaudhari, U., Singari, R. M., & Bhandarkar, S. L. (2025, January 2). *Investigation of multimodal transport integration for sustainable urban mobility.* Paper presented at the **International Journal of Advance Research and Innovation (ICARI-25) Conference**, Delhi State Centre, Institution of Engineers (India), New Delhi.

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CHAPTER 1

INTRODUCTION

Transport is an integral part of human civilisation, facilitating movement of people, goods and information across space. It is an important factor in the development of the economy, social interaction, spatial organisation and environmental outcomes. From primitive pathways and waterways to modern multimodal networks, transportation systems have continued to evolve in accordance with technological advancements, population growth and changing socio-economic requirements. In modern cities, transport is not only a way to reach mobility, but a major factor of accessibility, equity, productivity and overall quality of life (Rodrigue, Comtois, & Slack, 2020).

A transportation system can be defined as an integrated system of infrastructure, vehicles, services, institutions and users all of which facilitate movement in and between urban and regional spaces. This system comprises physical infrastructure such as roads, railways, stations and terminals; modes of transport such as buses, rail, private vehicles, walking and cycling; operational elements such as scheduling, pricing and information systems and governance elements that are responsible for planning, regulation and management (Vuchic, 2007). The effectiveness of a transportation system is not just dependent upon the availability of infrastructure to function but how these infrastructure components function together in a coordinated whole.

Historically, transport planning was primarily focused on mobility and, in many cases, this was measured in terms of vehicle speed, road capacity and traffic flow. This approach, which characterised much of the twentieth century, was based on the expansion of roads and the use of private vehicles as a sign of progress and economic growth (Banister, 2008). While such strategies increased short-term mobility, they also have unintended consequences such as traffic congestion, urban sprawl, environmental degradation and social inequity. As cities grew and motorisation took off, it became clear that infrastructure-led, vehicle-centric planning was not working to make cities sustainable and inclusive places to live.

In recent decades, there has been a paradigm shift in the way in which transport planning is done from mobility-oriented to accessibility-based and sustainability-oriented frameworks. Accessibility is more about the ease at which people access vital destinations such as workplaces, schools, healthcare facilities, and markets as opposed to the movement of vehicles (Litman, 2021). This shift recognises that efficient transport systems should not be traffic driven, but people driven and should support compact urban development, multimodal integration and equitable access. As a result walking, cycling and public transport have become once again important in urban transport strategies.

Transportation systems are inextricably linked with economic development. Efficient and reliable transport networks save on time and logistics costs, improve access to labour market and boost competitiveness on the regional market. Cities with effective

public transport systems are generally more productive and have more inclusive economic growth (World Bank, 2020). On the other hand, poor transport systems have high economic costs in the form of congestion, fuel lost and productivity losses as well as increased infrastructure maintenance. These are the economic implications and hence the importance of strategic transport planning as a tool for long term urban and regional development.

At the same time, there are very significant social implications of transport systems. Access to affordable and safe transport is a determinant in whether or not people are able to fully participate in urban life. Inequitable transport systems disproportionately have impact on low-income groups, women, elderly citizens and persons with disabilities; limiting their access to opportunities and services (Tiwari, 2011). Safety is another important issue as road traffic injuries are a leading cause of death globally, especially in low and middle-income countries (WHO, 2018). Inclusive transport planning thus involves taking into account the issues of universal accessibility, affordability, safety and gender sensitive design.

In this context the transportation systems are increasingly being perceived as complex socio-technical systems rather than isolated networks of infrastructure. Their performance is dependent upon interactions between land use patterns, travel behavior, technology, policy and institutional capacity. As cities continue to grow and confront challenges relating to climate change, inequality and resource constraints, the need for integrated, adaptive and sustainable transport systems is increasingly critical.

This changing understanding of transport and transportation systems is the foundation for modern research and policy endeavours to improve urban mobility. It highlights the need to move away from planning approaches that are mode specific and towards holistic planning approaches that incorporate accessibility, sustainability, governance and technological innovation. Such an approach is of particular relevance in the case of rapidly urbanising cities, where transport systems are expected to provide simultaneously support for economic growth, social inclusion and environment.

1.1 BACKGROUND

Delhi has one of the most complex and vast urban transport system in India affected by the rapid population growth, economic growth and spatial transformation. As the National Capital Territory of India, Delhi is home to over 20 million people, and has one of the highest travel demand in the country on a daily basis. The transport system of the city is inherently multimodal and consists of metro rail, public buses, suburban rail, intermediate public transport (auto-rickshaws and e-rickshaws), taxis, private motor vehicles, pedestrians, and cyclists. This diversity is both a planned investment and an organic evolution to catch up with the growing mobility needs (Tiwari, 2011).

Over the last 20 years, Delhi has made great progress in improving the mass rapid transit infrastructure, especially the Delhi Metro, which is now the backbone of the city's public transport system. The metro has improved the regional connectivity, decrease the travel time and provide a relatively cleaner option to private vehicle usage

(Cervero, 2013). The bus system, mostly run by the Delhi Transport Corporation (DTC) and the cluster services, still plays an important role for creating affordable mobility, especially for the lower income groups. In parallel, intermediate modes of public transport offer important last mile connectivity, but in many cases in an unregulated and fragmented way.

Despite all these advancements, Delhi's transport system continues to have structural issues. Rapid motorisation has resulted in high congestion levels, poor use of road space and falling average travel speeds. Vehicular emissions are a key factor in the decline of air quality, thus transport is a key public health issue (Guttikunda & Goel, 2013). Inadequate infrastructure for walking and cycling also adds to the safety risks and deters non-motorised travel, even though this mode of travel comprises a significant proportion of trips made on a daily basis. Additionally, inequalities of accessibility are still present between income groups, genders and peripheral urban areas.

Governance and institutional fragmentation makes transport planning and implementation even more difficult in Delhi. Multiple agencies working at local, state and national levels are in charge of different aspects of transport and this often leads to lack of coordination and poor integration between land use and mobility planning (MoHUA, 2017). Although recent policies such as the Delhi Transport Policy, the Electric Vehicle Policy, and the Master Plan for Delhi 2041 show a move towards sustainable mobility, there are key challenges in implementing and monitoring these policies.

This background underscores the need for a comprehensive, integrated, and sustainability-oriented approach to transport planning in Delhi, one that addresses not only infrastructure and technology but also governance, equity, and the long-term resilience of environmental systems.

Figure 1.1: Comprehensive, Integrated, and Sustainability-oriented approach to transport planning in Delhi

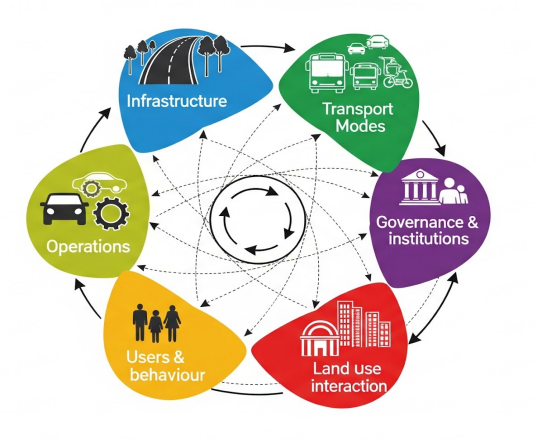

Figure 1.2 Modals of the transport network of Delhi

1.2 Motivation

Rapid urbanisation and motorisation have put unprecedented pressure on urban transport systems, in particular in the Global South megacities. Delhi being one of the world's fastest growing metropolitan areas, has persistent challenges in terms of traffic congestion, air pollution, inequitable accessibility, safety issues and fragmented institutional governance. Despite massive investments in mass transit, electric mobility, policy based initiatives like transit oriented development etc, transformation of strategic intent into a sustainable, inclusive and resilient mobility system is still limited. Existing transport plans often focus on provision of infrastructure, and not enough attention is given to governance integration, performance monitoring and social equity.

The motivation for such research is the need to move from the isolated project-based interventions to a comprehensive and systems-oriented approach in the area of sustainable transport planning. While global sustainability frameworks (including the United Nations Sustainable Development Goals) have established a strong normative basis, they remain underoperationalised in local transport planning processes. In the case of Delhi, there is a clear mismatch between sustainability goals, policy frameworks, and on-the-ground implementation outcomes.

This research is therefore driven by the need to evaluate existing transport plans through a multidimensional sustainability methodology and propose a context-specific framework that is, on one hand, measurable and on the other hand, actionable. By bringing together SDG-aligned indicators, expert consensus and decision support mechanism, the study is aimed towards strengthening the evidence-based transport planning and contribute towards a more inclusive, environmentally responsible and resilient urban mobility future for Delhi.

1.3 DELHI TRANSPORT

The national capital of India, Delhi, is a case study in the complexities and contradictions of the development of urban transport in rapidly growing megacities. With a population of over 20 million and a constantly increasing metropolitan area, Delhi has one of the highest levels of travel demand in the country (Census of India, 2011; MoHUA, 2017). The city's transport system is inherently multimodal and consists of buses, metro rail, suburban rail, intermediate public transport (auto-rickshaws, e-rickshaws etc.), taxis, private motorised vehicles, walking and cycling. Despite this diversity, Delhi suffers from persistent challenges of chronic traffic congestion, declining air quality, risk of road safety, poor non-motorised transport (NMT) infrastructure and poor last mile connectivity (Tiwari, 2011).

One of the most burning concerns that are associated with the transport system of Delhi is that of environmental sustainability. The transport sector is a significant contributor to urban air pollution and greenhouse gas emissions especially as a result of the rapid increase in private vehicles (Guttikunda & Goel, 2013). Delhi is often one of the most polluted cities in the world, from which vehicular emissions are a major contributor for particulate matter (PM2.5) and nitrogen oxides (NOx). These pollutants have direct and severe effects on the health of the public, including respiratory illnesses, cardiovascular diseases, and decrease in life expectancy (WHO, 2016). While policy measures such as the improvement of fuel quality, the introduction of compressed natural gas (CNG) buses and vehicle emission standards have had some benefits, the overall environmental

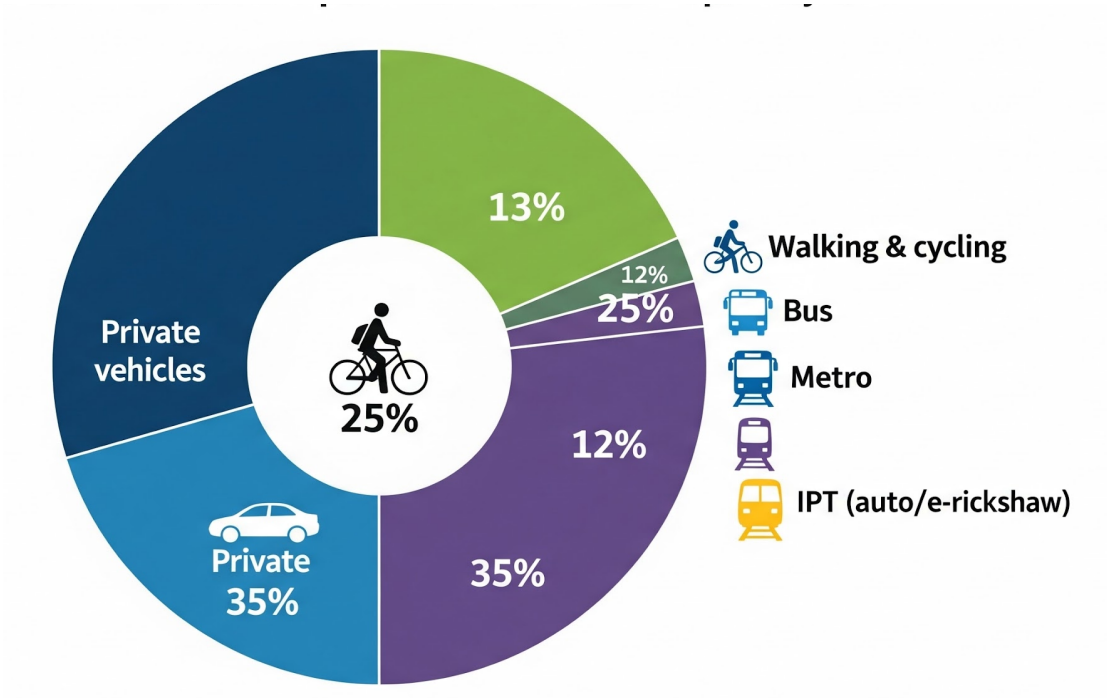

Figure 1.3 - Different models share of the Delhi Transport

1.4 Motorisation and Traffic Growth in Delhi

Rapid motorisation has emerged as one of the most critical challenges for Delhi's transport sustainability. As of 2022, Delhi had approximately 79.18 lakh registered motor vehicles. Two-wheelers account for nearly 66.5% of total vehicles, while cars and jeeps constitute around 26%, indicating a strong preference for private motorised transport.

Category	2015–16	2016–17	2017–18	2018–19	2019–20	2020–21	2021–22
Cars & Jeeps	29,86,579	31,52,710	32,46,637	32,49,670	33,11,579	33,84,736	20,76,113
Two-wheelers	61,04,070	66,07,879	70,78,428	75,56,002	79,59,753	82,39,550	52,68,685
Buses	34,365	35,206	35,285	32,218	33,302	33,294	17,522
Auto-rickshaws	1,98,137	1,05,399	1,13,074	1,13,240	1,14,891	1,14,869	93,578
Total Vehicles	97,04,741	1,03,82,757	1,09,86,015	1,13,91,551	1,18,92,877	1,22,53,350	79,17,898

Table 1.1 Year wise Growth of Vehicle Population in Delhi

Source: Economic Survey of Delhi 2022–23

1.5 Public Transport System in Delhi

1.5.1 Bus Transport: DTC and Cluster Buses

The bus system remains the backbone of affordable mobility in Delhi. The Delhi Transport Corporation (DTC) and Cluster Bus services together carry over 25 lakh passengers daily. In 2021–22, DTC operated approximately 3,762 buses, covering 6.45 lakh km per day.

Year	Fleet Size	Fleet Utilization (%)	Vehicle Utilization (km/bus/day)	Daily Passengers (lakh)
2017–18	3,951	85.69	191	29.86
2018–19	3,849	84.62	195	30.15
2019–20	3,762	85.04	193	33.31
2020–21	3,760	76.95	180	12.24
2021–22	3,762	85.27	201	15.62

Table 1.2 Performance of Delhi Transport Corporation (DTC)
Source: Economic Survey of Delhi 2022–23.

Cluster buses, operating under a Public–Private Partnership model, show higher fleet utilization and operational efficiency but face challenges related to integration and service design.

1.5.2 Mass Rapid Transit System (Delhi Metro)

The Delhi Metro Rail Corporation (DMRC) constitutes the backbone of high-capacity public transport in the city. As of 2022, the operational network length reached 348.12 km, with Phase IV under implementation.

Phase	Length (km)	Stations	Completion Status
Phase I	64.75	59	Completed (2006)
Phase II	123.30	86	Completed (2012)
Phase III	160.07	109	Completed (2021)
Phase IV	108.88	82	Under Implementation

Table 1.1 Summary of Delhi Metro Phases

The metro carried an average of 25.16 lakh passenger journeys daily in 2021-22, thus, playing a very crucial role in the mobility system of Delhi.

In response to the growing mobility challenges, the Government of Delhi has taken a number of transformative initiatives over the last two decades. The growth of the Delhi Metro Rail network is one of the most prominent interventions in the city's transport history. Since its inception in 2002, the metro has grown to become a large-scale mass rapid transit system, which provides high-capacity, reliable, and relatively low-emission mobility to millions of commuters on a daily basis (DMRC, 2022). Studies show that the metro has helped to save journey time, reduce the reliance on private vehicles for some routes and improve regional connectivity (Cervero, 2013). Similarly, improvements in the services provided by buses, such as the introduction of low floor buses and select bus rapid transit (BRT) corridors, are indicative of efforts towards improving the provision of public transport.

In addition to investments in mass transit, policy frameworks in Delhi have been focusing increasingly on measures which are sustainability-oriented. The promotion of the use of electric mobility through Delhi Electric Vehicle Policy (2020), promotion of non-motorised transport and adoption of the principles of transit-oriented development (TOD) under Master Plan for Delhi (MPD) 2041 indicate a strategic change towards low-carbon and compact urban development (Government of NCT of Delhi, 2021). TOD aims to integrate land use and transport planning in order to encourage higher density, mixed use development around transit nodes and so reduce travel distances and the associated need for private vehicles (Cervero and Murakami, 2009).

Despite these efforts, it is apparent from the existing literature that the transport interventions in Delhi have not been fully converted into a sustainable, inclusive and resilient mobility ecosystem. One area of restriction is in particular with respect to the

fragmented nature of governance and institutional coordination. Transport planning and implementation in Delhi is carried out by several agencies including municipal bodies, state departments and central government organisations, which is often leading to overlapping responsibilities and misalignment of policy (MoHUA, 2017). This fragmentation makes planning across modes difficult, and makes interventions that are driven by sustainability of lesser effectiveness.

Another important issue is one of social equity and accessibility. While high capacity transit systems, such as the metro, have increased mobility for many of its residents, access is uneven both between socio-economic groups and geographic areas. Peripheral and informal settlements generally are not well served by public transport networks and safe walking or cycling infrastructure, so inhabitants have to rely on informal or expensive modes of transport (Pucher et al., 2017). Women, elderly persons, children and persons with disabilities are faced with additional barriers concerning safety, affordability and universal access. These challenges point to the need for moving beyond the provision of infrastructure towards people-centred transport planning that explicitly deals with issues of equity and inclusion.

Figure 1.4 Delhi Metro Rail network

1.6. Sustainable Transport

Sustainability in transport requires systemic and integrated approach which is not limited to the provision of infrastructures and technological solutions. Urban mobility systems interact constantly with social well-being, quality of the environment, economic productivity, institutional governance and inter-organisational collaboration. Addressing transport sustainability therefore means striking the right balance between these interdependent dimensions rather than optimising for one objective such as speed or capacity (Bannister, 2008). In fast urbanising cities, where demand for mobility is increasing, as are the environmental and social challenges, such an integrated approach becomes critical in order to guarantee long-term urban resilience and livability.

The United Nations Sustainable Development Goals (SDGs) are a global accepted framework for guidance and evaluation of sustainable development in sectors, including transport. Although it is not explicitly modelled as a goal in itself, transport is deeply embedded across a number of SDGs, in particular SDG 11 (Sustainable Cities and Communities), and SDG 13 (Climate Action) (UN, 2015). Urban transport has an impact on the accessibility of housing, employment, education and public services, whilst at the same time influencing patterns of energy consumption, greenhouse gas emissions and local air quality. Consequently, sustainable transport systems form a part of the achievement of inclusive, low-carbon and climate resilient cities.

Environmental sustainability has become one of the most important issues of transportation systems. The transport sector is a major contributor to the greenhouse gas emissions, air pollution and energy consumption, especially due to the high dependency on fossil fuels and private motor vehicles (IPCC, 2022). Urban transport emissions play a large role in the air quality in urban areas which has negative health impacts (e.g. respiratory and cardiovascular diseases). In response, transport strategies in the area of sustainability have increasingly been based on low-carbon modes, energy efficiency, electrification and demand management measures. Integration of environmental issues into transport planning are now widely recognised to be an integral part of addressing climate change and public health issues.

Governance and institutional arrangements are an important part of the development of transportation systems. Transport planning is often the work of various stakeholders and agencies, working at different administrative levels, such as local governments, regional authorities, transport operators and the private sector. Fragmented governance and poor coordination and low levels of stakeholder participation often undermines the effectiveness of transport policies and projects (Pucher et al., 2017). Contemporary planning for transport therefore focuses on integrated governance, participatory decision making and evidence based policy formulation to help improve implementation outcomes.

Globally the idea of sustainable transport has been advertised as a guiding principle for the solution of the various social, economic and environmental challenges, which are connected in the context of mobility. Sustainable transport aims to satisfy the transport needs of the present without compromising the capacity of future generations to satisfy their own transport needs. It encourages transport systems which are accessible, affordable, safe, environmentally responsible and economically viable (Bannister, 2008). International frameworks such as the United Nation Sustainable Development Goals (SDGs) in particular SDG 11 (Sustainable Cities and Communities) and SDG 13 (Climate Action) emphasise the central role of transport in meeting wider sustainability goals (UN, 2015).

The SDGs are included in 5 overarching dimensions (or "5Ps"): People, Planet, Prosperity, Peace and Partnership. This framework offers a holistic lens for evaluation of urban transport systems through incorporating social, environmental, economic, institutional and collaborative aspects of the concept of sustainability (UN, 2015). The "People" dimension focuses on equity, accessibility, safety and inclusiveness and the need to focus on vulnerable groups, including women, the elderly, low income

populations and persons with disabilities. Transport systems that are affordable, safe and available to everyone contribute directly to a better quality of life and social well-being (Litman, 2021).

The "Planet" dimension is concerned with environmental performance, in particular reduction of emissions, energy consumption and ecological impacts. Transport is one of the largest contributors to air pollution in cities as well as climate change, and particularly in Global South mega-cities (IPCC, 2022). Shifting the demand for travel to public transport, non-motorised modes of transport and low emission vehicles is consequently important for reducing environmental externalities and achieving climate targets. The "Prosperity" dimension has to do with the relationship between transport and economic vitality as it is understood that efficient mobility systems increase productivity, facilitate labour markets and reduce economic losses due to congestion and travel delays (World Bank, 2020).

The other two dimensions - "Peace" and "Partnership" are particularly important to governance and institutional capacity in urban transport planning. One area where this is reflected is in the need to promote transparent, accountable and participatory decision-making processes which can build public trust and reduce the conflicts associated with land use, displacement and infrastructure development, including "peace". "Partnership" emphasises the cooperation between government agencies and various actors in the private sector, civil society and citizens to co-create a sustainable mobility. There is a consistent body of research showing that poor governance and lack of institutional coordination has undermined the effectiveness of transport policies in spite of the existence of technical solutions to problems (Pucher et al., 2017)

It should be underlined that there are differentiated concepts of "sustainable transport" and "sustainable development of transport". The concept of sustainable transport development is understood as the process of evolution in the transport sector, which has properties which increase sustainability. On the other hand, the concept of the sustainable transport refers to the impact of the transport sustainability which is also defined as the system of the sustainable transport or the transport system sustainability (Borys, 2009).

The urban transport need of a city is a cyclic nature and highly depend upon the travel behaviour of the citizens.

Integrated transport and land use planning - The lack of coordinated transport and land use planning means that development projects are carried out by different agencies without addressing urban environmental frameworks, resources and social and economic factors. Different structures of cities (land use designs) have different transportation framework needs. The set up was set ahead of the efficiency of the metropolitan transport framework to satisfy the necessities of the natural assets and urban assets.

Transportation has been regarded as connexion to all elements of life in the world. In such case, world's general habitat, social prosperity and economic development all largely depend upon the transportation systems. By and large, shielded, spotless,

sensible and evenhanded vehicle frameworks help nations, especially in urban areas and metropolitan centres to flourish. Notwithstanding, a huge number of research finds that transportation frameworks in a large part urban communities and metropolitan regions are not sufficient.

Figure 1.5 EV- Oriented bus transportation (DTC)

1.7 Problem statement

Delhi is a complex and dynamic case for sustainable transport planning, as it has a large spatial scale, socio-economic heterogeneity, and rapid urbanisation. As one of the largest metropolitan areas of the Global South, the city faces very high travel demand, which is influenced by population growth, economic concentration, and dispersed urban development. Scholars have pointed out time and again that the transport challenges in Delhi are systemic in nature and not isolated, but require integrated and long-term planning responses and not mode-specific interventions.

One of the most important issues that have emerged from the literature is the exponential increase in private vehicle ownership. Rising incomes, aspirational car ownership and lack of deterrents to private vehicle usage has led to rising levels of motorisation resulting in severe congestion and inefficient use of available road space (Tiwari & Jain, 2012). This trend has not only led to the reduction in the average travel speeds but also to the efficiency of the public transport system operating in a mixed traffic condition. Congestion-related delays have important economic costs and have negative impacts on the productivity of cities.

Environmental deterioration is another major problem arising out of the transport system in Delhi. Vehicular emissions are one of the primary reasons for the degradation of air quality, pollutants from transport have an important influence on the health of the general population. Studies have been reported on the contribution of transport emissions on high levels of particulate matter and nitrogen oxides that are associated with respiratory and cardiovascular diseases in Delhi (Guttikunda et al., 2018). Despite the policy measures like fuel quality improvements and emission standards, the environmental burden of transport is still a persistent challenge especially in the absence of any strong demand management strategies.

In addition, the city is also badly equipped for non-motorised transport (NMT) such as walking and cycling. Although a large share of daily trips are made in Delhi on foot or bicycle, these modes are given short shrift in terms of priority in design and investment of streets. Poor pedestrian environments, gaps in cycling networks and safety risks put off active travel - especially from vulnerable road users. Weak last mile connectivity further limits the access to public transport, and makes it less attractive and usable.

Governance and institutional fragmentation is contributing to such difficulties. Transport planning and implementation in Delhi is done by several agencies working at different levels of administration and this often leads to overlapping responsibilities, inconsistent implementation of policy and lack of coordination. Several studies attribute this to inadequate common governance and performance-based monitoring frameworks, which minimise the impact of transport policies and defuse the delivery of results for sustainability.

At the same time, there are also great options in Delhi, towards achieving sustainable mobility. The growth of Delhi Metro Rail Corporation has been mentioned frequently as a milestone in urban transport, and has delivered high capacity, reliable, and relatively low emission transport to the city. The metro has led to drastic improvement in travel time, and has proven the efficacy of mass rapid transit in shifting travel away from the private mode (Kathuria & Sterner, 2007). In addition, it has introduced progressive initiatives like Delhi Electric Vehicle Policy (2020), expansion of cycle infrastructure and adoption of transit oriented development (TOD) guidelines in the city.

However, existing research suggests that these initiatives are not sufficiently integrated, and weakly monitored. Dutta et al. (2020) mention that the lack of coordination between transport modes, land use planning and institutional frameworks, which restrict the long term effectiveness of sustainability oriented intervention. Furthermore, the Master Plan Delhi 2041 (MPD-2041) - while articulating a vision for sustainable mobility - continues to grapple with gaps on institutional reform, climate alignment, stakeholder engagement and metric-based evaluation. These limitations point out the need for integrated and comprehensive and performance oriented approach towards sustainable transport planning in Delhi.

1.8 Gaps in Existing Literature

1.8.1 Lack of Holistic Sustainability Evaluation Frameworks

A huge gap that exists in current transport literature is the absence of holistic frameworks for evaluating sustainability that address social, environmental, economic and institutional dimensions simultaneously. Most studies of urban transport systems tend to have a narrow scope in terms of infrastructural performance measures, e.g. capacity, speed and congestion levels or environmental performance measures, e.g. emissions and energy consumption. While these aspects are critical, they are only a part of the understanding of sustainability. Governance quality, policy coherence, institutional coordination, equity and inclusiveness are often considered as secondary,

if any, considerations. This piece-meal approach limits the ability of planners and policy makers to understand interconnected systems that exist in transport systems. As a result, the impacts of transport interventions can be positive in some dimensions, but negative in others (e.g. social exclusion, institutional inefficiency). The lack of an integrated framework also means that it is hard to compare plans and cities, and therefore that the usefulness of sustainability assessments for informed strategic decision making works is limited. This deficit makes the need for multidimensional evaluation frameworks to capture the full complexity of urban transport sustainability in rapidly urbanising contexts such as Delhi that do more.

1.8.2 Limited Application of SDG 5Ps in Local Transport Planning

Despite widespread reference to the Sustainable Development Goals (SDGs) in the global policy discourse, very limited focused applications have been made of the SDGs in local transport planning, especially in the Indian scenario. The SDG 5Ps framework - which comprises People, Planet, Prosperity, Peace and Partnership offers a comprehensive viewpoint for knowing sustainability through a unified lens of social equity, environmental protection, economic development, governance effectiveness and collaborative partnerships. However, existing Indian transport studies do not operationalise this framework much. Most research makes either conceptual reference to the SDGs without using the 5Ps as an integrated analytical structure or makes connexions to transport outcomes for individual goals. Thereby key dimensions such as institutional trust, stakeholder participation and inter-agency collaboration are frequently left out of sustainability assessments. This restricts the capacity of transport planning to be consistent with global sustainability agendas with any meaningful locus. The underutilisation of the 5Ps framework is missing an opportunity to implement a first line of action towards the translation of the globally accepted principles of sustainability into actionable and locally relevant planning instruments in urban mobility systems.

1.8.3 Weak Linkage Between Evaluation Outcomes and Framework Modification

Another important gap in literature is a poor relationship between results of sustainability evaluation and framework modification or policy refinement. Many studies concentrate on the diagnosis of problems within existing transport systems or plans but do not go so far as to provide structured and actionable solutions. Evaluation exercises are often considered as an end goal rather than an input into an iterative planning process. As a consequence, the important information from assessment generated is not shown by systematic translation into improved frameworks, policies and operational guidelines. This disconnect measures the relative unimpact of academic research and diminishes the importance of the research for decision-makers. In the case of complex urban systems such as Delhi, in which transport challenges are so deeply entrenched in the institutional and socio-economic structures, evaluation without reform-oriented results is of limited value. Addressing this gap necessitates researchers who directly link assessment results to the design of modified and context-

specific transport frameworks that could provide the direction for implementation and subsequent greening transitions above the long term.

1.8.4 Insufficient Integration of Expert Consensus Methods

The literature also shows that little is known about structured expert consensus processes in the development of improved urban transport frameworks especially in the case of India. While expert opinions are mentioned often enough, most of the time they come in and out of considerations informally or as per choice, without any systematic validation or approval building processes. Methods such as Delphi technique, which allow iterative consultation, anonymity and convergence of expert judgement, etc. are rarely followed by Indian transport planning research. This leads to frameworks that are potentially weak, and that are not contextually sensitive or accepted by practitioners. Given the complexity and multi-actor nature of urban transport systems, expert consensus techniques are critical to help capture diverse perspectives, compromise conflicting priorities and increase the credibility of proposed solutions. The lack of such methods controls a functional gap on methodology in weakening the evidence for the implementation of sustainable transport frameworks.

1.8.5 Absence of Decision-Support Systems Aligned with Sustainability Indicators

A further gap in existing literature is that there are not operational decision-support systems to align indicators of sustainability and planning and governance processes under real-world conditions within the transport sector. While there have been many studies proposing indicators and assessment frameworks, there have been few that have HCC into workable tools which aid data-driven decision-making. The lack of dashboard systems, monitoring systems, and analytical systems mean that policy makers are constrained in their ability to monitor performance, trade-offs and make adjustments over time. This is especially important in the case of large cities such as Delhi where data is becoming available but it remains underutilised for strategic planning. Without the help of assistive systems, sustainability frameworks are at risk of remaining a theoretical construct rather than an instrument for implementation purposes. Bridging this gap requires a combination of sustainability indicators with digital decision support mechanisms which will allow for the operationalization of planning frameworks, as well as supporting continuous monitoring and evaluation mechanisms.

1.9 Need and Significance of the Present Study

Collectively these gaps highlight the importance of the current research. This study takes response to the question by providing an SDG-aligned, 5Ps-based evaluation of MPD-2041, based on expert-validated gap analysis. It contributes to the current state of literature by proposing a Modified Sustainable Transport Framework (MSTF) which has a direct bearing on governance, inclusiveness, innovation and climate resilience. Further, through the conceptualisation of an assistive, decision-support

system, the research formulates the transition between evaluation and implementation. In so doing, the study reinforces the nexus between sustainability theory and real-life transport planning, whereby the context-specific practical methodology can be appropriately sized to serving Delhi and similar urban areas.

On the basis of research gaps identified (limited holistic evaluation of sustainability, poor integration of SDGs, framework modification not being undertaken and lack of tools for decision support) the research objectives are formulated as follows:

1.9.1 Objective 1:To understand the transport system of Delhi

This objective focuses on systematic analysis of transport subsystems of Delhi - public transport, private forms of transport, non-motorised transport, governance and infrastructure. It provides a contextual baseline through a review of policies, secondary data, and field insights to understand operational performance, intermodal linkages, and current sustainability challenges.

1.9.2 Objective 2: To identify major areas for improvement in line with the Sustainable Development Goals (SDGs)

This objective measures the transport system of Delhi vis-à-vis the UN Sustainable Development Goals in the framework of the 5Ps (People, Planet, Prosperity, Peace, Partnership). Expert-based assessment and indicator scoring help identify critical gaps, underperforming dimensions, and areas of concern where interventions are needed for sustainable mobility planning.

1.9.3 Objective 3: To modify the existing framework for an efficient Sustainable Transport System

This objective addresses the gap between evaluation and action by seeking to modify the existing transport framework by adding governance, inclusivity, innovation, and resilience. The framework is refined through Delphi-based expert consensus to ensure contextual relevance, feasibility, and compatibility with global sustainability principles.

1.9.4 Objective 4: To develop an assistive system for a sustainable transport system.

This objective is the translation of the Modified Sustainable Transport Framework into an operational assistive system. The system facilitates data-driven decision making among planners by indicators and performance dashboards, and scenario assessment, thereby helping it to continuously monitor and inter-agency coordination and measure progress towards achieving Delhi's sustainable transport and SDG targets.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The transport sector has a pivotal role in contemporary sustainable development debates because of the significant intrusion on the quality of the environment, economic productivity, social equity and public health. Globally, transport systems are whips across numerous proportions of emissions of greenhouse gases and energy, land conversion, and urban air pollution. At the same time, transport opens up access to jobs, education, healthcare and a place in society which makes it an essential factor determining quality of life and inclusive growth. The need to balance mobility demand with sustainability imperatives has therefore become one of the key preoccupations of urban planning and policy-making especially in rapidly urbanising metropolitan regions.

Over the last three decades, the academic debate on sustainable transport has been developed considerably. Early research was mainly directed towards reducing negative externalities on the environment through technological improvements such as cleaner fuels and vehicle efficiency. However, an expanding body of scholarship is emerging which realises that technological fixes are not enough to solve the systemic nature of transport-related sustainability challenges. Contemporary literature focuses on having a much more systems approach, incorporating land use planning, behavioural change, institutional coordination, governance structures and stakeholder involvement.

In developing countries like India, such challenges are further added to the issues of rapid motorisation, population growth, spatial fragmentation and institutional complexity. Metropolitan cities such as Delhi have acute pressures for sustainability, in the forms of traffic congestion, poor air quality, unequal access to mobility and fragmented arrangements of governance these cities experience. While major investments have been made in public transport infrastructure and policy reforms, the results are often falling short of sustainability objectives weak and low integration, poor monitoring and lack of adequate decision support mechanisms.

This chapter involves a critical review of the theoretical, empirical, and methodological literature relevant to the issue of sustainable transport systems.

The review is structured with a view to facilitate development of an SDG aligned Modified Sustainable Transport Framework (MSTF) for the city of Delhi. Specifically, the chapter addresses the following:

(i) theoretical background about sustainable transport,

(ii) global frameworks for sustainability and SDG 5Ps approach,

(iii) transport sustainability assessment models and indicators,

(iv) governance and institutional factors of transport planning,

(v) Urban transport system of Delhi against Master Plan Delhi 2041 (MPD-2041).

By synthesising both global and Indian scholarship in this chapter, critical research gaps are identified and the theoretical rationale for the present study is laid.

2.2 Conceptual Foundations of Sustainable Transport

2.2.1 Evolution of the Sustainable Transport Concept

The idea of sustainable transport was developed in the later part of the twentieth century after increasing awareness of environmental destruction and resource limitations. Early definitions have been based to a large extent on the notion of sustainable development more generally, as set out in the Brundtland Report, which focused on the idea of meeting the needs of the present without compromising the ability of future generations to meet their own. In the transport context, sustainability was at first defined in the context of reducing pollution, energy consumption and congestion.

Early policy-oriented definitions by international institutions had an emphasis on efficiency and protection of the environment. Such approaches commonly addressed reducing emissions per vehicle-kilometre travelled, fuel efficiency and alternative fuels. While such measures were important, in time scholars criticised them because they dealt with symptoms without addressing underlying structural causes for unsustainable mobility patterns.

As research continued to be conducted, the concept of sustainable transport began to branch out from the base of environmental considerations to add social and economic considerations. Scholars reasoned that transport systems should not merely minimise environmental detriments; they also should ensure social equity, accessibility, safety and economic viability. This shift was a move away from understanding sustainability only in a narrow technological idea, to a more holistic and normative conception.

Bannister's seminal work on sustainable mobility constitutes a very important turning point in the literature. He argues that to be sustainable it is necessary to move away from car-centric transport systems and towards integrated transport systems where walking, cycling and public transport are a priority. According to this school of thought it is not only a matter of cleaner vehicles, but rather focusing on the transformation of urban form, travel behaviour and societal values relating to mobility.

Similarly, Litman conceptualises sustainable transport as an accessibility-based system, emphasising the capacity of people to get to desired destinations and not the speed of movement on the vehicles nor the amount of traffic. This reconceptualisation is especially important towards dense urban environment where excessive motorisation cause diminishing returns in mobility efficiency & growing social costs.

2.2.2 Dimensions of Sustainable Transport

Modern literature narrows down on the opinion that sustainable transport is a multi-dimensional aspect that is interdependent:

Environmental dimension:

Among these is minimising emission of greenhouse gases, air pollution, noise and use of resources. Research emphasises the necessity of switching to low-carbon modes, energy conservation, and reducing the land occupation and ecological disturbance.

Social dimension:

Social sustainability in transport is associated with equal accessibility, affordability, safety, and inclusiveness. Studies focus on making vulnerable populations such as women, children, the elderly, and persons with disabilities to be served by the transport system. The major issues are also safety and the health results of the population.

Economic dimension:

Economic sustainability means ensuring that transport systems are economically viable and cost-effective, and that they support economic productivity. This involves effective distribution of resources, minimisation of congestion costs and incorporation with economic development strategies.

2.2.3 Systems Perspective and Sustainable Transport

A common finding in the literature is the weakness of single-intervention measures. According to the researchers, transport systems are characterised by complex feedback mechanisms, rebound effects, path dependencies. In the case of vehicle efficiency, for example, it can lead to reduced per-kilometre emissions, but it can also create new travel demand that negates the environmental benefits.

Systems-based approaches support integrated approaches that combine technological advancements, demand control, land-use planning, pricing, and behavioural interventions. These methods acknowledge transport as a socio-technical system that exists in more general urban, economic and institutional contexts.

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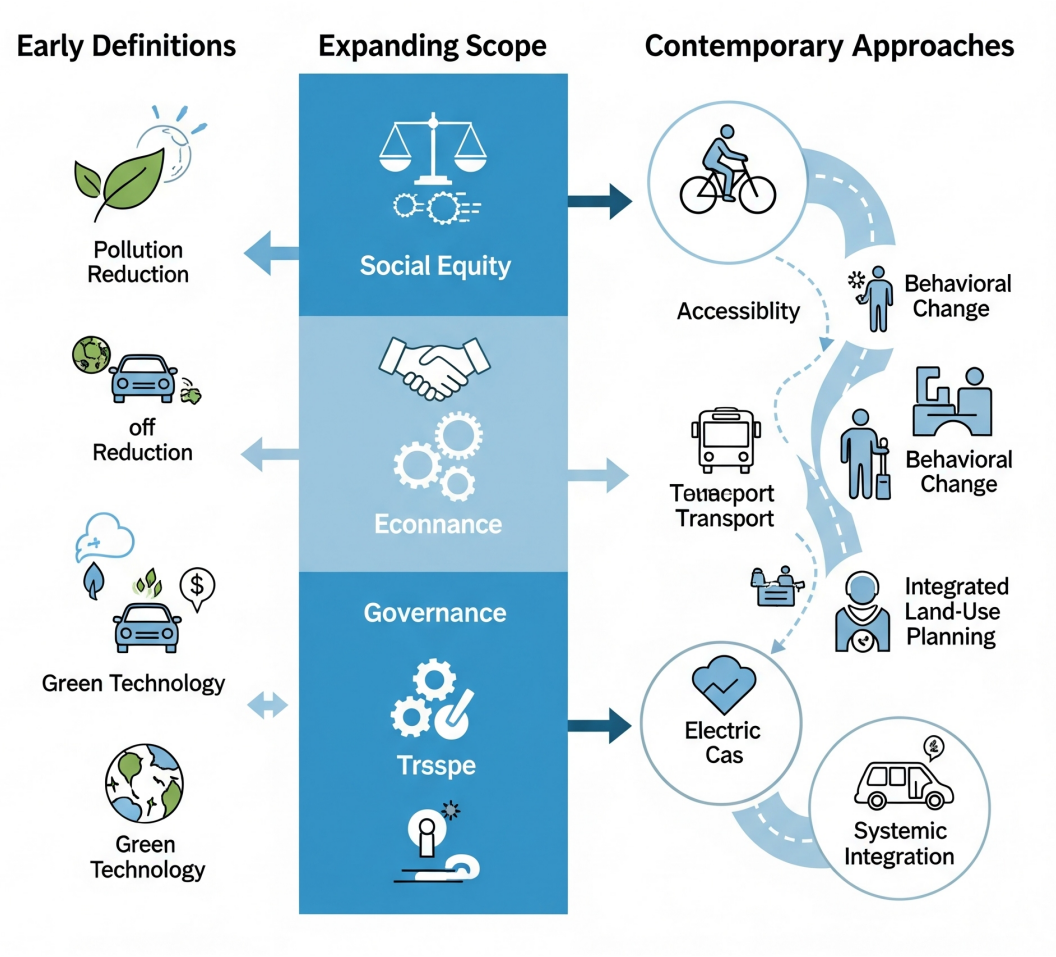

Figure 2.6 Evolution of sustainable transport

2.3 Sustainable Mobility and Global Policy Frameworks

2.3.1 International Sustainability Agendas and Transport

International policy systems are important in the determination of national and urban transport policies. Over the last 20 years, the global community has increasingly recognised the centrality of transport in achieving sustainability goals through international agreements. Sustainable mobility systems are all underlined by climate change mitigation agendas, urban resilience, and inclusive development.

The Paris Agreement is keen on the transport sector as one of the greatest contributors of greenhouse gas emissions, and proposes deep decarbonisation by modal shift, systemic change and electrification. Equally, compact, connected, and transit-oriented urban development is the theme that the New Urban Agenda encourages to build sustainable cities on.

All of these frameworks are indicative of a transition to integrated and long-term planning frameworks that no longer have sectoral boundaries. But the problem of global aspirations being translated into local action is a major issue especially in the developing nations.

2.3.2 Transport and Sustainable Development Goals (SDGs).

The United Nations Sustainable Development Goals is the most universal and generalised international model of sustainable development. Transport is not a goal by itself, but it is cross-cutting as it is reflected in several SDGs.

SDG 11 specifically demands that all people to have access to safe, affordable, accessible and sustainable transport systems. Transport is connected to other goals, such as health outcomes, economic growth, climate action, and social inclusion. According to scholars, transport is a systemic enabler which influences development throughout the SDG agenda.

The SDGs include the focus on universality, integration, and measurability. Therefore, they need assessment models that are able to reflect the multidimensional effects and interdependencies. Conventional transport performance indicators, which deal with the flow of traffic and supply of infrastructure, cannot be sufficient here.

2.3.3 The SDG 5Ps Framework

The SDGs are organised in five pillars, namely, People, Planet, Prosperity, Peace, and Partnership or rather known as the 5Ps. This model offers an integrated approach to the assessment of sustainability in sectors.

In the transport context:

People include accessibility, safety, affordability and social inclusion.

Planet deals with the issues of environmental impacts including emissions, energy consumption, and ecological footprints.

Prosperity is associated with efficiency in the economy, innovation and increased productivity.

Peace is an indicator of the quality of governance, institutional coherence, the regulatory frameworks and rule of law.

Partnership focuses on stakeholder involvement, inter-agency coordination and collaboration between the public and the privates.

Some researchers claim that the 5Ps paradigm has surpassed the shortcomings of traditional triple-bottom-line models in that it is explicit and integrates the dimensions of governance and collaboration. Nevertheless, the 5Ps have not been empirically applied to city transport planning, especially in the Indian setting.

This is an essential gap since it is a well-known barrier to sustainable transport implementation in Indian cities due to fragmentation of governance and poor institutional coordination.

2.3.4 SDG Framework Applicability to Indian Cities.

The Indian cities have distinctive sustainability issues, which are high population density, informal development, socio-economic inequality, and institutional complexity. Although national policies are increasingly mentioning SDGs, their implementation at urban level is not even spread.

According to the literature, SDG-aligned frameworks have the potential to allow a shared language of alignment of sectoral policies, tracking progress, and engaging stakeholders in dialogue. Nevertheless, effective implementation needs context-specific pointers, specialists and decision support systems that can convert the results of the evaluation into reforms that can be implemented.

This observation is a direct informing factor in the approach taken in terms of methodology in the current study.

2.4 Frameworks and Models of transport sustainability evaluation.

2.4.1 Assessment Approaches based on Indicators.

The literature on transport sustainability assessment is dominated by indicator-based assessment. Operationalisation of abstract concepts of sustainability into measurable variables is done through indicators that allow comparison, benchmarking and monitoring.

The initial models grouped indicators as environmental, social, and economic. These frameworks were criticised as simplistic and insensitive to context, though useful. The more recent research includes governance, participation, and resilience measures to mirror the changing sustainability priorities.

The literature underlines that indicator choice is one of the crucial factors affecting the results of evaluation. The indicators should be policy relevant, measurable and aligned. Poor or insufficient sets of indicators may result in wrongful interpretation and inefficient reaction to policy.

2.4.2 Composite Indexes and World Systems.

A number of composite indices have been constructed to measure the sustainability of urban transport. These are Sustainable Urban Mobility Plans, Sustainable Urban Transport Index, and the models that are life-cycle-based and scenario-based.

The Sustainable Urban Transport Index is an interesting initiative to make transport indicators consistent with the SDGs and specifically to the Asian cities. It combines various dimensions and uses the normalisation methods to allow cross city comparison.

Nevertheless, scholars also mention the weaknesses linked to composite indices, which consist of the equal weight of indicators, the lack of data, and the inability to capture governance dynamics. These problems are especially acute in the situations of developing countries where the institutional capacity and available reliable data are not even.

2.4.3 Multi-Criteria Decision-Making and Expert-Based Techniques.

The Analytic Hierarchy Process (AHP), the Delphi technique, and scenario analysis are multi-criteria decision-making (MCDM) techniques that are becoming more common in transport sustainability studies. These approaches allow using both qualitative and quantitative standards, which will help make judgements by experts.

Research using the AHP approach to transport planning in Delhi has shown that it is necessary to include qualitative criteria in the process, including institutional feasibility, public acceptance, and implementation barriers. Equally, Delphi-based research studies focus on the importance of consensus amongst the experts in identifying deep structural interventions as opposed to incremental solutions.

Such methods have not been fully exploited in the Indian urban transport planning practise, which is a big gap between academic studies and policy application.

2.4.4 Weaknesses of the Current Evaluation Frameworks.

The continuity of the criticism of the literature is related to the poor connexion between evaluation and action. Most studies do not go further to suggest how their frameworks can be altered, how policies can be reformed and how to assist in implementation.

More so, governance and institutional indicators are not typically represented well, even though they play a pivotal role in the determination of the outcomes. This weakness is especially applicable to such cities as Delhi, where both the lack of coordination and decentralised powers negate the effectiveness of policies.

These weaknesses highlight the necessity to have a revised governance-based assessment model with expert validation. and decision-support tools.

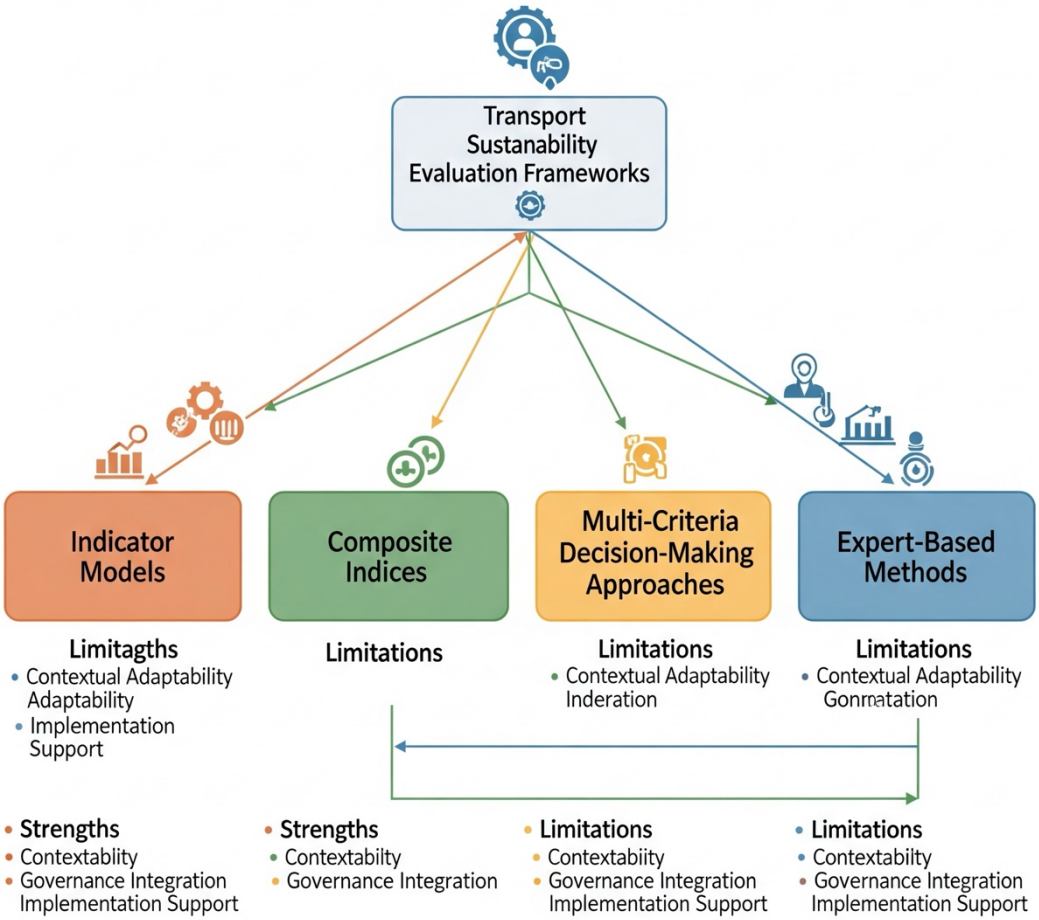

Figure 2.7 Transport Sustainability Evaluation Framework

2.5 Governance, Institutional Structures, and Implementation Challenges in Sustainable Transport

2.5.1 Importance of Governance in Sustainable Transport Systems

In modern literature, governance has become one of the most conclusive factors of sustainable transport. Though the initial research was mainly concerned with the provision of infrastructure and technological efficiency, the recent research has realised that the governance arrangements determine the coherence in policy, capacity of implementation, accountability, and long term sustainability. The complexity of governance is inevitable as sustainable systems of transport necessitates a coordinated effort in various sectors such as land use, environment, energy, public health and finance.

According to scholars, sustainable mobility is rather a governance issue than a technical one. Policies and infrastructural investments that are well formulated may end up failing without proper institutional coordination, alignment of stakeholders and

mechanisms of monitoring. Therefore, governance is also becoming abstracted as a pillar of transport sustainability alongside the environmental, social, and economic aspects.

2.5.2 Institutional Fragmentation and its effects.

One of the prevailing topics in the literature is the issue of institutional fragmentation. Transport planning and operations are often spread out among many agencies with overlapping or poorly defined mandates in most cities. This disintegration results in failure of coordination, inconsistency of policies, repetition of efforts and poor accountability.

Research in both the developed and developing nations points to the impediment of integrated mobility planning due to fragmented governance structures. Conversely, cities with developed unified transport authorities exhibit better service delivery, efficiency of fund and sustainability performance. Planning, operations, fare policy and data management are usually combined under one institutional umbrella by such authorities.

The literature highlights the fact that the situation of fragmentation is especially acute in the context of developing countries, when institutional reform lag behind the rapid urban growth. Informal practises, political interference and capacity constraints also contribute to the worsening of governance issues in such settings.

2.5.3 Indian Urban Transport Governance Troubles.

The cities of India are representative of numerous governance issues that have been recognised in the world literature. The transport functions in the city are normally shared by municipal corporations, development authorities, traffic police, state transport departments, metro rail corporations, and parastatal agencies. The numerous actors usually lead to poor coordination and divided decision making.

A number of studies that concentrate on Indian cities point out that lack of empowered metropolitan transport authorities is one of the significant obstacles towards sustainable mobility. National policies have encouraged the implementation of integrated planning and single governance, but this has not been effectively done at the city level.

The fact that the city of Delhi has a special administrative status and that it has more than one jurisdiction increases the complexity of governance in the case. There is always literature referencing to overlapping mandates and the absence of shared data platforms as well as poor monitoring mechanisms as ones that render the policies ineffective.

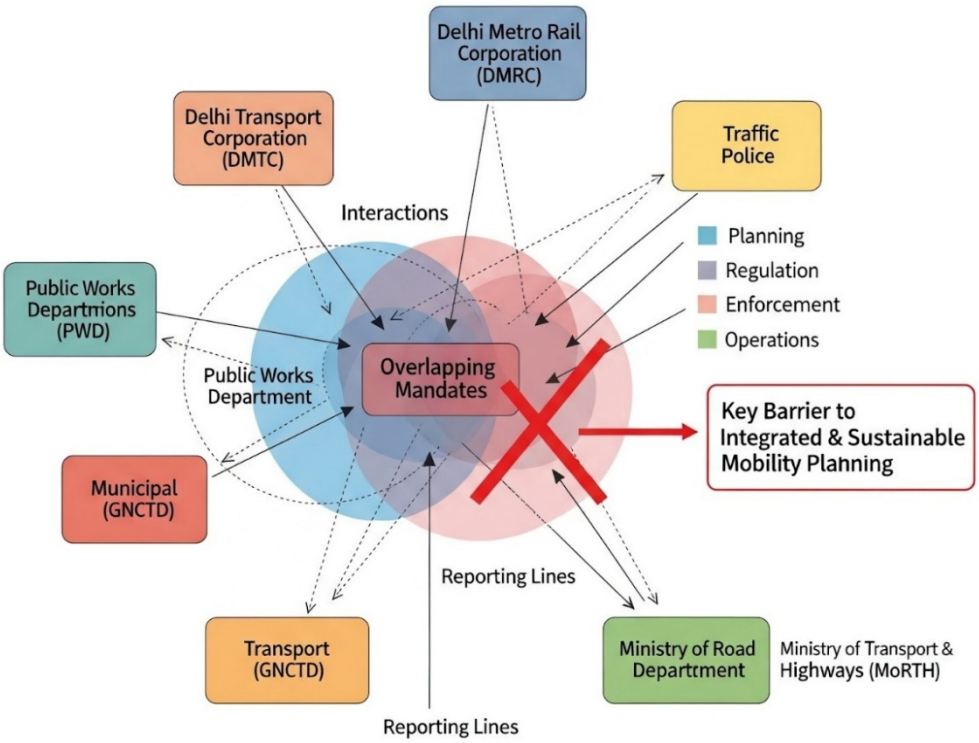

Figure 2.8 Transport Key Barrier

2.5.4 Decision-Support Systems and Evidence-Based Planning

The other important gap that was found in the literature is the low application of decision-support systems (DSS) in transport planning. The data-driven approaches are highly recommended but they are not practised especially in Indian cities.

The decision-support systems combine the data, indicators, and analytical tools and assist in making informed decisions. According to scholars, DSS is capable of increasing transparency, facilitating scenario analysis, and adaptive planning. The literature however indicates that the majority of transport plans are based on the static assessment as opposed to the dynamic feedback-based systems.

The lack of DSS is also consistent with the indicators of sustainability that inhibit the capacity of the planners to track the progress, assess the trade-offs and change the policy according to the conditions. This weakness supports the objective of an assistive decision-support mechanism as a component of the proposed MSTF.

2.6 Urban Transport System Delhi: Literary Evidence.

2.6.1 General Transport Environment in Delhi.

Delhi is one of the most complicated and difficult examples of the urban transport sustainability in the Global South. Being a fast-developing megacity, the city of Delhi is under severe pressure due to the population growth and space expansion as well as increased mobility demand. The transport infrastructure of the city shows both the high investments in the transport infrastructure and the opportunities to observe the systemic shortcomings.

The literature describes the mobility situation in Delhi as a highly motorised one, where in the last 20 years the number of privately owned vehicles is growing at an alarming rate. The effect of this trend has been the resultant high congestion, poor air quality, and the rising emissions of greenhouse gases. Meanwhile, users of non-motorised transportation still represent a significant portion of daily travels, usually in unsafe and unequal circumstances.

2.6.3 Public Mobility and Sustainable Transport.

Delhi has made a number of ambitious projects that would facilitate sustainable transport. The Delhi Metro has been an effective example that has been extensively mentioned in the literature as an effective mass rapid transit system that has enhanced accessibility, minimised travel time and helped to mitigate emissions. The policies of bus rapid transit, electric vehicle, and transit-oriented development give additional indications that the city is interested in the sustainable mobility.

Scholars however warn that these initiatives have not been incorporated adequately into a coherent system. Last-mile connectivity, fare integration, service reliability, and institutional coordination all continue to be problems. Consequently, benefits of investments in public transport to sustainability are not realised in full.

2.6.3. Non-Motorised Transport and Equity Concerns

Non-motorised transport (NMT) such as walking and cycling takes the centre stage of sustainable mobility discussion. The paradox is reflected in the literature on Indian cities as a significant percentage of journeys is carried out on foot or bicycle, but NMT infrastructure is poorly provided.

Infrastructure-based studies of unsafe pedestrian conditions, incomplete cycling infrastructure, and motorised competition have been recorded in the city of Delhi. The conditions are particularly disproportionately among the low-income groups and lead to social inequity.

The literature highlights the fact that NMT should not be promoted as an environmental strategy, but as a social justice requirement. Sustainable transport

systems should ensure that the vulnerable road users are put at the forefront and that the urban space is reclaimed by people and not vehicles.

2.6.4 Air pollution, climate change and human health.

The quality air crisis in Delhi has drawn the interest of a great number of scholars. The transport emissions are found to be a significant cause of the particulate matter and nitrogen oxide, with disastrous consequences in the public health. Research associates air pollution exposure with respiratory illness, life shortening and economic damages.

The need to address the issue of climate change also increases the urgency of the sustainable transport reform. It is highlighted in literature that mitigation measures should be supported by adaptation measures so as to be able to boost resilience to heatwaves, extreme weather events, and energy shocks.

Although these challenges are acknowledged by the policy, there still exist gaps in the implementation because of inadequate monitoring, enforcement, and fragmentation of governance.

2.6.5 The Master Plan Delhi 2041 (MPD-2041) in Academic Discourse.

The Master Plan Delhi 2041 contains a long-term vision of the urban development, mobility, land use, and environmental management. Researchers admit that the plan also includes such progressive ideas as the prioritisation of public transport, TOD, e-mobility, and promoting NMT.

The literature however criticizes MPD-2041 on lack of operational clarity, poor performance indicators and low institutional reform mechanisms. The success of the plan is reliant on good governance, inter-agencies coordination, and ongoing evaluation- areas where the current literature has found a lot of gaps.

These findings highlight the necessity of a SDG-consistent independent evaluation of MPD-2041, which is a task that the current study performs..

Sl. No.	Author (s)	Year	Journal / Source	Focus Area	Objectives	Methodology / Tools	Key Findings / Insights	Keywords	Limitations / Research Gaps
1	Gudmundsson et al.	2012	European Planning Stu	Decision support in sustainable transport	Examine influence of decision-support systems in	Case studies; conceptual framework	Strong decision support critical for implementation success	Sustainable transport, decision support	Limited operationalisation across contexts

			dies		transport planning				
2	Kadubek	2015	Elsevier	Sustainable transport & logistics	Link theory with practical transport examples	Conceptual analysis	Sustainable logistics balances economic & ecological goals	Sustainable development, logistics	Lacks empirical validation
3	Sztangret	2020	MDPI	Systemic sustainable transport	Examine transport through systems perspective	Exploratory systems analysis	Sustainability requires integrated economic–social–ecological actions	Systemic sustainability	Preliminary, needs empirical testing
4	Gudmundsson & Regmi	2017	UNESCAP	Sustainable Urban Transport Index (SUTI)	Develop SDG-aligned transport index	Indicator framework; expert consultation	SUTI suitable for Asian cities	SUTI, SDGs	Equal weighting of indicators
5	Jacyna-Goda et al.	2017	Journal of Vibroengineering	Scenario-based transport evaluation	Assess sustainability via scenario analysis	Simulation & scenario modelling	Scenario analysis aids infrastructure decisions	Scenario analysis, ecology	High software dependency
6	Yedla & Shrestha	2003	Transportati	Sustainable transpo	Prioritise transport alternatives	AHP (multi-criteria)	Qualitative criteria	AHP, Delhi, CNG	Implementation barrie

			on Research	rt in Delhi			alter rankings		rs not addressed
7	Vashisth et al.	2018	IJRASET	Principles of sustainable transport	Review ITDP principles	Literature review	Eight principles effective for cities	Walk, cycle, transit	Lacks contextual adaptation
8	Islam et al.	2020	IJRASET	Non-motorised transport	Review NMT impacts	Review study	Indian NMT infrastructure inadequate	NMT, pedestrians	No policy implementation model
9	Potter	2007	Sustainable Transportation	Sustainable transport pathways	Explore system-wide approaches	Backcasting model	Single-measure solutions insufficient	CO_2, backcasting	Conceptual, lacks city data
10	Liu et al.	2013	Energy Policy	Transport modelling (China)	Evaluate HSR, URT, EV strategies	Energy & emissions modelling	12–13% emission reduction possible	EV, HSR	Rebound effects underestimated
11	Greene & Wegener	1997	Elsevier	Sustainable transport theory	Identify research priorities	Conceptual review	Tech, pricing & land-use integration vital	Sustainability, policy	Dated, pre-SDG
12	Zhao et al.	2019	Elsevier	Bibliometric analysis	Map sustainable transport research	Scientometric analysis	Identifies 9 research clusters	Bibliometrics	Social sustainability underexplored

13	Hull	2007	Elsevier	Policy integration	Study inter-sectoral coordination	Case studies, interviews	Institutional rigidity limits outcomes	Governance, policy	UK-specific
14	Robèrt et al.	2016	Journal of Cleaner Production	Strategic transport planning	Develop FSSD-based framework	Strategic systems approach	Governance crucial for sustainability	FSSD, planning	Needs wider validation
15	Tseng et al.	2013	Energy Policy	EV affordability	Compare EVs & conventional vehicles	Lifecycle cost analysis	EVs environmentally superior	EVs, affordability	Dependent on fuel prices
16	Richardson	2005	Elsevier	Sustainability frameworks	Develop passenger & freight models	Framework development	Context-specific frameworks needed	Freight, passengers	Limited generalisability
17	Stephenson et al.	2017	Transportation Research	Deep interventions	Explore governance change	Delphi method	Incremental actions insufficient	Delphi, governance	Country-specific
18	Qureshi & Lu	2007	Tsinghua	Karachi case study	Evaluate transport sustainability	Review & policy analysis	Lack of holistic planning	Urban transport	Limited transferability
19	Gösslinger et al.	2016	Transport Reviews	Urban space allocation	Assess space distribution	GIS analysis	Reallocation needed for equity	Space justice	No longitudinal data

20	Button & Nijkamp	1997	Journal of Transport Geography	Social change	Examine transport & society	Survey analysis	Social factors shape transport	Social change	Conceptual focus
21	Han	2010	Journal of Transport Geography	Singapore model	Study motorisation management	Policy analysis	Double-track policy effective	Singapore, planning	Unique governance context
22	Janic	2006	Transport Reviews	EU sustainable transport	Review EU research	Policy review	Need comprehensive indicators	EU transport	Regional focus
23	Borowiak & Cywinski	2015	Journal of Cleaner Production	Trolley bus systems	Assess eco-efficient PT	Case study	Trolleybuses enhance sustainability	Public transport	Limited scalability
24	Banister	2007	Transportm	Sustainable transport	Analyse challenges	Review paper	Behavioural change essential	Modal shift	Political resistance

			etrica	paradigm					
25	Nijkamp	1994	Elsevier	Environmental transport	Review policy bottlenecks	Policy review	External costs must be internalised	Environmental policy	Pre-SDG era
26	Eliasson & Proost	2014	Transport Policy	Climate policy	Evaluate policy feasibility	Theoretical review	International agreements difficult	Climate policy	Limited city focus
27	ITDP (Referenced)	—	Practice Framework	TOD & sustainable mobility	Define urban design principles	Applied framework	TOD critical for sustainability	TOD, walkability	Needs localisation
28	MPD-2041 (Referenced)	2021	DDA	Delhi Master Plan	Guide long-term development	Policy document	Sustainability intent present	MPD-2041	Weak monitoring mechanisms
29	Present Study	—	—	SDG-based MSTF	Develop modified framework	5Ps + Delphi + DSS	Holistic, actionable framework	SDGs, MSTF	Validation underway

Table 2.2 Comprehensive Literature Review

2.7 Synthesis of Literature and Identification of Research Gaps

2.7.1 Thematic Synthesis of Reviewed Literature

The reviewed literature in this chapter is brought to the point of several important conclusions:

Sustainable transport is a systems-based concept with a multi-dimensional nature that needs to be approached through integrated means.

- Global policy frameworks like the SDGs are good normative guidelines but are to be localised.
- Indicators based assessment instruments are handy but tend to be incomplete and out of context.

- The key determinants of the success of implementation are governance and institutional capacity.
- The challenges that Indian cities encounter are peculiar to the rapid motorisation, equity, and institutional disunity.

Although much scholarly interest thereof has been paid, these insights have not been entirely converted into practical frameworks based on the Indian metropolitan contexts..

2.7.2 Identified Research Gaps

Based on the critical review, the following gaps are identified:

Gap 1: Absence of holistic, SDG-aligned transport evaluation frameworks
Most studies focus on isolated dimensions of sustainability without integrating environmental, social, economic, governance, and partnership aspects.

Gap 2: Limited application of the SDG 5Ps framework to urban transport systems
Although conceptually robust, the 5Ps framework has rarely been operationalised in city-level transport planning, particularly in India.

Gap 3: Weak integration of governance and institutional indicators
Governance is frequently acknowledged as important but inadequately measured or incorporated into evaluation frameworks.

Gap 4: Lack of expert-validated framework modification mechanisms
Few studies employ structured expert consensus methods, such as the Delphi technique, to refine and validate transport frameworks.

Gap 5: Absence of decision-support systems linked to sustainability assessment
There is a disconnect between evaluation outcomes and practical decision-making tools for planners and policymakers.

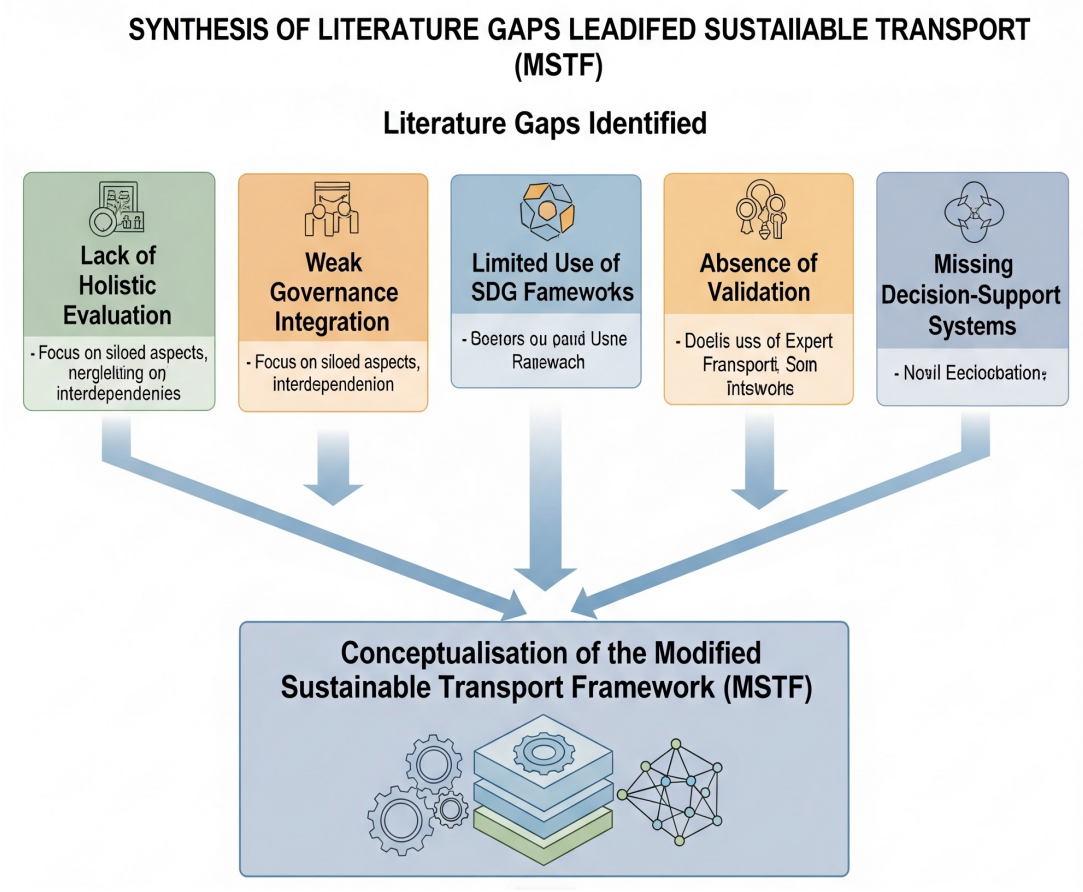

Figure 2.9 Synthesis of Literature Gaps

2.8 Positioning of the Present Study

The current study is specifically aimed to fill the identified gaps and bring forward the science of sustainable transport planning in the Indian society.

To begin with, the paper uses the SDG 5Ps framework as an integrative framework to assess the transport system in Delhi and, thus, transcends the traditional triple-bottom-line perspectives. This orientation makes it consistent with the global sustainability agendas and relevant to local circumstances.

Second, the study conducts a systematic analysis of Master Plan Delhi 2041 through SDG-based indicators to give a more evidence-based review of the strengths and weaknesses of the plan. This analysis overcomes the deficiency of empirical examination that is found in the literature.

Third, the research applies expert-based techniques, such as gap analysis and Delphi consensus building to narrow down and test a revised Sustainable Transport Framework (MSTF) that is specific to Delhi. This methodological strategy enhances the strength and viable applicability of the suggested framework.

Fourth, four Assistive Decision Support System is conceptualised by the research to operationalise the MSTF. The study by connecting the use of sustainability indicators with the mechanisms of governance and data-based tools will fill the gap between assessment and implementation.

Lastly, the study helps in providing a methodological model which can be duplicated in other Indian and international cities with the same sustainability issues. The study enhances the avenues to inclusive, robust, and sustainable urban mobility by its multi-dimensional approach that is integrated.

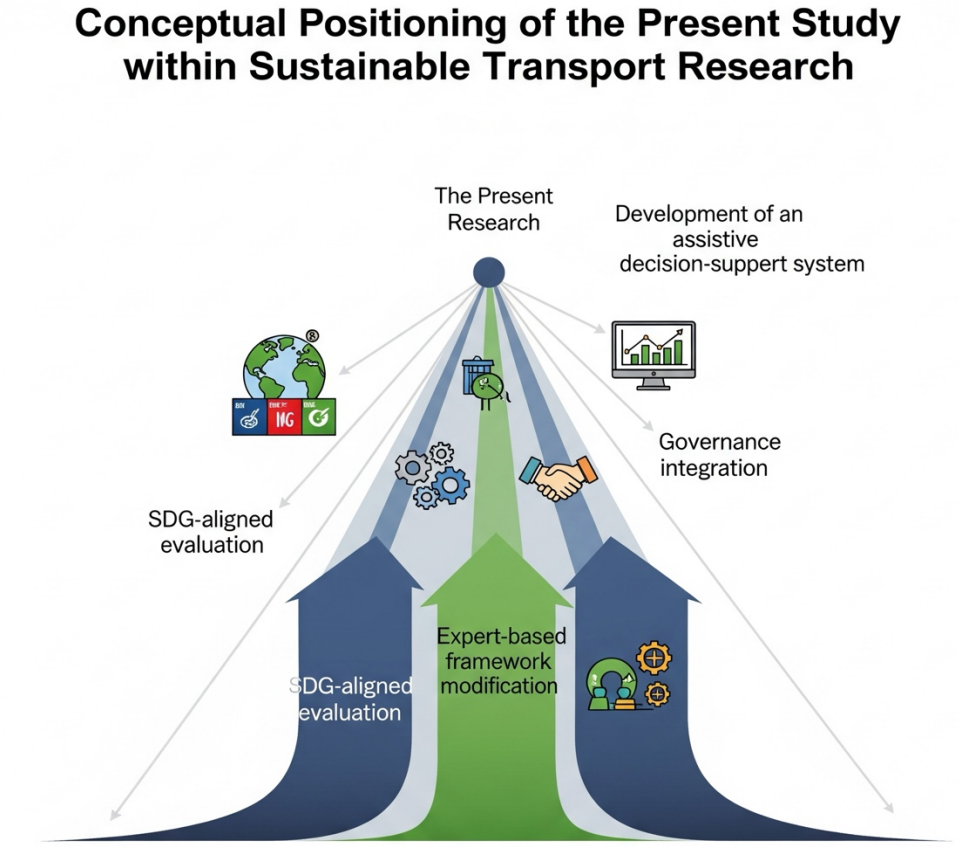

Figure 2.10 Sustainable Transport Literature

CHAPTER 3

RESEARCH METHODOLOGY

Introduction

This chapter introduces the research methodology that is followed to evaluate the transport planning frameworks that can be applied in the city of Delhi in a systematic manner, with the aim to detect the gaps in sustainability, and come up with a Modified Sustainable Transport Framework (MSTF) that is consistent with Sustainable Development Goals (SDGs). The methodological plan is set in such a way that it provides analytical rigour, transparency, and replicability; the multi-dimensional, complex nature of urban transport system in a rapidly expanding urban centre like Delhi is taken care of.

Due to the interdisciplinary characteristics of the subject of sustainable transport that includes infrastructure, governance, environmental performance, social equity, and technological integration, a mixed-method approach to research was chosen. The methodology is a combination of qualitative analysis of policy with quantitative analysis of policy by experts, gap analysis, framework modification and decision support structuring. Such a method allows to not only gain a contextual insight into the transport system in Delhi but also to evaluate the sustainability performance of the city through various policy frameworks. The methodological structure directly responds to the four research objectives:

1. To understand the transport system of Delhi.
2. To identify major areas for improvement in line with the Sustainable Development Goals (SDGs).
3. To modify the existing framework for an efficient Sustainable Transport System
4. To develop an assistive system for a sustainable transport system.

By following a sequential and objective-driven methodology, the study moves beyond descriptive assessment and contributes an operational, policy-relevant framework for sustainable transport planning.

Research Objective	Method Used	Output
Objective 1	Secondary data + field observation	System baseline
Objective 2	SDG indicators + expert scoring	Framework ranking
Objective 3	Gap analysis + benchmarking	Critical gaps
Objective 4	Framework synthesis + KPIs	MSTF

Table 3.3 Alignment of Research Objectives with Methodological Stages

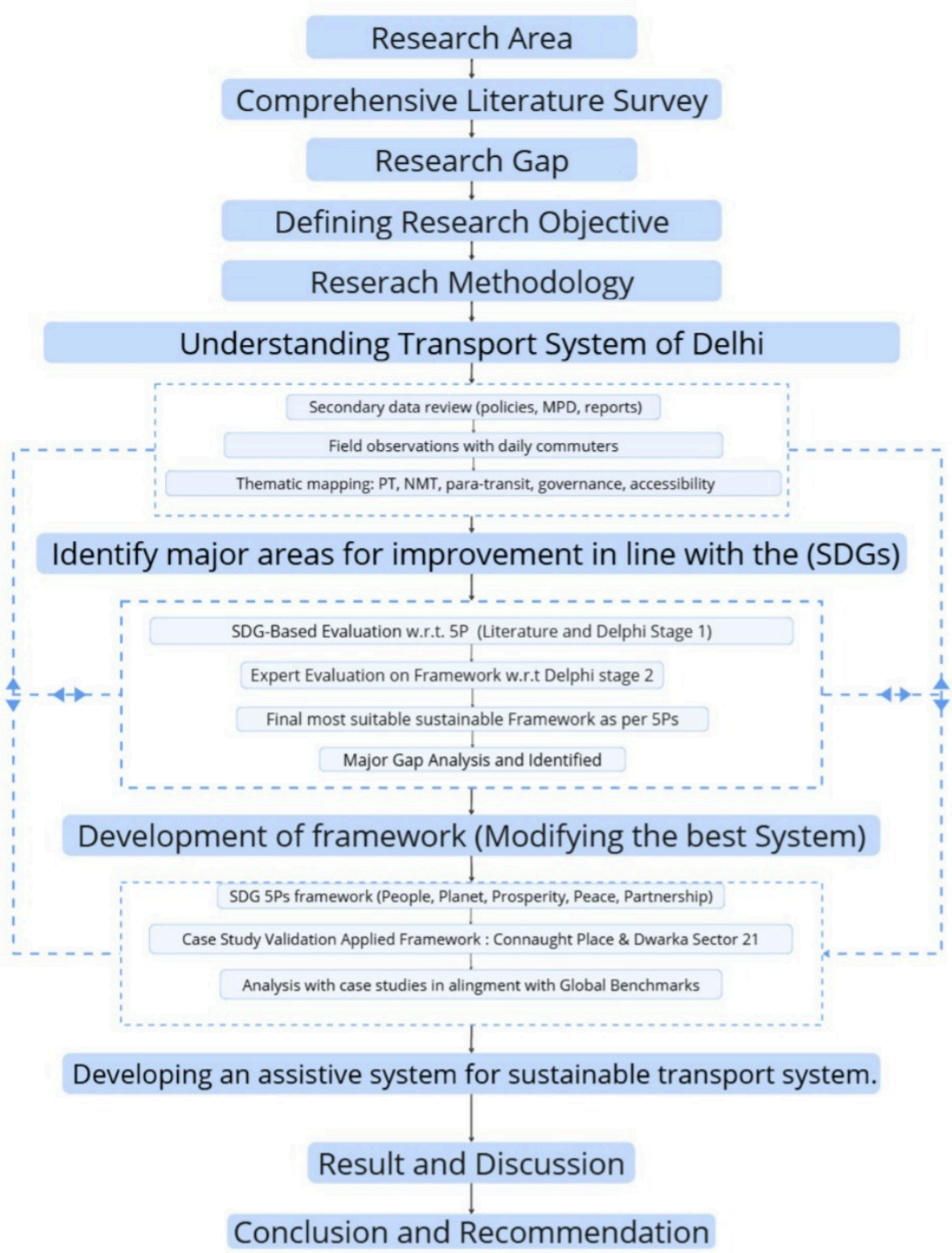

Figure 3.1 Research Methodology flowchart

3.2 Overall Research Design

The current study will use a sequential mixed-method research design to embrace the multidimensional and systemic planning of sustainable urban transport in Delhi. The design combines both qualitative and quantitative approaches in terms of logically arranged sequence of their application, where a methodological step informs and empowers the next step. This method is especially suitable when it comes to the research on the topic of transport sustainability, where the analysis of the policies, expert opinion, and performance measurement have to be integrated to produce not only theoretical knowledge but also practical solutions.

The research design starts with a contextual and systems based knowledge of the transport system in Delhi. This preparatory step aims at mapping of transport modes, infrastructure provision, institutions and governance mechanisms. This baseline is necessary because any intervention of sustainable transport should be based on the realities of the city, which are spatial, socio-economic, and institutional. The result of this phase gives the practical context needed to be able to assess the current planning structures.

The second stage of the study involves a comparative assessment of transport planning frameworks that can be used in the Delhi region. The systematic evaluation of fourteen national, state, and city-level policies and plans is conducted on the basis of a set of indicators based on the Sustainable Development Goals (SDGs). The integration of SDG 5Ps model of the People, Planet, Prosperity, Peace and Partnership will be used to make sure that sustainability will be viewed in a holistic manner that includes social equity, environmental protection, economic viability, governance and institutional partnership. Quantitative expert evaluation is used in this stage to make objective comparisons of frameworks.

The third phase is the structured gap analysis which is an important transitional step between evaluation and framework development. The gaps are determined through quantitative scores and expert consensus levels, qualitative feedback and benchmarking against best practices in sustainable mobility planning in other parts of the world. This is to make sure that the recognised gaps are not grossly score-driven but are also guided by experience and context. The gap analysis offers a diagnostic insight into the reasons behind poor performance of some sustainability dimensions in the framework selected.

The fourth stage is based on the identified gaps and aimed at changing and integrating the framework that led to the creation of the Modified Sustainable Transport Framework (MSTF). The research design focuses on change but not substitution; therefore, the current Master Plan Delhi 2041 (MPD-2041) is restructured into a stratified design to increase the clarity of operations and policy integration. All the layers of the MSTF are associated with specific interventions, desired results, and

indicators of performance, which allows the framework to serve as a strategic and an operational planning instrument.

The last phase in the research design will be validation using case studies. To determine the relevance and efficiency of the MSTF, two contrasting city settings are chosen, which are a central business district and a transit-oriented development zone. This validation process enhances the external validity of the study by showing how the framework works in various urban settings. The use of case studies makes sure that the outcomes of the research are not just imaginary but based on the real world planning situations.

All in all, the research design allows the study to be methodologically rigorous, logically progressing, and policy relevant so that it can contribute to sustainable transport planning in Delhi and other similar metropolitan areas both academically and practically.

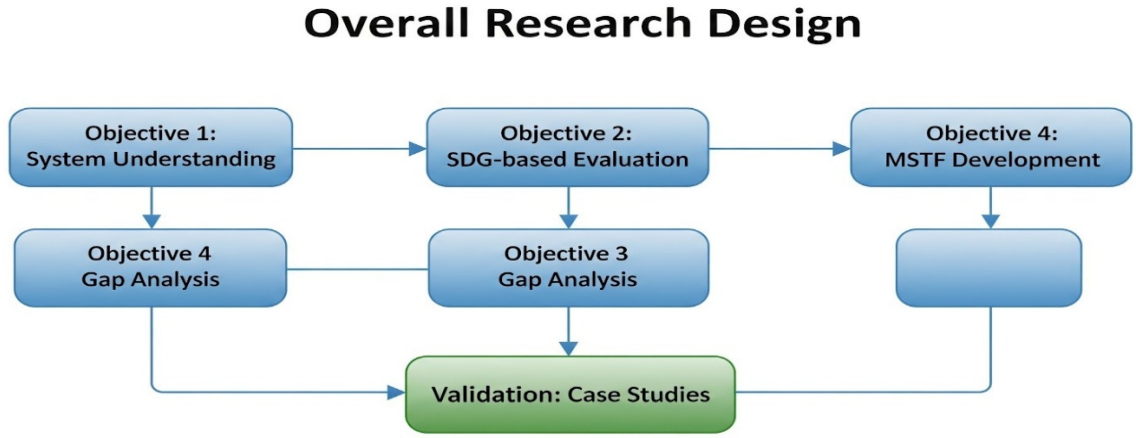

Figure 3.2: Overall Research Design

3.3 Data Sources

A comprehensive and multi-source data strategy was adopted to achieve the first research objective of developing an in-depth understanding of Delhi's transport system. Given the scale, complexity, and institutional fragmentation of urban transport in a megacity context, reliance on a single data source would be insufficient. Therefore, this study employed **s**econdary data sources, complemented by systematic field observations and previous empirical research conducted by the researcher, to ensure triangulation, contextual accuracy, and analytical robustness.

The primary source of information comprised secondary data obtained from official government documents, policy reports, and statistical publications**.** These included national- and city-level transport and urban development policies, planning guidelines, and master plans issued by agencies such as the Ministry of Housing and Urban Affairs (MoHUA), Government of National Capital Territory of Delhi (GNCTD), Delhi Transport Corporation (DTC), Delhi Metro Rail Corporation (DMRC), Unified Traffic

and Transportation Infrastructure (Planning & Engineering) Centre (UTTIPEC), and the Transport Department of Delhi. These documents provided authoritative insights into policy intent, institutional responsibilities, planned infrastructure investments, and long-term transport visions.

Additionally, transport-related statistical datasets were reviewed to gain an understanding of travel demand, modal share, vehicle ownership trends, public transport ridership, and network coverage. Census of India data, household travel surveys, mobility reports, and transport performance statistics were used to capture the evolving travel behaviour and spatial distribution of transport services across the city. These datasets enabled the identification of key structural challenges such as rising motorisation, declining bus share, uneven accessibility, and congestion-prone corridors. To complement policy and statistical analysis**,** field observations were conducted at selected representative urban locations, including central business districts (such as Connaught Place), transit-oriented development zones, major interchange nodes, and high-density residential and commercial areas. The purpose of field observation was not to generate primary quantitative data, but to qualitatively assess on-ground conditions related to walkability, last-mile connectivity, intermodal integration, traffic management, and informal transport operations. Observations were conducted using a structured checklist to ensure consistency and reduce observer bias.

Data Category	Source	Purpose
Policy documents	MoHUA, GNCTD, MPD-2041	Policy intent & governance
Transport statistics	Census, DMRC, DTC	Modal share & demand
Planning guidelines	UTTIPEC, CMPs	Infrastructure standards
Field observations	Selected urban locations	Ground realities
Prior research	Author's publications	Longitudinal insights

Table 3. 4 Data Sources Used for Understanding Delhi's Transport System

Furthermore, the study draws upon published empirical research authored by the researcher, including prior field studies, analytical papers, and transport assessments relevant to Delhi. These works provided longitudinal insights and methodological continuity, strengthening the credibility of the baseline system understanding. Intermediate and informal transport, governance structures, and environmental implications

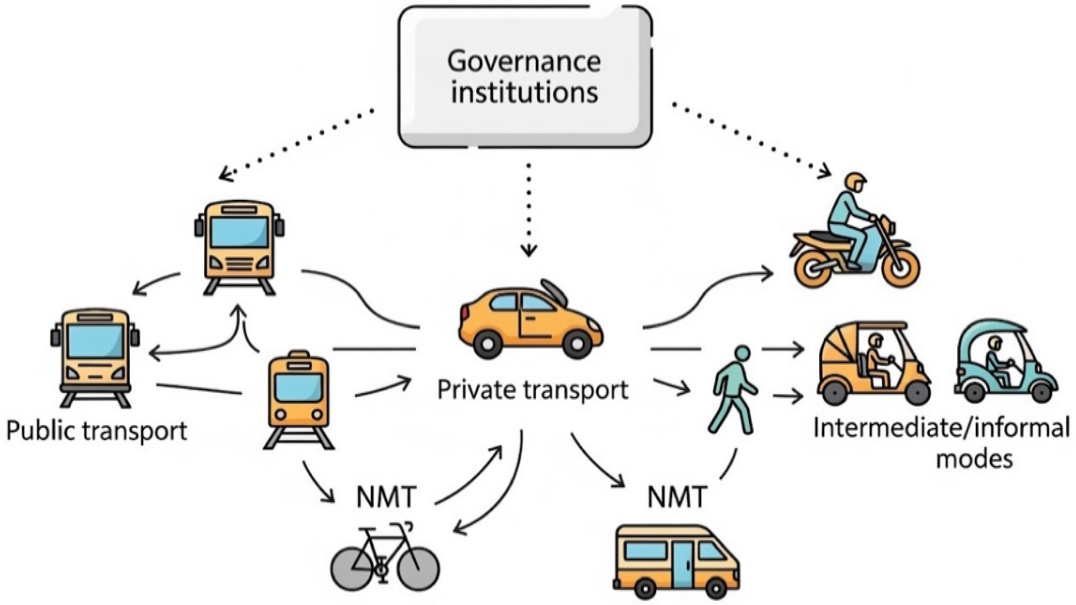

Figure 3.3 Governance Institution for transportation

3.4 Analytical Approach

Delhi's transport system. It was a descriptive study utilising an analytical method which was systems based. The method is especially appropriate to complex urban transport conditions, in which there are a variety of subsystems such as physical infrastructure, transport services, users, governance institutions and environmental processes interacting dynamically. Instead of considering the modes or policies separately, the analytical framework considers the transport system as a whole in which it is possible to identify the structural interdependencies and systemic constraints affecting sustainability results.

The analysis was designed based on four main dimensions of analysis: infrastructure provision, modal share and access, governance and institutional arrangements and environmental and social impacts. The choice of these dimensions was to capture the traditional transport performance indicators as well as more sustainability objectives, which would be in tandem with the Sustainable Development Goals (SDGs) that shall be covered later in the research.

The provision of infrastructure was evaluated in terms of the spatial distribution, capacity and functional integration of transport networks. This involved assessment of road hierarchy, coverage of metro and bus network, non-motorised transport (NMT) facility, and intermodal exchange point. The analysis was aimed at determining spatial imbalances, infrastructure gaps, and discontinuities which influence accessibility and multimodal integration in various areas of the city.

To know the travel habits and mobility preferences modal share and accessibility were investigated. Public transport use, ownership of personal vehicles, walking and cycling, and intermediate transport use were the data analysed to determine trends that include the growth in motorisation, the decrease in bus ridership, and challenges in the last-mile connectivity. The factors that were measured as regards to accessibility were distance to public transportation, frequency of the service, and whether it is accessible to vulnerable groups of users such as women, elderly citizens, and low-income groups.

Governance and institutional dimension examined the organisation structure, functions and coordination framework of different agencies that participated in transport planning and operations in Delhi. This involved evaluation of policy fragmentation, overlapping mandates and implementation issues that occur due to multi-agency governance. The study of institutional dynamics was vital in determining the non-physical restrictions to the realisation of sustainable transport, which is usually neglected in an infrastructure-focused analysis.

The analysis of environmental and social effects was made to be inclusive of the overall effects of transport systems on the air quality, energy consumption, road safety, and social equity. The focus was made on learning how emissions, congestion, and safety hazards related to transport impact some areas and population groups disproportionately. This aspect made sure that the system understanding was not confined to the efficiency but covered the sustainability and the justice perspective.

On all four dimensions, the results were synthesised in comparative matrices and thematic mapping, where it was possible to identify patterns and interconnection systematically. The method of analysis was still largely descriptive and diagnostic and normative judgements were avoided at this point. That way, the further SDG-based assessment and gap analysis were based on the objective interpretation of the current system.

Altogether, this method of analysis provided a solid underlying diagnosis of the Delhi transport system, serving as the necessary foundation for the analysis of sustainability, the comparison of frameworks, and the specific design of the intervention in the subsequent phases of the study.

3.5 Selection of Transport Planning Frameworks

The determination and identification of transport planning frameworks were a vital part of the research methodology because it formed the policy universe in which the sustainability performance would be assessed. Since transport planning in Delhi is a multi-layered government system, the study was conducted in a planned and systematic way to choose the framework and represent all the significant policy tools that can affect city mobility.

Fourteen transport related frameworks that could be applicable in Delhi were identified to be evaluated. These structures run across the national, state, and local fronts, and in effect inform the strategic vision, investment in infrastructure, regulatory, and operational practises in the transport sector. The four main criteria that were used in the selection process are policy relevance, spatial and sectoral coverage, sustainability intent, and implementation significance.

Firstly, the relevance of the policy was taken into account to make sure that the chosen frameworks directly affect the urban transport planning, mobility management, or land-use-transport integration in Delhi. The priority was given to frameworks offering a general direction in the development of urban areas, transport investment, or mobility control as they have a dominant influence on the formation of long-term transport results.

Second, the different scales in which transport planning functions were captured by the spatial and sectoral coverage as the criterion. The national-level policies are policies which set out broad principles of sustainability and mobility, which are then converted into region-specific plans by state-level policies, and finally implemented by city-level plans using spatial planning and project implementation. The inclusion of the frameworks on these scales allowed the evaluation of the vertical policy alignment and coherence comprehensively.

Third, the sustainability purpose of every framework was reviewed. Whereas certain policies clearly state the sustainability goals, e.g. reducing emissions, encouraging public transportation, or increasing the use of non-motorised forms of transport, others have the sustainability goals implicitly, i.e., via the accessibility, safety and coordination of institutions. The importance of both explicit and implicit sustainability orientations was taken into account, since the impact of policy is often greater than the declared goals.

Fourth, the significance of implementation was evaluated to make sure that the chosen frameworks are not just the dream papers without any practical impact on transport projects, regulatory decision-making, and institutional practises. Guidelines to govern funding distribution, standards of infrastructural design, or statutory planning procedures were placed in the first rank, because their sustainability delivery is immediately reflected in real life.

Among the chosen frameworks, there are the National Urban Transport Policy, Comprehensive Mobility Plans, Delhi Electric Vehicle Policy, Delhi Non-Motorised Transport Policy, Unified Traffic and Transportation Infrastructure Planning and Engineering Centre (UTTIPEC) Guidelines, and the Master Plan Delhi 2041 (MPD-2041). These documents are all the aspects of strategic, regulatory, and spatial planning instruments that regulate the transport system of Delhi.

The systematic selection and evaluation of these fourteen frameworks makes the research provide a comparative, balanced, and policy-relevant evaluation of transport sustainability. Such a method also allows determining the strengths, overlaps, and gaps between the frameworks, which will serve as a solid basis to further SDG-based reviews and gap analysis.

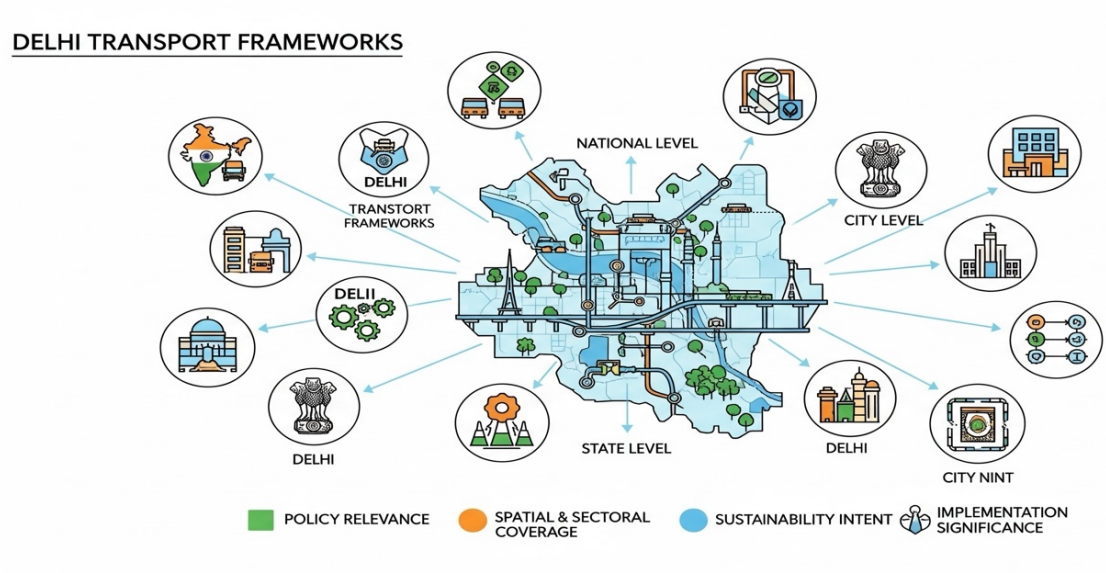

Figure 3.4 Delhi transport Frameworks

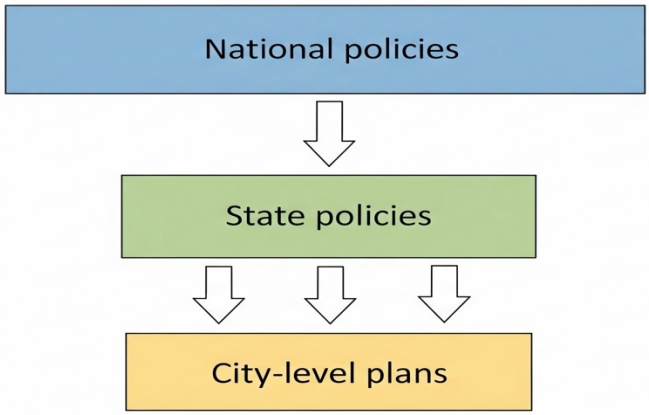

Figure 11.5 Hierarchy of transport planning frameworks

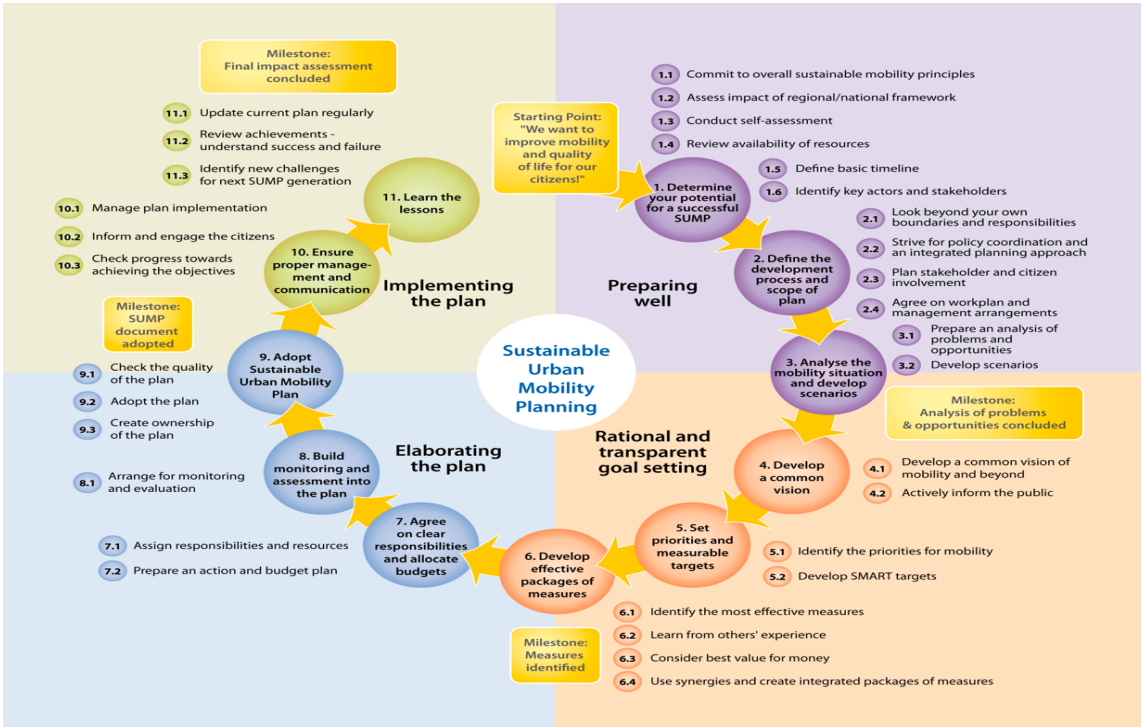

Figure 3.6 Sustainable urban mobility planning

3.6 SDG-Based Indicator Development

The process of coming up with sustainability indicators was included in the overall methodology aspect of this study in the fact that it converted the general normative goals of sustainable development into quantifiable and measurable variables, which could be incorporated into the models of transport planning. The development of the indicators was grounded on the United Nations-accepted Sustainable Development Goals (SDGs) and, specifically, the objectives that are transport-related in the SDGs targets in health, infrastructure, cities, climate action, and partnerships.

Sustainability in transport is not purely an environmental issue and as such the SDG 5ps framework that comprises of People, Planet, Prosperity, Peace and Partnership was adopted as an organising framework to develop the indicators. The rationale of selecting this framework is that the notion of sustainability is multidimensional in the sense that it involves issues of social equity, environmental protection, economic efficiency, quality of governance, and institutional cooperation in the same assessment prism. The 5ps also were applied to ensure the alignment of the global sustainability principles with the local priorities of the transport planning.

The development of indicators was a multi-phase and systematic process. Firstly, SDG targets and indicators which are relevant to urban transport were determined and analysed. Particular attention was paid to the goals in the spheres of accessibility, safety, emission reduction, energy efficiency, inclusive infrastructure, and institutional capability. Second, the global and regional sustainable transport assessment

frameworks available were consulted to come up with indicators most frequently used and best practises. Third, the information on the urban mobility measurement and policy analysis offered some understanding to make the methodological validity and situational applicability.

This synthesis revealed the presence of five indicators under each of the five SDG dimensions hence 25 indicators. The indicators were to be policy-interpreting rather than data-intensive since the most important unit of analysis in this research was transport planning frameworks and not the performance of the operational systems. This ensured that indicators could be employed in different policy documents consistently without necessarily having to utilise a large amount of primary data.

The indicators within the People dimension were pegged on accessibility, affordability, safety, inclusivity and universal design. The Planet dimension had been used to reflect environmental sustainability, which has emission reduction, energy efficiency, modal shift and mitigation of environmental impact indicators. The prosperity indicators were economic efficiency, transport-land use integration, innovation and sustainable economic growth. The quality of governance, the stability of the policies, the safety enforcement, and institutional stability was the Peace dimension and the coordination of inter-agencies, the engagement of stakeholders, the interaction of public and private, and data exchange infrastructure was the Partnership dimension.

To ensure that it is clear and that there is minimal ambiguity in the assessment of the experts, a short descriptive statement was given beside each of the indicators to explain the purpose and scope of each indicator. This played a significant role in minimising subjectivity and enhancing consistency in answers of the professionals. Moreover, the indicators were clearly developed in that way that they could be comparatively analysed in terms of various scale and statutory status.

In most cases, the SDG based indicator framework presented a standardised, clear and globally comparable tool of evaluating transport planning structures. It made possible a systematic comparison, which revealed the gaps in the sustainability, and gave the analytical foundation to the further adaptation of the framework and control over its functioning.

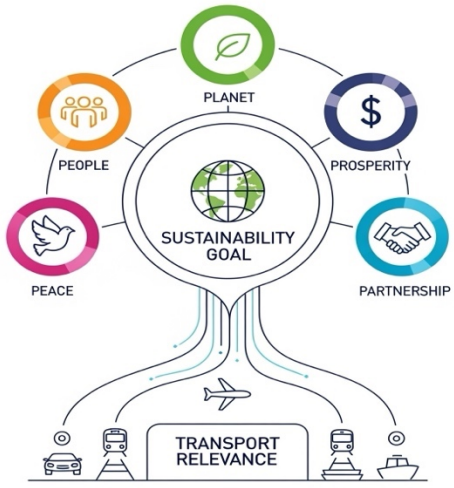

Figure 3.7 SDGs-Based indicator

3.7 Expert Evaluation Design

The judgement of the transport planning frameworks based on the sustainability indicators involves informed judgement that goes beyond what can be obtained only after an analysis of documents. This study, therefore, used an expert-based evaluation method to determine the sustainability performance of the chosen transport planning structures. Expert judgement is well understood as a powerful methodological instrument in policy evaluation research especially when multidimensional and qualitative criterion, including quality of governance, inclusiveness, and long-term sustainability intent, are considered.

Purposive expert sampling strategy was used to make sure that the evaluation results were informed by different but relevant opinions. The group of participants in the study was 33 in total, and the proportions of the participants were urban planners, transport engineers, policymakers, academicians, sustainability researchers, and people with first-hand experience in transport planning and implementation in India. The fact that both academic and practise-oriented experts were involved in the evaluation increased the validity of the evaluation as it combined the theoretical knowledge with the practical one.

In order to conduct a systematic evaluation, an expert questionnaire was designed systematically, with references to 25 SDG-congruent sustainability indicators outlined in Section 3.4.2. All the specialists were requested to rate all chosen transport planning frameworks on each indicator using the five-point Likert scale, whereby Very Low (1) and Very High (5) are the lowest and highest scores, respectively. The Likert scale allowed quantifying the perceptions of experts and maintaining adequate granularity in order to identify differences in sustainability performance across frameworks.

Before the questionnaire was locally implemented, it was piloted on a limited group of specialists to determine the clarity, relevance, and interpretability of the indicators. The pilot stage feedback was utilised in order to improve the description of indicators and decrease the level of ambiguity and, thus, improved consistency and reliability of responses. Each indicator was defined and explained in a clear manner so as to reduce subjectivity in the interpretation of the indicators.

The specialist review was done by individual and anonymous responses, which is in accordance with the principles of the Delphi method. Anonymity ensured in order to minimise dominance bias, group pressure and conformity pressure to ensure that experts gave independent and objective ratings. Even though the study was not a multi-delphi study, the design utilised the major Delphi features such as anonymity of experts, structured feedback, and response aggregation.

The evaluation design has also had measures that would guarantee reliability and robustness of results. Along with the mean scores, the study has also used percentage agreement measures to determine the degree of agreement among the experts. This two-metric methodology was used to make sure that high average scores were not due to lone voice opinions but there was a wide-range of expert agreement.

In general, the professional assessment design was a clear, repeatable, and methodologically adequate system of determining the sustainability performance of transport planning structures. A combination of structured quantitative scoring and expert judgement allowed this approach to compare the frameworks in an informed way and provide reliable inputs to be further used in the gap analysis and framework adjustment.

Figure 3.8 Graphical Representation of Experts

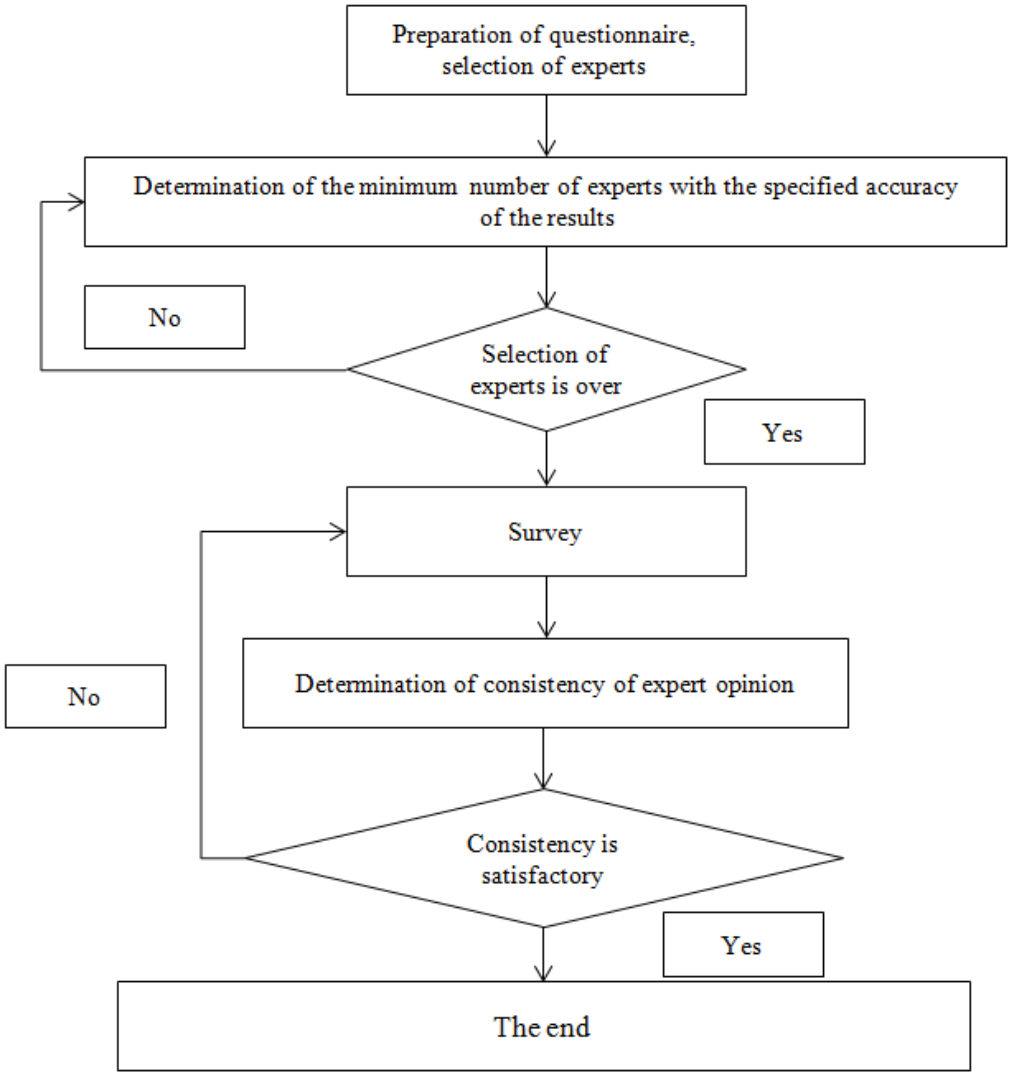

Figure 3.9 Flowchart of Overall Process

3.8 Quantitative Evaluation Methods

The data obtained by the expert evaluation as a result of the structured questionnaire were evaluated with the help of a group of quantitative assessment methods, which had to guarantee objectivity, comparability, and strength of the assessment of the sustainability performance of transport planning structures. Since sustainability is multi-dimensional and involves expert judgement, the strategy of analysis that was used is a combination of measures of central tendency and consensus to reduce bias and increase interpretative reliability.

The mode of analysis used was the mean score which was calculated on each of the sustainability indicators under each transport planning framework. The average score is the average perception of the expert respondents and gives a clear picture of the performance of a framework in relation to a particular indicator. The reason why mean

values were chosen was that it is commonly used in expert-based evaluation research, and when a sample size and response distribution are sufficient, it is appropriate to use mean values.

In order to capture sustainability performance on a larger scale, the indicator-level mean scores were summed to come up with dimension-level sustainability scores of each of the five SDG dimensions, namely, People, Planet, Prosperity, Peace, and Partnership. The dimensions scores were developed by averaging the five indicators that measure the dimension. The aggregation was useful in comparing not only between frameworks but also between dimensions of sustainability to show areas of relative strength and weakness in specific frameworks.

This was followed by the calculation of an Overall Framework Sustainability Index (FSI) of all the fourteen transport planning frameworks. The FSI was obtained by taking the average scores of the five SDG dimensions in terms of the dimension. Each dimension was given the same weight so that there was methodological neutrality and there was no subjective emphasis on one sustainability dimension over another. The FSI was a composite scale that allowed the ranking of frameworks with respect to their general sustainability orientation.

Although mean based indices give useful information, they can conceal discord among the experts. In order to overcome this weakness, the study added a Percentage Agreement (percent-A) scale to determine the extent of expert agreement. Percentage agreement was obtained as the percentage of experts who rated a particular indicator as High (4) or very high (5). The measure was done to be sure that indicators that had high mean scores were aimed by a high degree of expert agreement instead of being swayed by outliers.

The analysis of mean scores, dimension-based summation, overall index and percentage agreement offered a multi-layered analysis structure. This also made the evaluation more credible as it combined numerical aggregation with consensus evaluation. The frameworks that were found to have high FSI values and large percentage agreement were understood to have a strong suitability to sustainability.

In general, the quantitative assessment tools allowed to make a systematic comparison, introduce a transparent ranking, and justify the determination of sustainability gaps. These findings directly influenced the choice of Master Plan Delhi 2041 (MPD-2041) to be analysed in terms of the gaps and then be modified accordingly in terms of the framework.

Measure	Purpose	Output
Mean score	Central tendency	Indicator performance
Dimension score	Thematic aggregation	5P-wise performance
FSI	Overall comparison	Framework ranking
Percentage agreement	Expert consensus	Robustness check

Table 5.3 Quantitative Measures Used for Sustainability Evaluation

3.9 Selection of Master Plan Delhi 2041 (MPD-2041)

The choice of Master Plan Delhi 2041 (MPD-2041) as the target framework of the targeted gap analysis and the consequent adjustment was informed by the results of the quantitative sustainability assessment identified in the previous section. Due to the Framework Sustainability Index (FSI) and the percentage agreement metric, MPD-2041 was ranked the top framework out of the fourteen transport-related planning tools tested. This choice was thus not subjective or pre-determined, but evidence-based, transparent and methodologically justifiable.

The MPD-2041 showed a relatively good performance in a wide range of SDG dimensions, specifically in the long-term spatial planning, multimodal transport integration, transit-oriented development (TOD), and consistency with climate and sustainability objectives. The overall nature of the framework, that incorporates land use, transport, environment and infrastructure planning, led to its increased sustainability scores compared to other sector-based or mode-specific policies.

The other important factor that motivated the choice of MPD-2041 is its statutory and strategic importance. Being the major long-term spatial planning document that defines the development path of Delhi over the next 20 years (2041), MPD-2041 plays the key role in determining the investments in the transport infrastructure and the land-use patterns as well as the institutional coordination. The Master Plan unlike the stand-alone transport policies is binding and directly affects implementation in terms of zoning, development controls and infrastructure prioritisation. Therefore, enhancing the sustainability orientation of MPD-2041 can have system-wide and long-term effects.

Although MPD-2041 made good results in the general sustainability ranking, the evaluation outcomes also indicated the uneven performance in SDG dimensions. The score in the provision of infrastructure and strategic intent was high with relatively lower scores in the provision of governance coordination, performance monitoring, inclusivity mechanisms, and data-driven decision support. These results implied that MPD-2041, although strong, has key sustainability loopholes, which restrain its ability to operationalise sustainable transport outcomes.

The combination of solid underpinning and recognisable strengths and weaknesses made MPD-2041 especially effective in changing the framework. The use of the most effective framework guaranteed that the research will be based on an already

progressive policy foundation, whereas the gaps identified offered straightforward points of entry to the interventions. This policy does not involve the duplication of policy making and rather because it aims at improving and operationalisation of the existing planning instruments, this approach is more realistic and acceptable on the policy implementation aspect.

Additionally, the target of MPD-2041 helped the study to be in line with the prevailing practise of planning as well as the processes of planning in institutions in Delhi. With the suggestion of the changes in the framework of an already existing statutory document, the Modified Sustainable Transport Framework (MSTF) is contextually based and has a better chance of being adopted or modified by planning agencies.

Overall, it should be noted that MPD-2041 was chosen not only due to the highest sustainability performance but also due to the strategic relevance, statutory power, holistic approach, and the ability to prove the necessity of specific improvement. This choice is a strong base of the further gap analysis and reorganisation of the framework that is introduced in the following sections.

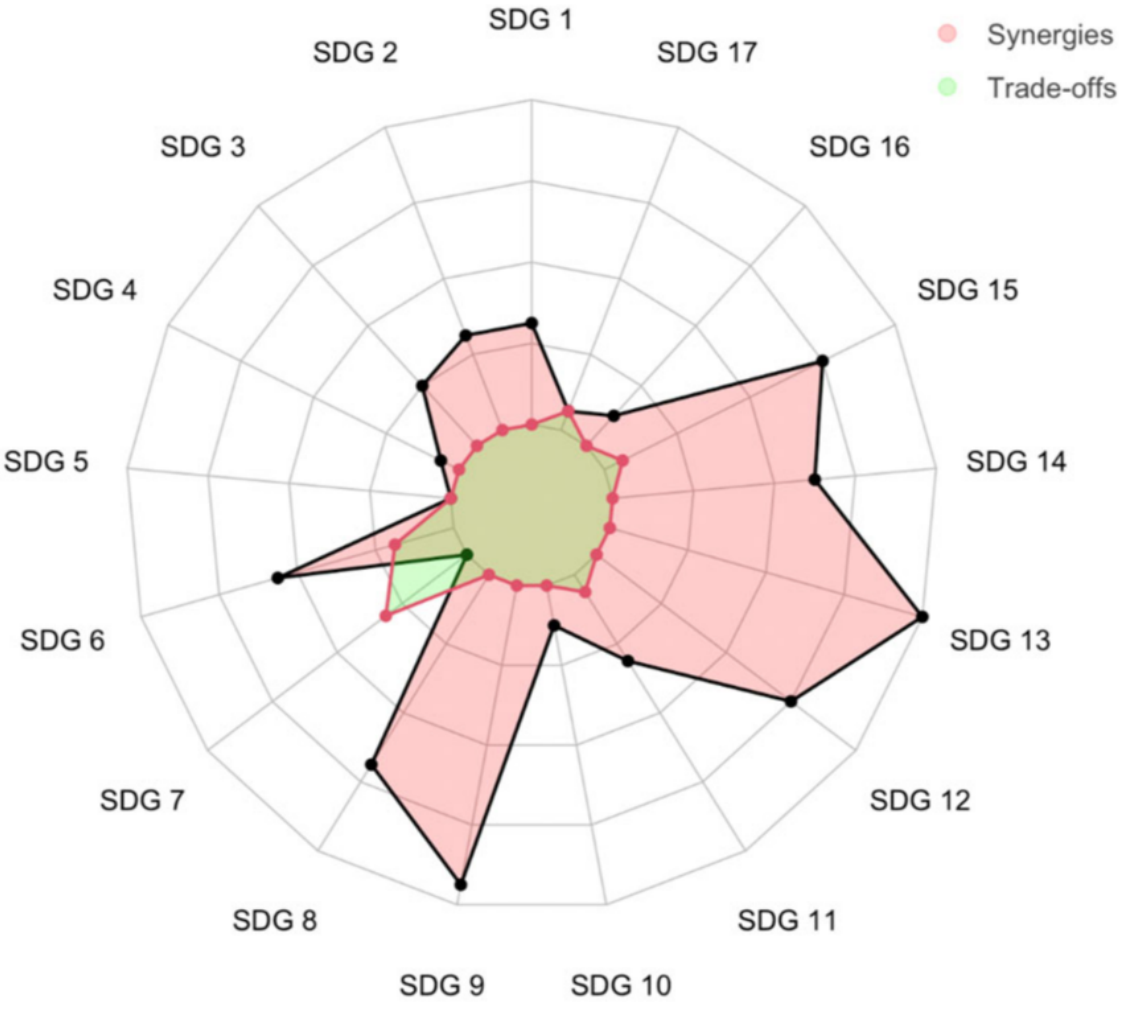

Figure 3.10 SDG Linkage web to transport

3.10 Gap Identification Logic

The recognition of sustainability gaps in the chosen transport planning framework was an essential analytical procedure of the research methodology since it formed the foundation of focused changes to the framework. A structured multi-criteria logic that incorporated quantitative evaluation results with qualitative expert judgments and comparison to the world best practises were used to undertake gap identification. This triangulation methodology was critical and ensured that the gaps that were identified had a strong foundation, were evidence-based and contextually pertinent as opposed to being perception-focused.

Quantitative evaluation outcomes based on expert scoring of SDG-based indicators were the main source of the input to identify the gaps. Sustainability scores on the indicators levels and dimension-wise sustainability scores were analysed to define weak performance areas. Those indicators with a mean score that was below 3.5 were tentatively defined as underperforming, which implies that the overall professionals felt that there was not enough sustainability alignment in these aspects. This was chosen as the maximum level of sustainability performance differentiation, and it was sensitive analytically.

Divergent expert views, however, can be masked by depending on mean scores. In order to overcome this constraint, the analysis used percentage agreement (%A) as an additional measure. Percentage agreement is defined as the percentage of specialists who place a score of High or very high to a particular indicator. Those indicators that had less than 60 percent of the percentage agreement were taken as having a weak consensus indicating ambiguity, uncertainty of implementation, or systemic weakness within the framework. Those indicators that fulfilled either of the two criteria, low mean score, and low agreement, were classified as critical sustainability gaps.

Besides quantitative thresholds, the qualitative feedback of experts in the process of evaluation was also systematically examined. Thematic analysis was used to examine open-ended comments to get an insight into the roots of low performance scores. This qualitative layer was beneficial to identify gaps that may have occurred due to policy omission, poor implementation machinery, institutional fragmentation, or absence of measurable performance indicators. The incorporation of qualitative perspectives made certain that gap identification was not only done in terms of numerical ranking, but also the structural and governance-related shortages.

Additional confirmation of the gaps accepted was the benchmarking on international best practises in sustainable transport planning. The international frameworks and case studies of cities known to have progressive mobility systems were examined to determine whether the same dimensions of sustainability were handled in a better manner in other places. This comparative look played a crucial role in ascertaining whether the gaps that were identified were actual weaknesses or contextual restrictions.

The last process was triangulation of all sources of evidence quantitative scores, expertise, qualitative insights and benchmarking outcomes. The gaps that were repeatedly substantiated by various streams of evidence were only accepted to be modified in the framework. This was a conservative method that minimised the chances of over-identification and made the further interventions strategic.

In general, the gap identification logic converted the results of evaluation into actionable insights. The systematic diagnosis of the areas and reasons why sustainability performance was poor gave a clear and justifiable basis to restructure and fortify the transport planning framework, through the Modified Sustainable Transport Framework (MSTF).

3.11 Gap Categorization

The second methodological task after the systematic identification of sustainability gaps was to divide the identified gaps into thematic domains. Gap categorisation plays a crucial role in a framework-based study because it converts an unstructured list of deficiencies on an indicator level into problem areas that can be addressed strategically using a set of interventions. Gap analysis will not work without categorisation, which will leave it in fragments that are hard to convert into actionable framework adjustments.

The categorisation procedure was informed by both nature of identified gaps as well as functional role of the same in the transport planning system. The study was more operational and used to group gaps in line with planning and implementation processes as opposed to grouping gaps based on dimensions of SDGs. That resulted in the categorization of gaps into five thematic domains, which are policy coherence, infrastructure adequacy, technology and data availability, sustainability and inclusiveness, and governance and institutional capacity.

The former area, which is policy coherence, incorporates gaps in the areas of misalignment in transport policies, land-use planning tools, and sustainability goals. These loopholes are indicative of inconsistencies in national, state, and city frameworks, and poor integration of transport with other related sectors, including housing, environment, and public health. The gaps in policy coherence can tend to be in the form of contradictions in priorities, inconsistent mandates, or absence of specific ways of implementation contained in statutory texts.

The second area, infrastructure adequacy, incorporates the gaps relating to physical provision and integration of transport infrastructure. These are inadequate multimodal connectivity, last-mile and first-mile access, non-motorised transport infrastructure, and fair service distribution space. The gaps that are connected with infrastructure influence the performance of the system and user experience directly and are thus highly visible but usually difficult to address because of the limits of resources and coordination.

The third domain is technology and data availability which includes gaps connected to the application of intelligent transport systems (ITS), real-time data integration, performance monitoring and digital decision-support tools. Lack of sound data structures and technological connectivity impedes the capacity of planning agencies in tracking outcomes, assessing interventions as well as dynamically adjusting the policies. Such gaps become all the more important in the environment of smart mobility and the data-driven urban governance.

The fourth domain, sustainability and inclusivity, has gaps which have an impact on environmental performance, social equity, and user inclusiveness. This category will include the shortcomings in climate resiliency, emissions reduction, affordability, gender-sensitive planning and vulnerable populations access. These shortcomings draw the contrast between the intent of sustainability and the actual on-ground operationalisation of the planning models.

The fifth area, governance and institutional capacity is an indication of gaps in areas of inter-agency coordination, accountability mechanisms, stakeholder participation and institutional preparedness to implement. Governance gaps are often like cross cutting constraints that destroy the efficacy of policies and infrastructure investments that were otherwise well formulated.

The research developed a clear analytical bridge between the evaluation outcomes and the framework adjustment by categorising the gaps into these five domains. The categorisation facilitated the creation of a stratified framework structure at later phases and saw to it that interventions put forward were focused on root causes and not a single symptom. In general, gap categorisation was helpful in making the process of framework development more clear, prioritised, and strategic.

Gap Domain	Nature of Gaps	Examples
Policy coherence	Misalignment, overlaps	Weak land-use–transport integration
Infrastructure adequacy	Physical deficiencies	Poor last-mile connectivity
Technology & data	Monitoring gaps	Lack of real-time data
Sustainability & inclusivity	Equity and climate gaps	Limited gender-sensitive design
Governance & institutions	Coordination failures	Fragmented agency roles

Table 3.4 Categorisation of Sustainability Gaps into Thematic Domains

3.12 Framework Reorganisation into Five Layers

The classification of sustainability gaps, the study went on to restructure the chosen planning structure into a stratified design. This restructuring is a very crucial methodological shift between diagnosis and solution design. Instead of putting forward single policy suggestions, the study assumes a systems-based, stratified framework perspective so that the sustainability interventions are systematically designed, operationally defined, and implementable within the current planning and governance systems.

The need to restructure the framework into five functional layers was based on the nature of the identified gaps, their interdependences, and their location in the transport planning process. Layering facilitates vertical and horizontal integration by making a clear distinction between strategic intent, physical provision, operational mechanisms and institutional enablers. It also enables the planners and policymakers to determine the areas of responsibility and performance indicators of each layer.

3.12.1 Policy Integration Layer deals with policy gaps in terms of coherence and alignment. This layer aims at combining the transport planning with land-use policies, environmental regulations, and climate action strategies. It makes sure that the sustainability goals are incorporated throughout the statutory documents and that the transport policies are aligned with the wider urban development objectives. The framework recognises that long-term goals of sustainable transport depend on the policy direction by setting policy integration as the base layer.

3.12.2 Infrastructure Layer, is related to the lack of physical provision and spatial connectivity. This layer deals with multimodal network integration, last-mile connectivity, first-mile connectivity, non-motorised transport infrastructure, and fair distribution of services across space. This requires a distinct layer of infrastructure that allows the design standards, network continuity, and spatial accessibility to be given specific attention without losing the consistency with policy objectives that are set in the first layer.

3.12.3 Technology and Data Layer, addresses gaps in the areas of monitoring, digital integration and decision support capabilities. This layer includes intelligent transport systems, (ITS), integrated mobility data platforms, real time performance monitoring and analytical tools to assist in the evidence-based planning. The framework acknowledges the increasing importance of technology and data as their very own layer through the explicit inclusion of the two in facilitating adaptive and responsive transport governance.

3.12.4 Sustainability and Inclusivity Layer, integrates the environmental and social equity issues. This layer guarantees that climate resilience, reduction of emission, affordability, universal availability, gender sensitive planning, and safety are realised in transport interventions. By making sustainability and inclusiveness a layer in their

own right, their cross-cutting significance can be emphasised and they will not be relegated to a secondary or peripheral consideration.

3.12.5 Governance and Institutional Layer covers issues that are associated with coordination, accountability, capacity building, and stakeholder engagement. The layer is concerned with inter-agency collaboration, role clarity, participatory mechanisms, and institutional readiness to implement the same. Governance is placed as facilitating layer which helps in the proper operation of all the other layers.

Generally, rearranging the structure into five layers will increase clarity, traceability, and operational relevance. It gives the framework of the formulation of the Modified Sustainable Transport Framework (MSTF) and allows making systematic connections between gaps, interventions, outcomes, and performance indicators in the further steps of the study.

3.13 Key Performance Indicator (KPI) Formulation

Key Performance Indicators (KPIs) is an important process of operationalising the Modified Sustainable Transport Framework (MSTF). Although the re-structuring of the framework into functional layers creates a strategic structure, KPIs convert the strategic structure into measurable, monitorable and actionable results. KPIs can be considered as a balance between policy intent and on-ground performance in the context of sustainable transport planning to help planners and decision-makers to evaluate the progress, determine deviations and undertake corrective actions.

The KPI formulation process in this research was informed by the fact that indicators should be policy relevant and at the same time practical in implementation within given institutional capacities. Based on this, KPIs were formulated to be specific, measurable, action-oriented, and time-bound to be clear on purpose and accountable. The KPIs in contrast to generic sustainability indicators were specifically connected to the five layers of the MSTF and each of the layers could be tracked separately, yet be coherent with the entire framework.

KPIs were developed in a logical Gap - Intervention - Expected Outcome - KPI. An intervention was suggested in the applicable layer of the framework to every identified sustainability gap. The anticipated outcomes were then stated as improvements in the observable systems and KPIs were established to measure the outcomes in a quantitative or qualitative manner. This causal pathway made sure that KPIs were not random measures but they were directly correlated with the diagnosis of the underlying problem and the intervention plan.

Policy Integration Layer KPIs that were aimed at alignment and coherence included the degree of transport and land-use plan integration, SDG-compatible targets, and the existence of cross-sector coordination mechanisms. Infrastructure Layer contained KPIs of network coverage, multimodal connectivity, quality of non-motorised

transport infrastructure and accessibility within specific service radii. These measures allowed measuring physical gains and spatial equity.

KPIs that covered the real-time availability of data, intelligent transport systems, integration of mobility datasets, and performance monitoring frequency were included in the Technology and Data Layer. The above KPIs were a manifestation of the growing role of digital tools in facilitating adaptive and evidence-based transport governance. Sustainability and inclusivity Layer featured the KPIs associated with savings of emissions, safety measures, affordability, accessibility to everyone, and gender sensitivity, so that the environmental and social goals were tracked directly. Lastly, Governance and Institutional Layer KPIs were aimed at inter-agency coordination, stakeholder engagement, capacity building, and holding agencies accountable.

KPIs were created to be based on the data sources that are easily available or can be obtained realistically like government reports, transport agency databases, and periodic monitoring exercises to ensure feasibility. Where quantitative measures could not be accurately obtained, qualitative or proxy measures were suggested, and these measures were to have clear assessment criteria.

In general, KPI formulation process turned MSTF into a performance-oriented system that made it possible to monitor, evaluate, and improve continuously. Engaging KPIs in every layer of the framework has made the study such that sustainability goals are not just a wish but are converted into actual, quantifiable results.

Framework Layer	Sustainability Gap	KPI
Policy Integration	Weak alignment	% of plans aligned with SDGs
Infrastructure	Poor last-mile access	% population within 500 m of PT
Technology & Data	Limited monitoring	Availability of real-time dashboards
Sustainability & Inclusivity	High emissions	Reduction in transport CO_2
Governance	Fragmented agencies	Frequency of inter-agency meetings

Table 3.6 Illustrative KPIs for the Modified Sustainable Transport Framework

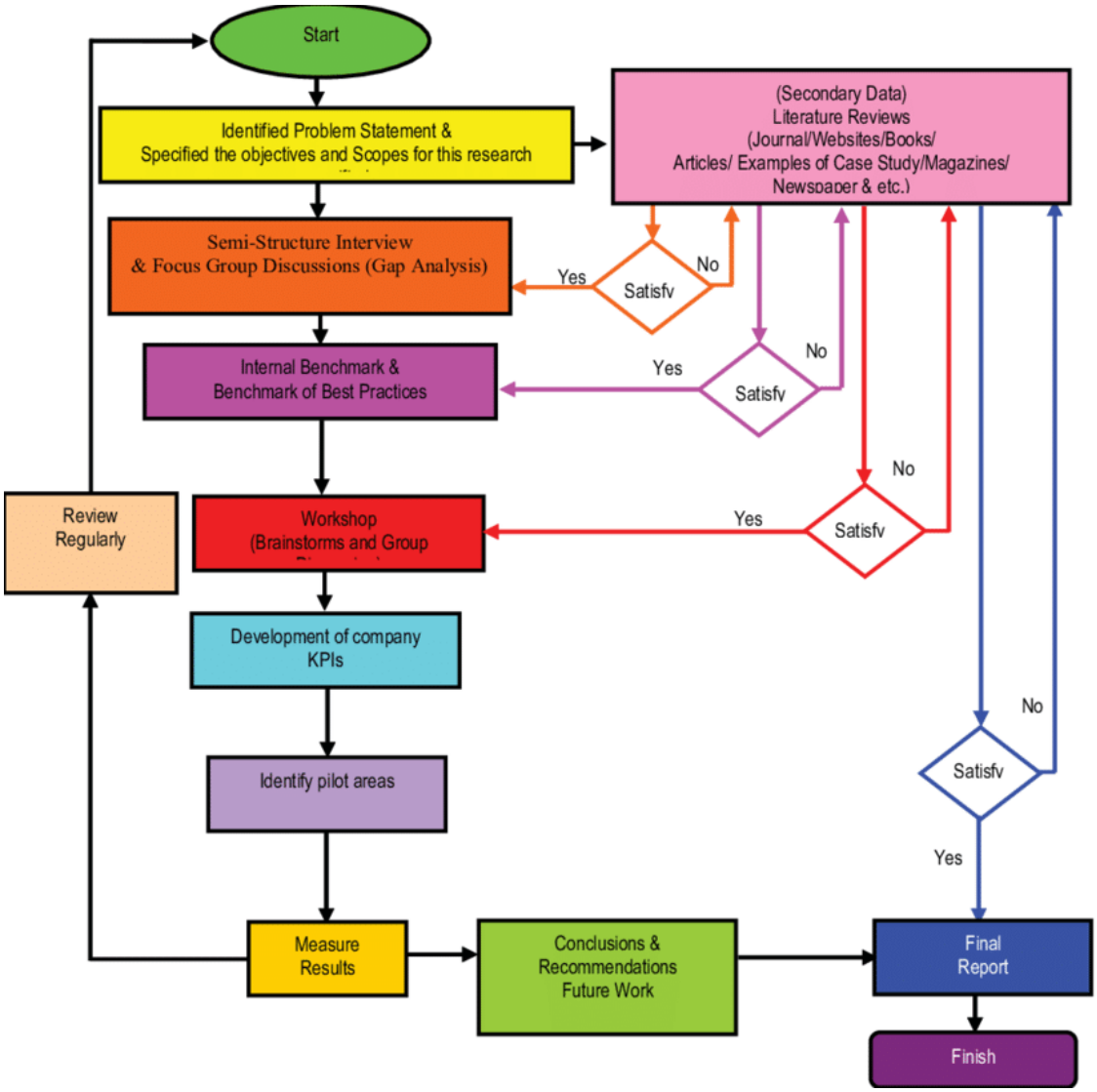

Figure 3.11 KPIs for the Modified Sustainable Transport Framework

3.14 Implementation and Monitoring of the MSTF through an Assistive Decision-Support System

Although it may be true that the Modified Sustainable Transport Framework (MSTF) has a structured and indicator-based approach to sustainable mobility planning, its performance, in the end, is determined by its ability to be implemented in a systematically implemented and continuously at a long term basis. In order to deal with such a crucial shift between planning and practise, the research conceptualises the assistive decision-support system (DSS) as a part and parcel of the MSTF. This system transforms the framework into a structured monitoring and feedback system that entails the embedding of the data, indicators, and performance logic.

The assistive system is meant to serve as a digital and institutional interface between the agencies in the planning, the transport operators, the policymakers as well as the

end users. In essence, the system allows one to track KPIs related to individual MSTF layers continuously, thus turning the non-performance-related policy documents into dynamic performance-focused planning resources. The assistive system contributes to evidence-based decision-making and adaptive governance through the connexion of the framework objectives with the measurable indicators.

Implementation wise, the assistive system provides a layer-wise monitoring. In the case of the Policy Integration Layer, the system will allow monitoring of policy alignment, milestones of implementation, and intersector coordination. The Infrastructure Layer is fostered with the help of spatial and service-level indicators, which are associated with network coverage, accessibility, and multimodal integration. In the case of Technology and Data Layer, the system is a data aggregation and analytics platform, where real-time and periodic datasets of various agencies are combined.

The Sustainability and Inclusivity Layer is realised based on the indicators of emissions, safety, affordability, and accessibility to enable the planners to understand whether sustainability benefits are evenly distributed. Lastly, the Governance and Institutional Layer is under cheque using the indicators concerning the coordination mechanisms, stakeholder participation, and institutional capacity, which ensures the assessment of governance performance in addition to physical and environmental performance.

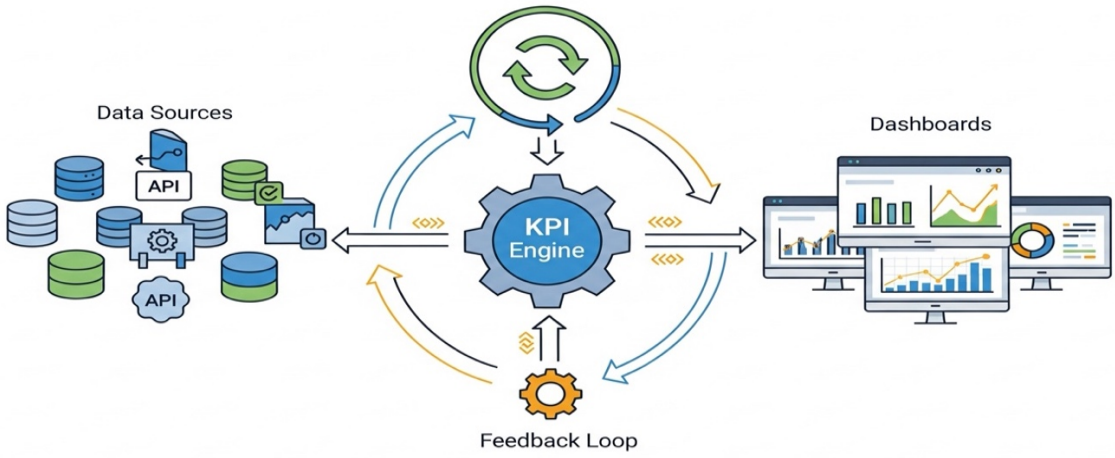

Figure 3.12 Monitoring and Feedback Loop

Notably, the assistive system is theorised as scalable and replicable. Although it was originally specific to Delhi, its design can be adapted to other cities by changing indicators, sources of data, and institutional connexions. The system is not an alternative to the current processes of planning but instead complements them by creating a common platform through which sustainability monitoring and performance assessment can be done.

In general, the assimilation of an assistive decision-support mechanism makes sure that the MSTF goes beyond idea reformation to the real-life, trackable and responsible execution. This method reinforces the contribution of the research as it shows how sustainability frameworks can be put into practise in the context of actual planning.

MSTF Layer	Monitoring Function	Example Output
Policy Integration	Policy alignment tracking	SDG compliance reports
Infrastructure	Service and access monitoring	Coverage maps
Technology & Data	Data integration	Real-time dashboards
Sustainability & Inclusivity	Outcome assessment	Emission & safety trends
Governance	Coordination monitoring	Inter-agency performance

Table 3.7 Role of the Assistive Decision-Support System in MSTF Implementation

3.15 Scalability, Replicability, and Long-Term Applicability of the MSTF

A critical aspect that must be taken into account during the modelling of the Modified Sustainable Transport Framework (MSTF) would be its scalability, reproducibility and applicability in the long term not just to the instant situation in Delhi. The problems of sustainable transport that include congestion, emissions, unequal access, and fragmentation of governance are not confined to a single city but are also common to the metropolitan areas in India and other fast urbanising environments. Thus, the MSTF is deliberately structured as a modular, flexible and context-adaptive structure as opposed to a city-specific prescriptive model.

The MSTF has a layered structure that facilitates scalability. The five layers: Policy Integration, Infrastructure, Technology and Data, Sustainability and Inclusiveness, and Governance and Institutional may be established either through a single-step or a gradual implementation approach based on the local capacity, resources at hand, and readiness of the institution. In smaller cities or new urban areas, the framework can first target the fundamentals layers like infrastructure and governance and more developed cities can actualise the technology-based monitoring and real-time decision support. This flexibility allows the opportunity to implement it in stages without undermining the sustainability logic.

This is because the replicability is achieved by using globally consistent but locally flexible indicators. The MSTF conceptual consistency ensures that the framework remains consistent in all contexts and that the indicators thresholds, data sources, and performance benchmarks may be adjusted to local circumstances due to the reliance on the Sustainable Development Goals (SDGs) concept and the 5Ps model. The indicator-based design allows other cities to follow the same methodological pattern - framework assessment, gap recognition, layer-based intervention, and KPI observation

by altering certain parameters to match their spatial, socio-economic, and governmental contexts.

The applicability in the long-term is also enhanced by incorporating the assistive decision-support system that was mentioned in the preceding section. This system allows constant observation, regular revision and dynamic modification of the framework as mobility trends evolve, technology advances, and priorities in the policies are altered. The MSTF conceptualises sustainability as a continuous and iterative process as opposed to a fixed end state, facilitated by performance based learning and feedback loops.

Institutional wise, the structure is meant to supplement, but not to substitute the current statutory and planning mechanisms. This increases its political and administrative viability since it does not necessitate radical restructuring of the governance systems to be adopted. The MSTF instead offers a systematic prism within which currently existing plans, projects and policies can be reviewed and enhanced over the long run.

Notably, knowledge transfer, as well as comparative learning, is also supported by the framework. Through universal layers and indicators, cities are able to compare their performance, exchange best practices, and also work together to further sustainable mobility agendas. This aspect is in line with the SDG focus on collaboration and inter-city collaboration.

In short the MSTF is envisioned as a future-proof, flexible and portable planning structure. Scalability, replicability, and long-term applicability increase the overall contribution of the research, which makes the framework an important source of the transport planning of the sustainable transport in Delhi and other cities.

CHAPTER 4

TO UNDERSTAND THE TRANSPORT SYSTEM OF DELHI

The Indian capital, Delhi, is undergoing a fast urbanisation process and this has been accompanied by enormous transportation problems that are threatening its social inclusivity, economic productivity and environmental sustainability. In this paper, the author is going to be thorough in reviewing the urban transport system in Delhi in terms of its key elements, infrastructure, pattern of travel and policy framework. It analyses the private and public transport systems such as the Delhi Metro, Delhi Transport Corporation (DTC), feeder transport, non-motorised transport, and the trend of mobility like electric vehicles. Critical assessment of structural inefficiencies, such as inadequate multimodal connectivity, institutional fragmentation, increasing reliance on personal vehicles, and lack of access to affordable and safe transportation to marginalised populations, especially women and low-income populations are evaluated in the study. Although there are some ambitious policies like the Delhi Electric Vehicle Policy and the National Urban Transport Policy, the challenges of implementation are still present because of the overlapping of the institutional roles, the lack of the data, and the poor involvement of stakeholders. It is stressed in the analysis that local transport planning should be aligned with the Sustainable Development Goals (SDGs) and specifically SDG 11 (Sustainable Cities and Communities), SDG 3 (Good Health and Well-being), SDG 9 (Industry, Innovation, and Infrastructure), and SDG 13 (Climate Action). Finally, this review preconditions the development of a sustainable, inclusive, and data-driven transportation system that would be specific to the urban environment of Delhi.

Introduction

The economic, social and environmental dynamics of cities are greatly affected by urban transportation. In rapidly urbanizing countries such as India, transportation systems are a key part of inclusive access, public health, climate resilience and sustainable urban development (Pojani & Stead, 2015). Among the cities of India, Delhi as the national capital territory is unique in terms of its size, population, infrastructure complexity and policy importance.

Transportation in Delhi which is utilised by more than 30 million people of national capital region is admiring example of urban India. Its historical planning, population growth, economic liberalisation and political advancements the city's transportation system to undergo various significant changes over the years. The city faces the traffic congestion, air pollution, road safety concerns, social inequality in order to transportation despite of being significant amount of investment in infrastructure like, Delhi Metro, Expressways and growing fleet of electrical vehicles (MoHUA, 2021). Delhi has complex environment of governance which having number of overlapping

institute, policy framework and jurisdictions aggravates these difficulties (UTTIPEC,2019).

The base cause of these problem is misalignment between transport planning and goals. Inefficiencies are caused by many factors including huge growing reliance on private vehicles, poor last mile connectivity, very less investment on non-motorised (NMT) infrastructure. And have a failure to adequately land use and transport planning. Total no. of vehicle is registered in Delhi is 13 Million as on 2023 with two wheeler and cars for the majority of urban travel (Transport Department, GNCTD, 2023)

The rise in motorization has led to deterioration of the air quality; Delhi is often one of the most polluted cities of the world with as much as 40% of PM2.5 levels being contributed by the transportation emissions (CPCB, 2022).

In order to be considered sustainable, transportation has to be considered as a multifaceted socio-technical system, which interacts with the economy, governance, equity, urban forms, and environmental health. Sustainable, inclusive and effective transport systems are critical for the attainment of the Sustainable Development Goals (SDGs) particularly SDG 11 (Sustainable Cities and Communities), SDG 3 (Good Health and Well-Being), SDG 9 (Industry, Innovation, and Infrastructure) and SDG 13 (Climate Action) (United Nations, 2015). However, implementing these goals on a local scale requires a thorough understanding of the existing transportation systems, their shortcomings, user experiences, and barriers in their structure.

The coexistence of a top notch metro system, congested road system, erratic public transportation and a large unofficial transportation industry of shared cars, e-rickshaws and cycle rickshaws makes Delhi an exceptional case study. It is important to evaluate the system from a people-centred and equity-oriented view because the city also shows considerable disparity in mobility according to the location, gender, and income. For instance, travel trends show that women in Delhi tend to walk and take public transportation but face barriers in terms of accessibility, safety and dependability (Borker, 2018).

In addition, Delhi transport governance is deviated, with various stakeholder overseeing the land use traffic management air quality road network and metro operations with the very few integrase co-ordination organisation like Delhi Metro Rail Corporation (DMRC) Delhi Transport Corporation (DTC) Delhi Development Authority (DDA) and Unified Traffic and Transportation Infrastructure (Planning and Engineering) Centre (UTTIPEC) are function independently. In terms of multi-mode transport planning, the cause of these institutional fragmentation is implementational delays, as well as doubling the efforts (Jain & Tiwari, 2018).

After introduction of various policies and programmes to cater these issues including Delhi Electric Vehicle Policy (2020), National Urban Transport Policy (2006), Smart

Cities Mission and Gati Sakti Master Plan, their effectiveness lies on strategies to implement, Stakeholder involvement and local adaption (NITI Aayog, 2021). One major problem to attain for the long term improvement in Delhi's mobilities landscape in the absence of a cohesive framework that include sustainability, inclusivity and efficiency.

One of the major drawback on sharing the data of the transport planning and technology. The very promising impact of intelligent transport systems (ITS), mapping based on GIS, and real time vehicle tracking has been very limited in cities due to unavailability of mobility data and dashboard, it make more difficult to make demand forecasting, planning and real time policy interventions.

Sustainability of the environment is also threatened. Noise pollution, urban heat island and greenhouse gases emission are all greatly affected by Delhi's transportation system. Low-emission zones, bike sharing schemes and moving to electric buses are still in their infancy. Nevertheless, there are ways to introduce climate goals into transportation reforms, such as by promoting green mobility corridors, mapping emissions and creating carbon budgets (TERI, 2022).

In light of this, it is important to conduct a comprehensive and multi-pronged assessment of the transportation system of Delhi as the first step in developing a modified sustainable transportation framework for the Delhi. In addition to infrastructure, such a review should focus on gendered mobility, modal share, and travel behaviour, the role of stakeholders, policy effectiveness, and technology applications. The foundation for creating an assistive system that is in line with the SDGs and realities of urban India can be laid by doing this, as well as to identify important leverage points for intervention.

By analysing the transportation system of Delhi in a critical manner, identifying the pros and cons of the city's transport methods and exploring possible reforms, this article aims to fill that gap in knowledge. The results will provide support to the bigger journey of establishing such a framework for sustainable urban transportation in Delhi that is contextual, evidence-based and relevant to policy. Such a framework could later be used as a template for other Indian cities with similar challenges towards the country's goals of inclusive and sustainable urban mobility.

4.1 Components of Delhi’s Transport System

Public transportation, private automobiles and non-motorised transportation are just a few of the modes that comprise the transportation network in Delhi, which is a hybrid between formal and informal transportation modes. Although the capital city is a transportation hub for the National Capital Region (NCR), the city is struggling with issues of equity, sustainability, and integration in the provision of mobility services.

4.1.1 Delhi Metro

One of India's most important public transportation initiatives is called Delhi Metro and is operated by the Delhi Metro Rail Corporation (DMRC). The metro system has greatly enhanced the intercity connectivity, especially between the residential and commercial areas, with over 390 km of operational network spread over 12 lines and over 285 stations (DMRC, 2023) as shown below in Figure 1. The metro is a vital part of the urban transportation system and carries over 6 million passengers daily. Additionally, through the encouragement of densification along corridors, its expansion has helped with Transit-Oriented Development (TOD) (MoHUA, 2021).

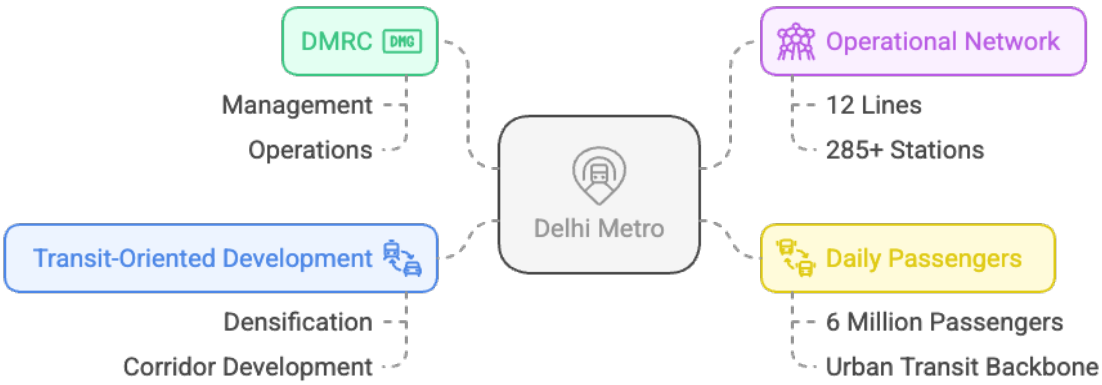

Figure 4.12 Delhi Metro: Urban Transit and Development.

4.1.2 Delhi Transport Corporation (DTC) and Cluster Buses

The DTC has a fleet of about 3,800 low-floor buses, large in India. The Cluster Scheme that is managed by the Delhi Integrated Multi-Modal Transit System (DIMTS) introduces approximately 3,000 more buses using numerous public-private partnership (PPP) models (Transport Department GNCTD, 2022). This is caused by limited route rationalisation, overcrowding, poor maintenance and inconsistent frequency, resulting in reduced ridership in spite of reach. The cause and effect analysis of the delivery of bus services in Delhi is in the form of figure 2.

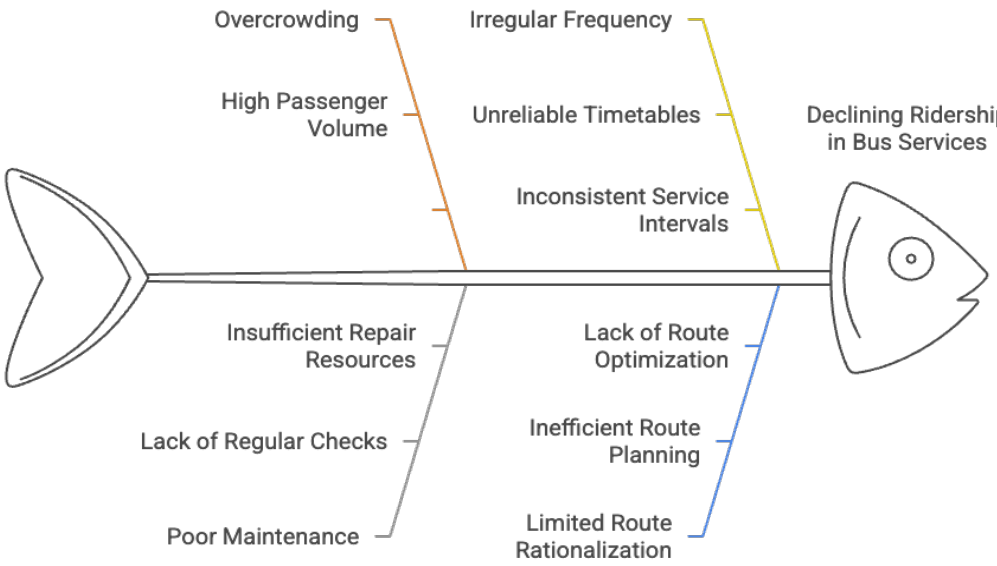

Figure 4.13 Analysing Declining Ridership in Delhi's Bus Services.

4.1.3 Feeder Services and Last-Mile Connectivity

Feeder buses, autorickshaws and more lately electric rickshaws (e-rickshaws) provide last-mile connectivity in locations that do not lie directly on the mainline or metro bus circulation as depicted below in Figure 3. UTTIPEC (2020) estimates that more than 100,000 e-rickshaws operate across Delhi, yet this sector of the economy remains largely unregulated and informal. The reason for the low utilisation rates in outlying areas is that a significant number of metro stations still do not have efficient first- and last-mile connections.

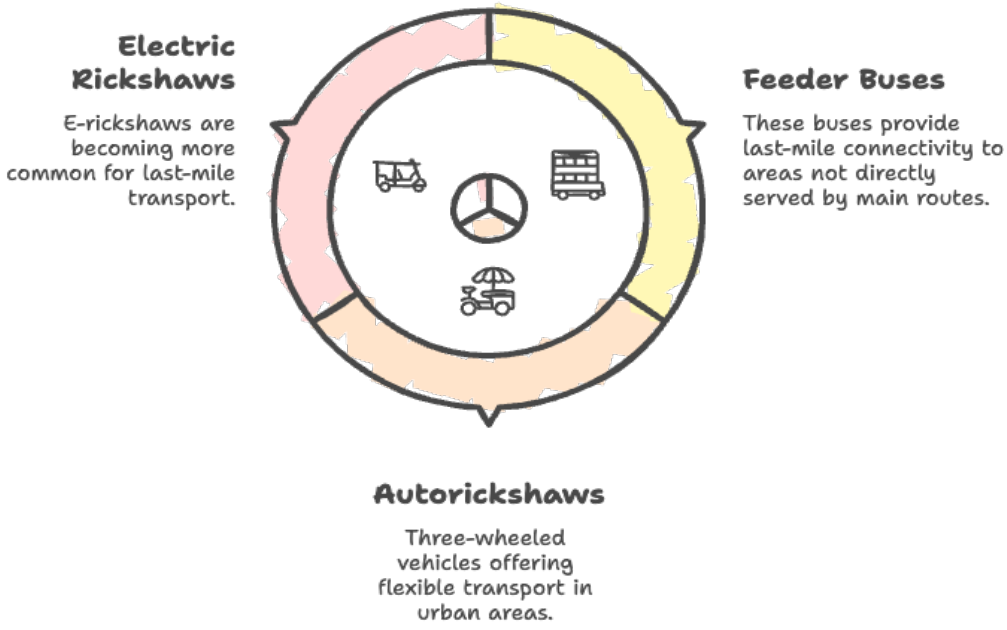

Figure 4.14 Last-mile connectivity options

4.1.4 Private and Intermediate Transport

The number of vehicles owned privately in Delhi has been increasing and now exceeded 13 million registered vehicles in 2022, of which a larger percentage (more than 65) is two-wheelers (Transport Department GNCTD, 2022). The high rate of ownership has been brought about by the perceptions of convenience, lack of reliability of the public means of transport and the social status that is attached to the ownership of a car.

Ola, Uber, and Rapido are ride-hailing services that have gained popularity due to their flexibility in terms of movement of people in the middle and upper classes. Their role in traffic, taking up of road space, and carbon emission is controversial, although they are convenient and relieve road parking pressure (ITDP, 2021). Such aggregators often operate outside of the existing systems of governance in urban transportation, establishing gap in governance..

4.1.5 Non-Motorized Transport (NMT)

In the case of the lower-income population and short-distance commuters, in particular, walking and biking constitute a large percentage of everyday transport in Delhi. According to the Comprehensive Mobility Plan (CMP), approximately 34 percent of the trips are made by walking and 11 percent by bicycles (primarily in unauthorised colonies and resettlement areas, UTTIPEC, 2020).

Even with the large modal share, NMT infrastructure is still lagging. They are in many cases improperly planned, encroached or discontinuous. There are also dedicated cycle tracks along some of the main roads but they are either not used sufficiently, or they are discontinued, or turned into parking spaces. Although these remain city-wide scale (MoHUA, 2021), some areas such as Connaught Place and Lutyens Delhi have begun pilot enhancements of the Smart Cities Mission and the Cycle4Change Challenge.

4.2 Intermodal Integration and Infrastructure

Lack of intermodal integration is also a major problem to the transportation system in Delhi. Although such initiatives as the One Delhi Card exist, commuters often need to switch between the modes (metro to bus or e-rickshaw). Consequently, there is no one common mobility card that is equally recognised by all modes. The peripheral areas often do not have the infrastructure required to allow a seamless exchange, including integrated terminals and wayfinding signage (DIMTS, 2022).

Moreover, there is still a controversial issue of parking management. On-street parking, which is uncontrolled or free, reduces road space efficiency and leads to congestions in most of the urban centres especially in commercial and residential colonies. (NIUA, 2020).

4.2.1 Travel Behaviour and Modal Share

Sustainable transportation plans in Delhi would need an appreciation of travel behaviour and modal share. Mobility pattern in the city is diverse and often spread and is dependent on distance, gender, socioeconomic status, existence of reliable infrastructure. The major travel in Delhi is within urban periphery and unlike in the metropolitan centre, due to traffic and ineffective infrastructure, a good proportion of journeys is not only within short distance but also time consuming.

The Comprehensive Mobility Plan (CMP) (2021) of Delhi estimates that approximately 60 percent of daily journeys are within the 5km distance range yet the non-motorised transport (NMT) infrastructure, i.e., safe bike lanes and walking paths, is still absent. As Figure 4 indicates, the proportion of walking trips has decreased since 2008, and now is around 25 per cent, indicating a shift toward other motorised vehicles, which in part can be explained by urban sprawl and safety concerns (UTTIPEC, 2021).

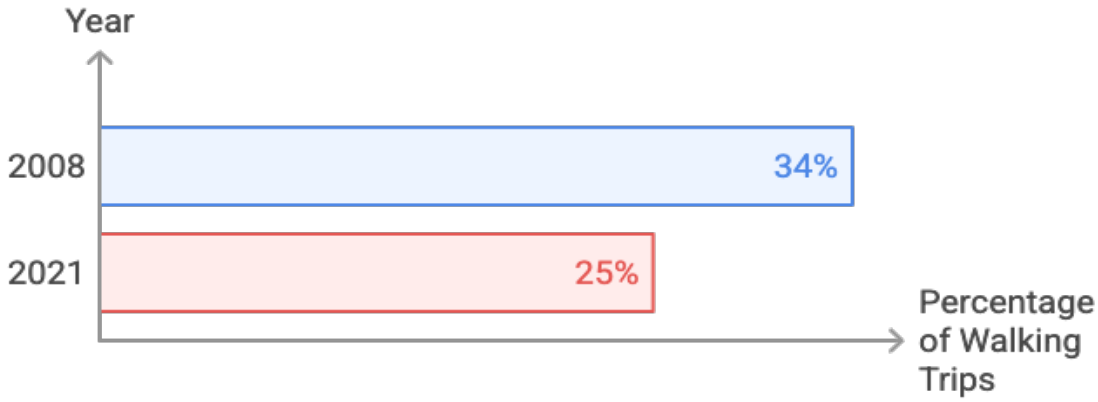

Figure 15.4 Trends in Walking Trips in Delhi

The proportion of individuals who use the public transport has been decreasing. The projected 2020 modal share of the total number of modes of transportation (Delhi Metro and buses combined) was lower than 40 percent compared to the 60 percent target by the National Urban Transport Policy (MoHUA, 2014). This decline has been attributed to poor last-mile connectivity, differences in service quality, and the increasing popularity of the personal car and intermediate transit modes of transportation (RITES, 2020). Accessibility is another problem of the Delhi Metro due to its distance between homes and absence of feeder services despite its large coverage and over 5 million daily riders before COVID (DMRC, 2022).

Replacement has been done by the use of the private vehicles, particularly the two-wheelers. According to the Delhi Statistical Handbook (2022), two-wheelers are more than 65 percent of the registered cars, followed by cars, which is approximately 25 percent. The degree of regulation and formality can be used to rank the types of

vehicles in Delhi as visualised in figure 5 below. This trend of motorisation directly affects road safety, emissions and congestion. In low-income and peri-urban regions, especially, it is important to note that paratransit modes such as shared autorickshaws, and e-rickshaws play a vital role in satisfying the demand during the last mile. These are, however, largely unregulated and informal and poorly integrated with the official transit system (TERI, 2021).

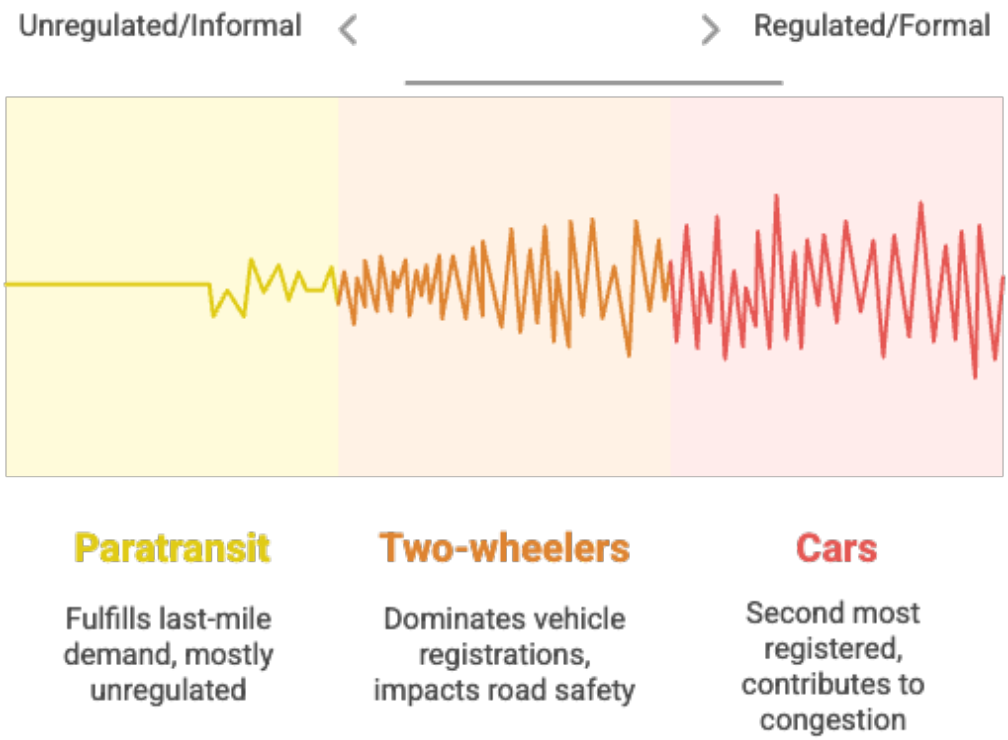

Figure 4.16 Vehicle types ranked by regulation and formality.

There are significant differences between mobility data by gender. A study conducted by Jagori and UN Women (2018) shows that only 18 percent of the women in Delhi use a personal vehicle to get around. A greater portion of them use buses and shared transport. The effects of safety, cost and trip chaining, where women integrate work, shopping and child care into one trip, are also of great importance to women travelling, which highlights the importance of developing gender sensitive regulations on transportation.

Socioeconomic status also affects the selection of the mode of travel. Most people in the lower income strata use buses, e-rickshaws or walking, to reach their destinations often at the cost of long commutes as well as being exposed to dangerous elements. The higher probability to possess and use a private vehicle and higher incomes worsen the spatial and mobility inequality (CSE, 2020).

Moreover, the frequency and patterns of travel have begun to shift as middle- and upper-class persons are increasingly exposed to telecommuting and flexibility in work,

which is caused by COVID-19 (NITI Aayog, 2021). However, since blue-collar and necessary workers continue to rely on overloaded systems, this shift has not had a significant impact on alleviating traffic.

These different travel behaviours and the active manipulation of mode choices through infrastructure, policy and service design must be understood and have an active role to the transition to a sustainable transportation future. Balanced investments in NMT, enhancement of the public transport, and multimodal integration, led by behavioural knowledge, will be necessary to enhance the transport outcomes in Delhi.

4.2.2 Transport Governance in Delhi

The administration of the transportation system in Delhi has been very fragmented and it has a multiplicity of agencies that work at separate administration levels. This institutional complication has been known to be an essential issue to plan and execute an integrated and sustainable urban transport system in Delhi (RITES, 2021; TERI, 2020).

4.3 Relevant Institutions and their functions.

4.3.1 Government of NCT of Delhi (GNCTD) Transport Department: It is the nodal agency that regulates the transportation industry, the implementation of road safety programs, assigns vehicle registration and driving licenses, and formulates policies, including the Delhi Electric Vehicle Policy (GNCTD, 2020).

4.3.2 Delhi Transport Corporation (DTC): DTC being the largest state-owned bus operator in the city of Delhi operates the state-owned bus service serving millions of commuters each day. Nevertheless, they have been reported to have issues regarding fleet modernization, scheduling, and falling ridership (Delhi Dialogue Commission, 2019).

4.3.3 Delhi Metro Rail Corporation (DMRC): DMRC is a project which is a joint venture between the Government of India and GNCTD. It has also been applauded in the world as having an efficient metro rail but with low integration with other other modes of transport such as buses and intermediate transport (CSE, 2021).

4.3.4 Delhi Development Authority (DDA): As a part of the ministry of housing and urban affairs, land use planning is handled by DDA. Nevertheless, the lack of synchronisation of transport planning and land development has contributed to urban sprawl and communities that rely on cars (Jain et al., 2018).

4.3.5 Unified Traffic and Transportation Infrastructure (Planning and engineering) Centre (UTTIPEC): UTTIPEC was set up in the context of the DDA and is mandated to develop plans to enhance mobility, street plans, design, and

multimodal integration plans. Despite making progressive plans, they become slow to implement because they do not have the power to enforce them (UTTIPEC, 2019).

4.3.6 Municipal Corporations (MCDs and NDMC): These are the local authorities in charge of roads (non-arterial), footways and streetlights maintenance. The lack of coordination between the city governments and transport entities leads to duplication of services or delays during urban mobility programmes (MoHUA, 2022).

4.3.7 Delhi Traffic Police: Deals with the implementation of traffic laws, traffic congestion areas control, and collaborates with the civil engagement of authorities. Nevertheless, the lack of manpower and old-fashioned enforcement devices impede its performance (Delhi Traffic Police Annual Report, 2021).

4.4 Challenges

The political system in Delhi does not have a central transportation body so the activities and policies are siloed and inconsistent. The agencies tend to have their own priorities, mandates and budgets so there is a lack of coordination between planning, service delivery and sharing of data (TERI, 2020). As an example, metro stations are often not connected to the bus stations, and shared auto stands are also not controlled, which causes inconvenience and safety issues to commuters (RITES, 2021) as indicated below in Figure 4.6.

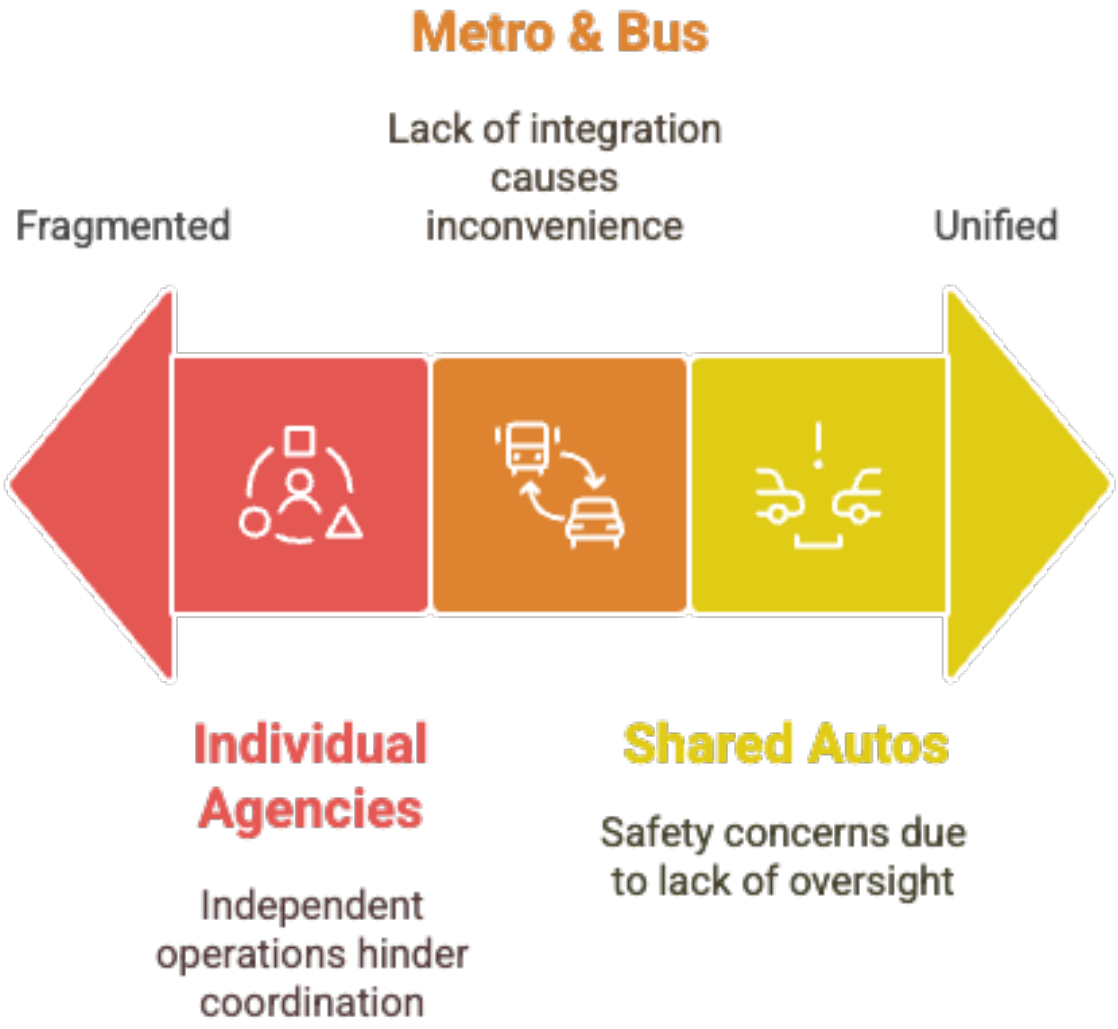

Figure 4.17: Transportation governance ranges from fragmented to unified control.

Also, it lacks a central database or platform of integrated mobility data among agencies, which restricts the capacity to optimise the transport planning and monitoring process through evidence-based transport planning (MoHUA, 2022). Lack of policies of multimodal integration: common ticketing, coordinated schedules, and shared mobility passes make the user experience weaker and lower the appeal of the public transport.

There is a recent trend among urban mobility professionals and policy-makers that Delhi requires one unified transport authority, after the examples of other cities around the world, e.g., Transport for London (TfL). This body would be able to organise the planning, operations, budgeting, and data systems of all modes and agencies. National Urban Transport Policy (NUTP, 2006) and the Smart Cities Mission have also underlined the need to have integrated urban transport governance (MoHUA, 2015), but Delhi has not institutionalised such an arrangement.

4.4.1 Challenges in Delhi's Transport System

The transport ecosystem in Delhi is not only vast, but suffers structural, operational, and environmental issues, which slow down the process of making it sustainable. These problems are multidimensional as they appear as congestion, pollution, and safety, inadequate infrastructure, and institutional fragmentation.

4.4.2 Traffic Jam and Vehicle increase.

Severe traffic congestion is also one of the most enduring problems. The ownership of the vehicles has increased exponentially in Delhi. According to Economic Survey of Delhi (2022-23) it is projected that the city had more than 13.9 million vehicles with close to 10 percent of the total population of vehicles in India (Government of NCT of Delhi, 2023). The high vehicle to population ratio has put a strain on the existing road system. The TomTom Traffic Index (2022) reports which place Delhi among the topmost congested cities in the globe where commuters take more than 60 percent of additional time in the traffic jams during rush hours. The availability of road space is still biassed, with the occupation of more than 75 percent of the road space by the private motor vehicles that perform the transportation of the less than 20 percent of the passengers (MoHUA, 2021). Figure 7 demonstrates the vehicle-based transport system in Delhi that is a paradox. Delhi, despite the 10 percent of the total number of vehicles in India accounts 75 percent of the road space, carries only 20 percent of the total number of passengers in the city. Furthermore, congestion leads to an additional 60 percent in average time of travel in peak time, which has a great negative effect on productivity, fuel consumption, and the health of the people.

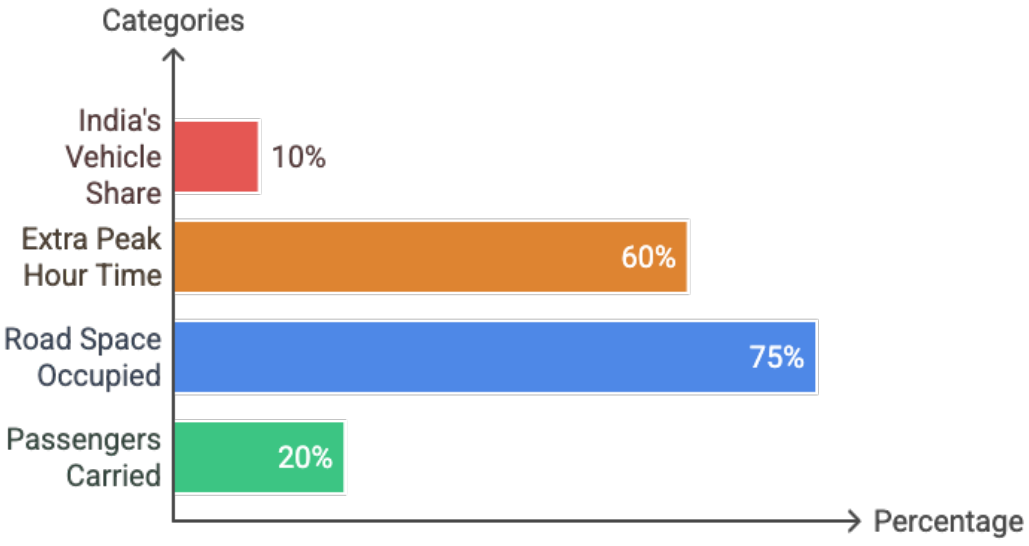

Figure 4.18 Traffic Congestion and Vehicle Distribution in Delhi.

4.4.3 Air Pollution and Environmental Impact

Delhi has a significant air pollution disaster caused by transportation. The Central Pollution Control Board (CPCB, 2022) points out that during peak seasons of high PM 2.5, vehicle emissions contribute to as much as 30-40 percent of the emissions as illustrated below in Figure 8. The rate of emissions is worsened by the high use of diesel-powered vehicles, older engines, low-quality fuel, and idling traffic (Guttikunda and Jawahar, 2018). Although buses are now also being operated on CNG, and more and more of Delhi has been covered by the Delhi Metro, the sheer number of the private vehicles has been counterbalancing them. Moreover, Indian pledges to the Paris agreement are negated by the fact that coal combustion during transportation leads directly to the carbon emission..

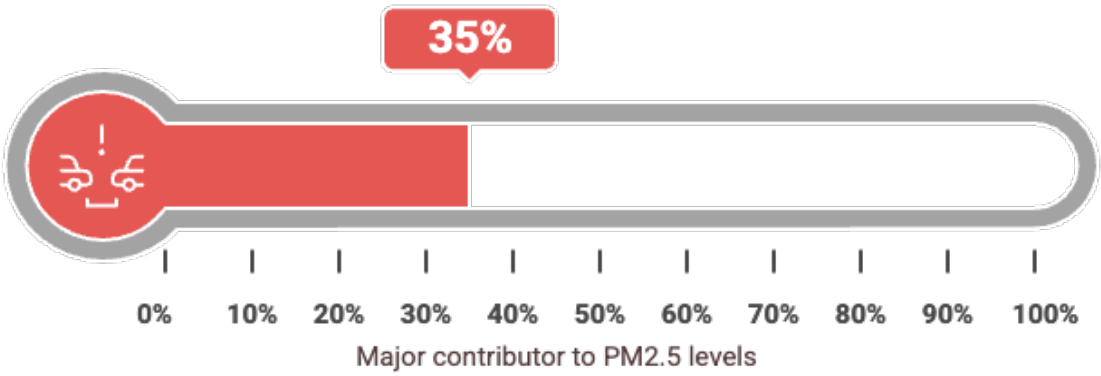

Figure 4.19 Contribution of Transport to Delhi's Air Pollution.

4.4.4 Public Transport infrastructure.

Although Delhi Metro is a global image of the efficient mass transportation, the system of public transport in general is lopsided and underused. The bus system owned by DTC and Cluster services is old and in a poor condition and is not large enough to meet the demand. As per the Comprehensive Mobility Plan (CMP) of Delhi (2020), the bus fleet per capita in Delhi is far lower than the norm that has been set up by the Ministry of Urban Development.

There are numerous organisations such as Transport Department, DMRC, UTTIPEC, DTC, PWD and municipal co-operations, that are stakeholders in governance in transport sector in Delhi. There is a major gap in multimodal integration in the Transport system in Delhi. The area has high level connectivity to metros and hence shared mobility but there is lack of co-ordination of e-rickshaw and buses. According to a study carried out by ITDP in 2019, that Delhi lacks the real-time information systems and a consistent smart ticketing, which makes it difficult to transfer and makes public transportation less desirable. Furthermore, physical infrastructure is occasionally not universally designed, and therefore children, elderly and individuals with impairments may find it difficult to utilise the system.

4.4.5 Safety and Sensitivity to Gender.

Safety concerns the transport system, particularly to female commuters and pedestrians. Delhi is one of the cities with the highest incidences of deadly road accidents in the Indian cities. The statistics of the Ministry of Road Transport and Highways (2022) indicate that there was a death of 1,213 people on the roads in Delhi alone. Unsafe cycling conditions, poorly lit bus stops, and the absence of pedestrian crossing are also the reasons that result in low non-motorized transport (NMT) uptake. According to a survey carried out by Jagori and UN Women (2018), over 90 percent of women in Delhi said that they had been harassed in one way or another when riding on a public bus. This implies that it has had serious failures in safety and inclusiveness.

The transportation safety issues in Delhi are common and widespread as illustrated in the issues on the subject. This is because the use of non-motorised modes of transport (NMT) like cycling is under-adopted due to the absence of safe cycling routes. Moreover, deadly accidents (especially at crossings and uncontrolled ones), reinforce the critical need of traffic calming devices and structures where pedestrians have to be prioritised..

Figure 4.20 Safety Issues Impact Delhi Transport.

4.5 Partnering with the policy landscape and initiatives.

The situation with the policy of urban transportation in Delhi is vivid with both national guidelines and state-level regulations colliding with experimental projects aimed at the promotion of inclusive and sustainable mobility. With some improvements, however, there are still a number of issues that are faced because of an incoherent system of governance and the lack of steady policy implementation. This part evaluates the major laws which influence the transport system in Delhi and how they are related to the sustainability goals.

4.5.1 National Urban Transport Policy (NUTP), 2006.

The Ministry of Housing and Urban Affairs (MoHUA) has developed the National Urban Transport Policy (NUTP) as a guiding principle to sustainable urban transport

in the Indian cities. It pays much attention to the concept of placing people above vehicles, integrated land-use planning, public transportation, and the use of non-motorised traffic (NMT) (MoHUA, 2006). NUTP suggests that Unified Metropolitan Transport Authorities (UMTAs) should be formed to help in the coordination of the planning process and also supports the idea of multimodal transportation systems. UTTIPEC partially carries out this advice in Delhi. Although NUTP offers the perfect structure, some cities such as Delhi have a problem of adherence as a result of challenges such as institutional fragmentation, insufficient resources, among others (Kumar & Agarwal, 2013).

4.5.2 Policy on Electric vehicles, Delhi, 2020.

To address the increase in vehicular pollution, the Delhi Electric Vehicle Policy (2020) was introduced in which 25 percent of the newly registered vehicles should be electric vehicles (EVs) by 2024 (Government of NCT of Delhi, 2020). This policy provides a holistic package of fiscal incentives, scrap incentives, interest subsidies and a specific interest on two wheelers, three wheelers and electric buses. The key pillars of the EV policy of the city of Delhi are summarised in figure 9 below.

It also facilitates establishment of EV charging equipment in partnership with the third side and motivates fleet electrification by aggregators and delivery companies. There are already positive indications of the uptake of electric two-wheelers, though the process of switching to the electric public transport fleet (e.g. DTC buses) has been delayed, both because of issues with procurement and infrastructure preparedness (CEEW, 2021).

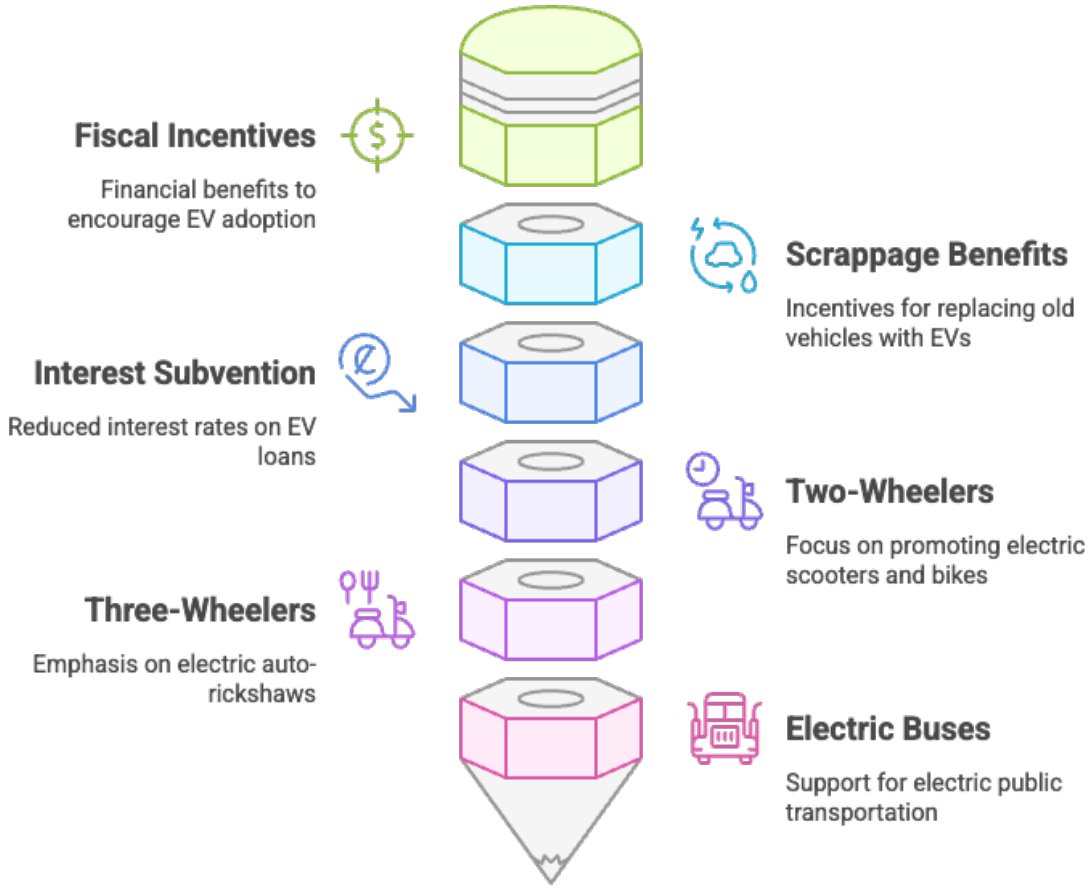

Figure 4.10 Delhi's Electric Vehicle Policy Overview.

4.5.3 Comprehensive Mobility Plan(CMP) and UTTIPEC Guidelines.

The Comprehensive Mobility Plan (CMP) in Delhi that was prepared under the oversight of UTTIPEC is an undertaking to harmonise transport investments and sustainable development. It embraces land use and transport planning, priority given on the mass transit systems, the non-motorised modes, and the decongestion strategy (UTTIPEC, 2011). It introduces the following strategies Transit-Oriented Development (TOD), congestion pricing and multimodal integration hubs.

However, many of the projects offered by CMP remain to be realised because the approvals are too long, funding is problematic, and there are overlaps of institutions (RITES, 2020).

4.5.4 Odd-Even Scheme

One of the pollution control schemes declared by the Delhi Government in 2016 and called the Odd-Even scheme bans the use of private cars on specific days of the week and relies on the car number at the peak period of pollution (Sharma and Dikshit, 2016). Even though it is a proven method of reducing peak-hour traffic, its long term

environmental impacts have been doubted due to modal substitutes and exemptions of certain kinds of vehicles.

4.5.5 National Electric Mobility Mission Plan (NEMMP) and the FAME Scheme.

The EV adoption goals in the city of Delhi are encouraged by the Faster Adoption and manufacturing of (Hybrid and) Electric Vehicles in India (FAME) scheme of the NEMMP 2020. FAME-II also subsidises the electric buses, three-wheelers, and two-wheelers and the charged infrastructure (Ministry of Heavy Industries, 2022). The procurement and disbursement process is normally behind the demand and this is one of the largest beneficiaries of the scheme in Delhi.

4.5.6 Street Design and Non-Motorised Transport Initiatives.

Delhi conducted Smart Cities Mission and India Cycles4Change Challenge campaigns under the name Street for People and redesigned specific roads to allow people on foot and bicycles. Walkable and low-carbon areas have already been successful in such places like Chandni Chowk and Connaught Place, but the utilisation of walkable and low-carbon areas has not been significantly implemented at a mass scale (ITDP India, 2021).

Street Design Guidelines of UTTIPEC include Complete Streets, universal accessibility, and climate-sensitive urban design as well, however, its introduction to the entire road network of Delhi has not been uniform (UTTIPEC, 2019).

4.6 Policy Gaps and Challenges

Despite the progressiveness, the transport management in Delhi is a combination between different bodies, DMRC, DTC, PWD, MCDs, UTTIPEC and Transport Department, a majority of which are presently working in silos. This leads to:

- Slow embrace of such schemes as multimodal ticketing and shared mobility cards.
- Conflict in jurisdiction especially in land use, parking policy and NMT infrastructure.
- Lack of built-in data systems, which employs real time decision-making.

Therefore, the most suitable strategies to achieve policy-practise gap in transport sector in Delhi are to improve institutional coordination, ensure that there is a proper financing mechanism and involvement of the citizens.

On the one hand, Sustainable Transition presents opportunities.<|human|>On the one hand, there are opportunities of Sustainable Transition.

The paradigm shift required in emission to achieve sustainable urban mobility in Delhi should be to have people-centric instead of vehicle-centric with reference to national

and global sustainability objectives. Several major opportunities of transforming the current transport system to more sustainable and inclusive one exist.

4.6.2 Transport Electrification Public and Intermediate.

The impetus of electric mobility in Delhi in the Delhi Electric Vehicle Policy 2020 has provided the decarbonization of urban transport with a great opportunity. The policy will ensure that 25 percent of the total new vehicle registration in 2024 is an electric vehicle, which will include not only the modes of transport but also one of them a personal one (Government of NCT Delhi, 2020). Through electrification of buses particularly the DTC and Cluster buses, the rate of particulate emissions and noise pollution can be significantly reduced, which are the greatest problems of the overcrowded urban setting of Delhi.

In addition, through electrification of three-wheelers and e-rickshaws (which form the main part of the last-mile and para-transit systems of Delhi) one can create massive environmental and social effects. It has been shown that the electric three-wheeler can emit greenhouse gases, with the emission being as low as 60 percent lower than that of the petrol ones (IEA, 2022). The other important facilitating factor to this transition is the deployment of charging infrastructure especially battery swapping station at high density nodes.

Although the Delhi Metro Rail has been successful, overall modal share of public transport is reducing because metro, buses and last-mile transport are not properly integrated (UTTIPEC, 2021). One of the biggest prospects is the creation of a coherent public transport system by creating unified ticketing, unified schedules, and multimodal centres.

Besides, it is important to enhance the coverage and reliability of buses. The Comprehensive Mobility Plan (2019) has found that more than 30 percent of the population in Delhi does not have access to buses that they can trust in a 500-metre radius. The renewal of the bus service in under-represented and outskirt locations can make it more convenient to the low-income population and decrease the reliance on personal cars.

The needs of women, the aged and differently-abled people should also be taken into account in integration. By making the transportation more inclusive (e.g., improving the quality of lighting, surveillance, safe waiting spots, etc.), gender-sensitive design would help women become more confident in their use of transportation (Tiwari and Jain, 2021).

4.6.3 Transport Strengthening Non-Motorised Transport (NMT).

NMT- walking and cycling- is the most sustainable form of travel particularly when travelling short distances within cities. However, the NMT has low latent demand at Delhi that is not met by infrastructure. Nowadays, over 30 percent of travel is less than 5 km, and it is suitable to walk or ride a bike (MoHUA, 2020).

The Streets for Person and Cycle4Change as part of the Smart Cities Mission are good initiatives, but they need institutionalisation and implementation. Specific and secure walk and bike paths and cycle tracks, traffic management devices, and connectivity with the nodes of the transport system can also considerably enhance the mode share of NMT. According to a study by the World Bank (2020), the presence of cycle lanes that are safe can boost the number of people using it by 35-50 per cent, particularly when there is an employment and education centre nearby.

Transit-Oriented Development (TOD) occurs when people choose to reside in residential zones near transportation routes instead of utilising garages and vehicles, despite this area being prone to various dangers and crimes.

4.6.4 Transit-Oriented Development (TOD)

Transit-Oriented Development (TOD) takes place when individuals prefer to live in residential areas close to routes rather than use garages and cars, even though this location is prone to many dangers and crimes.

Traditional development of Delhi has been independent of its land use and transport systems. The National TOD Policy provides a model of densification and development of mixed-use communities along the public transport corridors. Delhi already has announced TOD requirements around the Metro Phase-III corridors, which seek to encourage the formation of compact and walkable urban form (DDA, 2021).

TOD does not just increase access to public transport but also decreases long distance motorised travel hence reducing emissions and traffic congestion. The benefits of better transport access should be affordable to all income populations, and this can be ensured by incentivizing affordable housing in TOD areas.

The technology and data-driven planning are utilised.

The efficiency, transparency and responsiveness of the transport system in Delhi can be significantly increased with the help of smart technologies. Integrated Command and Control Centres (ICCCs) can also be developed to allow the provision of real-time monitoring of traffic, buses, and incidents in order to make timely decisions and optimise the system (NIUA, 2022).

Applications and online dashboards can assist the user in making planning trips more efficient, monitor buses in real time and give feedback. Planning-wise, big data

analytics, which is founded on the data of the mobile phones, GPS and smart cards use, can help the policymakers find out the clusters of demands, create dynamical routes and improve the allocation of resources (ITDP, 2021).

4.6.5 Behaviour Change and Public Engagement.

Sustainable transport is not a mere infrastructure concern, but also requires behavioural change. Examples of such successful programmes that have shown how awareness, experience and social involvement can change modal shift include Raahgiri Day and Car-Free Zones. These participatory events are to be institutionalised and extended to all the districts in order to establish a culture of sustainability (Jain and Agarwal, 2019).

The involvement of the people also creates responsibility and confidence, which will guarantee long-term success. The gap between policy and practise can be addressed by using such tools as mobility satisfaction surveys, citizen transport forums, and inclusive planning workshops.

4.7 Conclusion

The greater transport issues of megacities of developing countries are echoed in the transport system of Delhi. An over-dependent use of the private automobiles, a lack of infrastructure to support non-motorised mobility, connectivity of the last mile, social and environmental concerns is knotted dialectic between the public and the private form of transport. The city boasts of an excellent metro system which is said to be among the best in India and excellent fleet of buses. But its transport system is a victim of disjointedness in its planning and execution, and hence its sustainability, accessibility, and effectiveness.

In this paper, it can be seen that the transport system in Delhi is regulated by an overlapping that is likely to stifle integrated decisions and hence freeze any improvements made to the system. The current trend in modal split is alarming where the utilisation of public transport keeps on decreasing and the ownership of personal vehicles increases accordingly. This presupposes the regular traffic jams, longer commuting time, higher gasoline usage, and poor air quality. Is it that they would be technical or infrastructural problems in nature? They are key problems that are respectively, public health, social equity, and urban planning. The transport systems in Delhi are of extreme environmental concerns on the sustainability aspect. The situation of bad air quality is almost unique in that vehicular emissions are a primary source of bad air quality and are also contributed by the fact that people heavily rely on the use of fossil fuels as their means of transportation.

However, certain concerns are still unaddressed that, in most instances, cannot be overlooked: the first one is the issue of pedestrian and cyclist safety that is crucial during short distance travelling. Secondly, there is an unparalleled social equity gap within the whole mobility sector that constitutes a major barrier to safe, reliable, and

affordable mobility among the disadvantaged groups of people in the society, including women, the aged and the poor. The Delhi policy framework consists of three major components; the Delhi Electric Vehicle Policy, and measures on transit-oriented development rules and the measures in transport integration initiatives. There are severe limitations to real-world application due to institutional vulnerability, lack of structures to enforce them, and systemic flaws. This is even aggravated by the fact that there are poor data exchange protocols and only slight involvement of public level stakeholders in the transport planning process.

The overall assessment of the intricate transport system in Delhi makes it possible to find out about the pervasive inefficiencies, which are the foundation of designing an inclusive, sustainable urban mobility system. Sustainability features have been brought forward to ensure that the main emphasis is on the transport model that will be applied in Delhi.

The tenets of the sustainability aspects include unprecedented accessibility, profound minimisation of environmental footprints, and maximisation of cross-modal interconnectivity. Besides, of excessive importance is the implementation of the utilisation of digital technologies, infrastructures of real-time data, and governance with participatory feature embracing all stakeholders, including individual people and private mobility providers, and government.

The analysis will give a background reference to select the required intervention strategies and to redesign the current transportation system. It will be a roadmap to the further phases of research that will be optimal in terms of mobility outcomes and making the transportation infrastructure of Delhi less burdened with the Sustainable Development Goals (SDGs), a data-driven, user-centric, and assistive sustainable transportation model being the ultimate goal, also suitable in the urban structure of the city.

CHAPTER 5

ASSESSING DELHI'S TRANSPORTATION SYSTEM FOR SUSTAINABLE DEVELOPMENT: A FRAMEWORK-BASED ANALYSIS ALIGNED WITH THE SDGS

Transport systems in the city are very important in determining the environmental, economic, and social environment of cities. As the case of the capital of India, Delhi, there are several transportation systems which have been unveiled over time to deal with mobility problems with the objective of achieving sustainability. This paper evaluates the key transportation systems in Delhi in terms of the Sustainable Development Goals (SDGs), namely, the use of a 5P-based sustainability assessment framework. A structured questionnaire with a 5-point Likert scale was used to collect expert opinion about the relevance of each framework to each of the People, Planet, Prosperity, Peace, and Partnership dimensions. The findings have discovered the Delhi Master Plan 2041 as the sustainable transportation structure. The paper also suggests ways in which this plan can be improved to be more in line with sustainable development goals and gives policy guidelines that the policymakers can use.

5.1. Introduction

In contemporary urban areas, transportation is a central factor that determines the livelihood, economic growth, and sustainability of the environment. Transport systems are not only important in the rapid urbanizing areas especially in the Global South but they are also the drivers of inclusive development, environmental sustainability and social justice. Delhi, the Indian capital city, is an example of the potential of urban mobility in the 21 st century as well as the challenges. With population of above 30 million and increased demand, transportation ecosystem in the city is experiencing tremendous demands of not only serving the increased needs but also in line with the national and international sustainability objectives (MoUD, 2014).

The modern trends in transport in the city of Delhi are characterised by both developments and stumbling blocks. Even though great efforts have been put on metro rail, bus rapid transit (BRT), and non-motorised transport infrastructure, the city still struggles with traffic jams, auto emissions, inadequate last-mile connectivity, and increasing road casualties (EPCA, 2019). Transport emissions according to the Centre for Science and Environment (CSE, 2021) also cause the air pollution in the city by almost 30 percent in the peak winter seasons. This tendency presents the critical necessity of the reassessment of current transportation policy on the basis of a sustainability perspective.

Sustainable transport is currently understood as a facilitator of the United Nations Sustainable Development Goals (SDGs), especially SDG 11 (Sustainable Cities and

Communities), SDG 13 (Climate Action), and SDG 9 (Industry, Innovation, and Infrastructure). The SDGs, which are designed based on the 5Ps such as People, Planet, Prosperity, Peace, and Partnership provide an integrated roadmap to inclusive, resilient, and environmentally conscious development (UN, 2015). Transportation systems that are planned with such objectives in mind can make all more mobile, decrease carbon emissions, increase green jobs, and promote institutional responsibility and innovation (ITDP, 2020).

Delhi has over the years presented numerous offers related to transport such as the Delhi Transport Policy 2018, the Unified Traffic and Transportation Infrastructure (Planning and Engineering) Centre (UTTIPEC) Guidelines, the Comprehensive Mobility Plan (CMP), and the revisions of the Delhi Master Plan (DMP). Although these frameworks have useful strategies and action plans, their congruence with sustainability objectives, especially on the 5ps of the SDG framework, has not been comprehensively scrutinised. Besides, the overlapping mandates and decentralised government systems tend to result in policy stagnation and implementation lapses (Singh and Sharma, 2022).

In order to fill this gap, the current paper suggests an integrated analysis of the key transportation systems in Delhi through a 5P-based analytical model that is in line with the SDGs. An organised professional-delphi survey was carried out to measure the selected frameworks through the Delphi technique where planners in the urban setting, transport experts, and policy analysts were requested to rank the chosen frameworks on a 5-point Likert scale in each of the 5Ps. Such a participative model makes it possible to gain a more detailed insight into to what extent each framework can be used to address the concerns of social inclusiveness (People), environmental sustainability (Planet), economic growth (Prosperity), governance (Peace), and collaboration (Partnership).

The initial results of the professional analysis showed that the Delhi Master Plan 2041 (Draught) is the most sustainability-oriented structure. It got the highest score in environmental responsibility, infrastructure foresight and institutional coherence. Nevertheless, even this document has gaps especially in the mechanisms of involvement and the scalability of the implementation by the stakeholders. Thus, the paper builds a modified sustainable Transportation Framework based on the expert feedback and comparative insights, which will play a bigger role in improving the Delhi Master Plan 2041 by incorporating more sustainability indicators and global best practises.

The second part of this research will be the benchmarking of the improved structure to the best approaches of transportation in the world in cities like Copenhagen, Singapore and Bogota. These cities have been recognised across the globe as using efficient sustainable urban transport systems with interventions such as transit-oriented development (TOD), bicycle infrastructure, low-emission zones, and people-focused city governance (GIZ, 2020; UITP, 2018). This study reveals the applicability and

flexibility of the Delhi framework to the world by drawing parallels between the Delhi framework and these models.

The timeliness and policy-relevancy of this research is high. With national missions such as the Smart Cities Mission and Gati Shakti, which require significant investment in infrastructure in India, a major opportunity to mainstream the sustainability of transport planning exists. This analysis and improvement of the most promising local framework, Delhi Master Plan 2041, provides the practical insights that could be used in the further policy-making in not only Delhi, but also in the other Indian cities that struggle with the issue of urban mobility..

In summary,

1. Analyse how well current Delhi transportation systems align with the sustainability criterion with a 5P model.
2. Determine the most sustainable framework by means of expert opinion.
3. Optimise the chosen framework to make it more sustainable.
4. Compare the adjusted framework with the international best practices.

By providing a multi-faceted solution to the issue, the study has provided a replicable solution to sustainability-oriented urban transport planning in such a complicated megacities as Delhi.

5.2 Methodology

The study is a qualitative study that uses a combination of both qualitative and quantitative methods to evaluate and improve the sustainability of the transportation systems in Delhi. The research is organised into two main steps: (1) expert based assessment with the use of the Delphi method based on the SDGs through the 5P framework (People, Planet, Prosperity, Peace, and Partnership); and (2) the benchmarking process of the most sustainable framework against the best practises on the global arena. This part describes the rationale, design, as well as the data collection and analysis procedures employed to guarantee the robustness, transparency and academic validity of the research process.

5.3 Research Design

The study is based on a two-phase research:

- Phase I: Analysis of important transportation policy frameworks in Delhi through assessing expert views through a structured Delphi process.
- Phase II: International comparison of the most sustainable framework (defined in Phase I) with the best practices in sustainable urban transportation in the global case studies.

Combining professional opinion and comparative international analysis will ensure that the presented changes in the framework of Delhi are more context-dependent and informed by global experience.

5.4 Framework

Out of the 14 significant transportation-related structures implemented or proposed in Delhi, 14 were selected for evaluation based on their policy relevance, recency, and strategic impact on the city's mobility.:

1. National Urban Transport Policy (2006)
2. National Electric Mobility Mission Plan (2020)
3. Delhi Transport Policy (2018)
4. Unified Traffic and Transportation Infrastructure Planning & Engineering Centre (UTTIPEC) Guidelines
5. Comprehensive Mobility Plan (CMP)
6. Delhi Master Plan 2021
7. Delhi Master Plan 2041 (Draft)
8. Delhi Electric Vehicle Policy (2020)
9. Delhi Non-Motorized Transport Policy
10. Gati Shakti Master Plan (Delhi Chapter)
11. Delhi Metro Rail Policy (2017)
12. Smart Cities Mission (Delhi Initiatives)
13. National Transit Oriented Development (TOD) Policy
14. Street Vending Policy (Delhi Implementation)

These frameworks were selected as they are the major strategic documents that would govern the planning, governance, and investment on the infrastructure related to transportation and mobility in Delhi. The analysis has been done concerning the fit of each framework to the 5P model of SDGs.

5.5 The 5P Framework to be assessed.

The 5P framework is based on the Agenda 2030 of the United Nations and 17 Sustainable Development Goals. Every conceptual pillar of the SDGs is organised into interconnected themes with the 5Ps, namely People, Planet, Prosperity, Peace, and Partnership (UN, 2015). This model offers an integrated perspective based on which transport structures should be assessed to have a proper balance on the focus of social equity, environmental responsibility, economic development, governance, and collaboration.

All the frameworks were evaluated at the following five dimensions:

- People: Availability, inclusiveness, affordability, security.
- Planet: Environmental conservation, carbon emission, energy use, land conservation.
- Prosperity Economic viability, investment in infrastructure, generation of jobs, innovation.
- Peace: Co-ordination in institutions, mechanisms of governance, transparency, coherence of policies.

- Partnership: Inter-agency cooperation, involvement of stakeholders, public-private involvement.

All these dimensions were further broken down to 3-5 sub-criteria to enable a comprehensive appraisal in the process of expert consultation.

5.6 Phase I: Expert Assessment Using Delphi Method.

5.6.1 Rationale for the Delphi Method

In this research, the Delphi technique was used to get expert opinions on the suitability of different transportation policies and projects in Delhi. Due to the context-specific and multidimensionality of sustainable transport, the issue of expert evaluation is essential to determine the relevance of each initiative, feasibility, and impact in practice. The iterative nature of the methodology enables refining and consensus making especially useful in complex systems that deal with policy, environment and infrastructure (Linstone and Turoff, 2002).

5.6.2 Questionnaire Design and Evaluation Framework

The questionnaire used in the study (attached as Annexure I) was designed to represent the expert opinion on the five pillars of sustainability (5) or 5Ps that are: People, Planet, Prosperity, Peace, and Partnership according to the SDG model by United Nations (UN, 2015). To evaluate the perceived contribution of each policy or project to each of the pillars, it was measured with the 5-point Likert scale:

- **1 = Very Low Contribution**
- **2 = Low Contribution**
- **3 = Moderate Contribution**
- **4 = High Contribution**
- **5 = Very High Contribution**

The evaluation included 14 policies and initiatives, ranging from legacy plans like the Delhi Master Plan 2001 to recent developments such as the Delhi EV Policy 2020, TOD Guidelines, and Unified Mobility Card. Experts were asked to provide scores for each initiative across all 5Ps, ensuring a comprehensive evaluation of their sustainability dimensions.

Sections of the questionnaire included:

- Section A: Expert profile (years of experience, domain expertise)
- Section B: Quantitative evaluation of 14 transport policies/projects using the 5P-Likert matrix
- Section C: Open-ended qualitative feedback on additional initiatives, implementation challenges, and suggestions for improvement

This structure ensured both quantitative scoring and qualitative insights, allowing for triangulation in data analysis.

5.6.3 Expert Panel Selection

A total of 30 experts were invited to participate in the Delphi rounds. Participants were recruited using purposive sampling that was based on their expertise and practical experience in the following areas: urban planning, public transportation, electric mobility and SDG related governance. They represented a cross-section of institutions that included:

- Delhi Development Authority (DDA).
- Centre for Science and Environment (CSE)
- Transport Research and Injury Prevention Programme (TRIPP), IIT Delhi
- Private planning of consultancies
- Non-Governmental Organisations (NGOs)
- Academic institutions & Think tanks

Minimum criteria for participation was 7+ years of experience in the transportation or sustainability space & knowledge of Delhi transport ecosystem.

5.6.4 Delphi Round I: Initial Evaluation and Thematic Analysis

First round required the experts to be given the questionnaire and summaries of the policies. They evaluated every transport initiative on the Likert scale and answered questions in open-ended domains qualitatively (Section C). This session allowed the gathering of:

- Base ratings of each of the initiatives on the 5ps.
- Determination of gaps, redundancies or inconsistencies in the implementation of the policy.
- Additional initiatives that are suggested by experts (e.g., green freight corridors, non-motorization transport promotion)

The open-ended questions were analysed using thematic coding (Miles and Huberman, 1994), and the insights were categorised according to the 5P framework for future analysis and revision of the frameworks.

5.6.5 round II- Delphi: Consensus Evaluation.

A second round was initiated after the analysis of the responses received during Round I in order to polish the assessments and proceed to consensus. The experts were presented with aggregated mean scores and thematic summaries of Round I and were requested to confirm, amend, or provide justifications for their scores. This feedback loop helped in:

- Enhancing unity on the policies that are most effective (e.g., Delhi Master Plan 2041, Delhi EV Policy).
- Weak initiatives that are not strongly supported are discarded or reclassified.
- Approving recommendations to improve the Delhi Master Plan 2041.

5.6.6 Analysis of Responses

The descriptive statistics were used to process quantitative responses and compute:

- Means and median scores of every initiative of each 5P.
- Average of all five dimensions composite sustainability score per framework

Programmes with an average score of ≥4.0 were taken as highly sustainable, 3.0-3.9 as moderately sustainable, and less sustainable.

The Delhi Master plan 2041 (Draught) was rated the best among all the initiatives, it scored consistently in all the five pillars, especially in the Planet, Prosperity, and Peace dimensions.

The evaluation scores of 14 transportation-related policies and frameworks in Delhi have been provided in the table 6.1 below as evaluated using the five dimensions of sustainable development (People, Planet, Prosperity, Peace and Partnership). All scores represent the evaluation of the experts on a 5-point Likert scale.

Framework	People	Planet	Prosperity	Peace	Partnership	Total Avg
National Urban Transport Policy (2006)	3.6	3.8	4.0	3.5	3.2	3.6
Nat. Electric Mobility Mission Plan (2020)	3.9	4.3	4.1	3.4	3.5	3.8
Delhi Transport Policy (2018)	3.8	4.1	4.0	3.6	3.7	3.8
UTTIPEC Guidelines	4.2	4.3	4.2	3.9	4.0	4.1
Comprehensive Mobility Plan (CMP)	3.4	3.5	3.7	3.2	3.1	3.4
Delhi Master Plan 2021	3.7	3.8	3.9	3.5	3.3	3.6
Delhi Master Plan 2041 (Draft)	4.4	4.5	4.6	4.2	4.1	4.4
Delhi Electric Vehicle Policy (2020)	3.9	4.4	4.2	3.5	3.5	3.9
Non-Motorized Transport (NMT) Policy	4.2	4.5	4.0	3.5	3.8	4.0
Gati Shakti (Delhi Chapter)	3.5	3.7	4.3	3.3	3.4	3.6
Delhi Metro Rail Policy (2017)	3.8	3.9	4.1	3.7	3.3	3.8
Smart Cities Mission (Delhi)	3.9	3.8	4.0	3.6	3.9	3.8
TOD Policy (National Guidelines)	4.0	4.1	4.3	3.7	3.6	3.9
Street Vending Policy (Delhi)	4.1	3.5	3.6	3.4	3.3	3.6

Table 6.8 Sustainability Scores of Delhi Transportation Frameworks Aligned with the SDGs.

5.6.7 Open-Ended Findings

The qualitative feedback had some major themes:

- Requirement of better last-mile connectivity within the People dimension.
- Absence of transparency and accountability systems of the Peace.
- There is poor incorporation of stakeholder and community alliances, which implies unsatisfactory Partnership.
- The advocacy of e-mobility and TOD is perceived as a strong force, which justifies its focus in the context of the changing scheme in Delhi.

The discoveries were used directly to establish the Modified Sustainable Transportation Framework thereby improving the Delhi Master Plan 2041 by introducing strategies that are globally aligned and locally relevant.

5.7 Results and Discussion

In order to assess how the transportation planning in Delhi is aligned with the Sustainable Development Goals (SDGs), the responses of experts were systematically evaluated using a set of fourteen policy frameworks using a structured questionnaire. The reviews of every framework were conducted by experts within 5 dimensions of SDG implementation, namely People, Planet, Prosperity, Peace, and Partnership, on a 5-point Likert scale (1 = Very Poor, 5 = Excellent). The frameworks constitute the combination of central policy initiatives, state policy initiatives, city-level policy initiatives, and institutional policy initiatives that affects the transport planning in Delhi.

The study involved 25 professionals, including urban planners, transport engineers, policy researchers, environmentalists, senior government and academia professionals. The quantitative answers were averaged to ascertain the score of each of the frameworks in the 5ps and then a comparative analysis done to establish the framework that is more aligned with sustainability.

5.8 Frameworks Overview Analysed.

It analysed 14 frameworks as follows:

- National Urban Transport Policy (2006).
- National electric mobility mission plan (2020).
- Delhi Transport Policy (2018)
- Guidelines of Unified Traffic and Transportation Infrastructure Planning and Engineering Centre (UTTIPEC).
- Comprehensive Mobility Plan (CMP).
- Delhi Master Plan 2021
- Delhi Master Plan 2041 (Draft)
- Delhi Electric vehicle policy (2020).
- Delhi Non-Motorized Transport Policy.

- Gati Shakti Master Plan (Chapter Delhi).
- Delhi Metro Rail Policy (2017)
- Delhi Initiatives Smart Cities Mission.
- National National Transit Oriented Development (TOD) Policy.
- Delhi Implementation of Street Vending Policy.

5.8.1 Framework by Framework Aggregate Scores.

In order to make a visual representation of the comparative performance, a heatmap was created that displays the mean score of each framework in all the indicators that were evaluated. This aided in the rapid determination of the trends of strengths and weaknesses to each structure (see Figure 6.1)

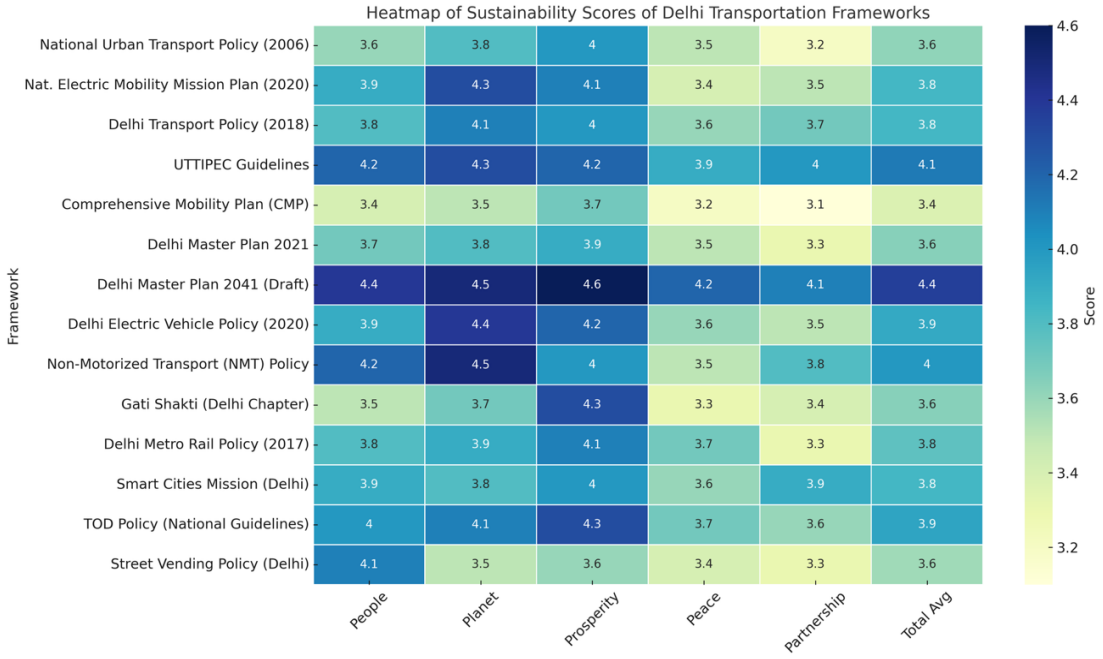

Figure 5.21 Heatmap showing the average score distribution of 14 transportation frameworks based on expert evaluations.

To demonstrate the overall mean score of each framework, a bar chart was generated to visualise the heatmap with all indicators summarised to show one mean. This representation determines the most and least sustainable frameworks in general. Delhi Master Plan 2041 (Framework 7) was the most sustainable with an overall average score of more than 4.3, then UTTIPEC (Framework 4), and NUTP (Framework 9) followed closely as seen in Figure 6.1. Framework 5 on the other hand scored least indicating that it is less aligned with the sustainability objectives.

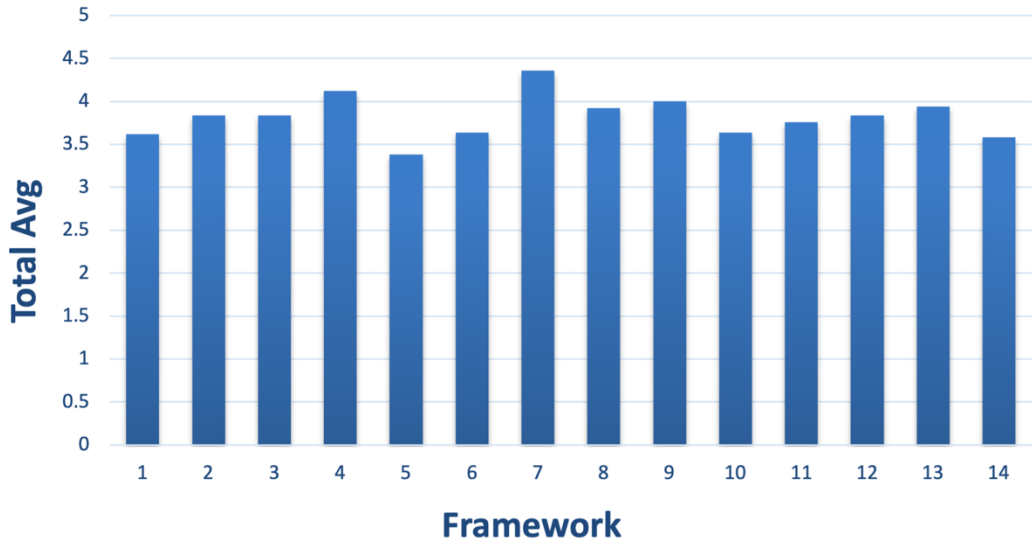

Figure 5.22 Bar chart depicting the total average scores (on a 1–5 scale) of each transportation framework.

These visual summaries offer a clear overview of how each policy performs and set the foundation for deeper framework-specific analysis presented below.

5.8.2 High-Performing Frameworks

Delhi Master Plan 2041

The Master Plan of Delhi 2041 had the highest aggregate mean score, **4.36** and this made it the framework with the most sustainability-oriented alignment. It was rated highly in all the five dimensions, especially doing well in:

- **Planet** (4.5): Having high emphasis on environmental sustainability which includes the strategies on EV integration, green corridor, and urban greening.
- **Prosperity** (4.6): Focus on Transit-Oriented Development (TOD), modernization of infrastructure and decentralisation of economy.
- **Peace** (4.2): There are better governance mechanisms represented by institutional mechanisms such as Unified Command Centres and digital dashboards.

Professionals valued the futurist nature of the plan and its systematic inclusion of the environmental and equity-related factors.

5.8.3 UTTIPEC Guidelines

With a total score of **4.12**, the UTTIPEC guidelines were judged as good regarding:

- **People** (4.2): Putting centrally the features of flavor-walkability, universal design and gender-inclusiveness.
- **Planet** (4.3): NMT and zoning of land use in decongestion encouragement.

The framework was regarded as the standard of street planning and inclusive planning in the Indian setting.

5.8.4. NMT Policy and Delhi Electric Vehicle Policy (2020)

The two policies scored high in the Planet dimension (4.4 and 4.5, respectively), which implies that they are highly environmentally focused. Nevertheless, the scores for Peace and Partnership are slightly lower, and it seems people are concerned about policy coordination and stakeholder involvement.

5.9 Delphi Master Plan 2041 Analysis.

5.9.1. Strengths of Delhi Master Plan 2041

Delhi Master Plan 2041 is unique in that it provides a holistic approach to sustainable city transport. Among the strengths that it enjoys is the fact that it focuses on multimodal integration whereby the public transport schemes, e.g. buses metro and non-motorised transport (NMT) are to be interlinked. This guarantees the last-mile connectivity, minimizes the reliance on personal cars, and will encourage modal shift.

The plan also focuses on the encouragement of non-motorised transport e.g. walking and cycling, by providing special infrastructure, green corridors, and streetscapes that are conducive to the walker. These programmes improve access, particularly to vulnerable populations, such as older people, women, and children.

One more strength is its clear emphasis on green mobility and pollution control. The road map will also entail measures to mitigate car emissions, enhance the use of electricity powered cars, and popularise use of clean energy powered means of transport. One of its cross-cutting themes is the environmental sustainability that cuts across its objectives.

Regarding social sustainability, the strategy aims to cover inclusivity and affordability through offering equal opportunities to use public transport and focusing on underserved regions. It also demands the use of gender sensitive designing and accessibility to individuals with disabilities, which gives a people-focused approach of mobility.

5.9.2 Identified Gaps

In spite of the merits, analysts found some major gaps in the Delhi Master Plan 2041 that can cripple the successful implementation of the plan. One of the key issues is that there are no strong implementation and monitoring mechanisms. Although the plan is extensive in terms of vision, it does not present well articulated Key Performance Indicators (KPIs), timelines, and institutional responsibilities that are instrumental in monitoring the progress and accountabilities.

The second weakness is that smart mobility technologies are not properly integrated. Even though the plan comes up with the concept of modernisation, it does not adopt wholesomely the application of intelligent transport systems (ITS), real-time data sharing, and mobility-as-a-service (MaaS) platforms which are becoming more significant in the contemporary digital urban setting.

Moreover, the plans do not have good mechanisms to meet the transport demands of the informal settlements and low-income population. Whereas inclusivity is stated, there is no elaborate action plans and funding mechanisms that are focused on these communities.

Lastly, the plan has fewer provisions regarding the partnership between the public and the private (PPP). The transportation infrastructure is resource-intensive hence utilising PPPs is necessary to achieve innovation, efficiency, and scalability. The plan could be improved with better strategies on the involvement of the private stakeholders in the project development and service provision.

5.9.3 Future Improvement Recommendations.

In order to make the Delhi Master Plan 2041 more sustainable, it is suggested to improve it in the following manner:

1. **Efficient Technology Adoption**: Introduce modernisation of the transportation ecosystem in Delhi by including smart technologies. This involves real time bus and metro tracking mobility systems, infrastructure optimisation GIS-based planning systems, and electronic ticketing systems that encourage the use of contactless and cash-free travel. ITS has the capacity to optimise traffic control, to respond to incidents, and to make informed decisions.
2. **Inclusive Planning**: Plan transport systems that cater to the needs of the marginalised populations and groups including those who live in the low-income and informal settlements. These are the extension of transport systems and networks to the underserved areas, fare subsidies, physical accessibility of people with disabilities, and the introduction of last-mile connectivity services. Inclusive planning also involves active participation of the representatives of the community in the process of policy-making
3. **Green Transition Targets**: Have well defined and measurable targets that can be used to lead the transition towards sustainable transport. This entails defining quantifiable targets to be achieved within the electric vehicle adoption, the reduction of carbon emissions by the transport sector, and the growth of the proportion of public and non-motorised transport. These goals must be time-based, reviewed on a regular basis, and incorporated with the wider climate and air quality goal of Delhi.
4. **Stakeholder Involvement**: Increase the stakeholder involvement in the process of planning and implementation. This is by establishing institutionalised forms of partnership among government agencies, partners in

the private sector, civil society organisations and the local communities. Infrastructure investment, service delivery, and innovation of mobility solutions may be exploited by means of public-private partnerships. Open stakeholder consultation will increase trust and transparency.

Mechanisms of monitoring: Establish effective mechanisms of performance monitoring and evaluation. All the significant elements of the plan should have key performance indicators (KPIs) that should be measured by data collection protocols and yearly progress reports. Objective assessment of the process might be provided by independent third-party reviews and facilitate corrections made during the course. Transparency and citizen control can be increased with the help of a public dashboard or digital platform.

5.10 Conclusions

This study was a systematic evaluation of different transportation systems that regulate the urban mobility in the city of Delhi through a systematic evaluation procedure that was in accordance with the Sustainable Development Goals (SDGs). The study was able to determine the relative strengths and weaknesses of each of the frameworks by analysing the expert responses obtained using a Likert-scale questionnaire through sustainability criteria.

The comparison made it possible to conclude that the Delhi Master Plan 2041 is the most sustainability-conscious plan out of the discussed ones. Its advantages are that it is integrated in terms of multimodality, is dedicated to green mobility, encourages non-motorised mode of transport and is also concerned with inclusivity. Nevertheless, there are still serious issues, especially related to the successful implementation, application of intelligent technologies, integration of informal sectors, and strong stakeholder involvement.

Each of these gaps was resolved by providing a series of specific recommendations in the study, which include the implementation of smart mobility solutions, development of quantifiable green transition goals, and the establishment of participatory and third-party systems of monitoring. These additions are expected to make the Delhi Master Plan 2041 a vision into a plan that can be executed successfully and be a strong roadmap towards sustainable urban mobility.

Finally, when implemented, the recommendations have the potential to greatly enhance the direction of the city aiming at equitable access, fewer emissions, and urban resilience in the long term, which would take the city further in addressing its local development goals and its UN SDGs commitments.

CHAPTER-6

TO MODIFY THE EXISTING FRAMEWORK FOR AN EFFICIENT, SUSTAINABLE TRANSPORT SYSTEM.

6.1 Introduction

The development of sustainable urban transport policies has been increasingly viewed as no longer the aspirational vision document but rather the data-driven framework that is in line with the United Nations Sustainable Development Goals (SDGs). Here, the previous stage in the study would constitute a systematic SDG-based professional assessment of the sustainability performance of fourteen national and international transportation planning systems concerning their relative performance on the five dimensions of the 5Ps: People, Planet, Prosperity, Peace, and Partnership. The findings of this appraisal determined Master Plan Delhi 2041 (MPD-2041) as the most holistic and sustainability-matched plan of all the reviewed. Nevertheless, with a relative strength, the analysis showed that MPD-2041 has various structural and operational constraints that limit its capacity to produce an effective, inclusive, and implementable sustainable transport system to help Delhi.

Under the expert-based evaluation, it was pointed out that just as MPD-2041 is revealing of a great policy intent and adherence to long-term urban development objectives, it is largely normative in nature. The main gaps could be seen in the fields of governance integration, institutional coordination, monitoring mechanisms, inclusivity, data-driven decision-making, and accountability structures. Specifically, worse mean scores and weak-percentage agreement was registered in Peace dimensions (governance) and Partnership which showed fragmented institutional arrangements, low stakeholders participation and lack of performance indications that could be measured. These loopholes are indicative that the current structure lacks the operative level of the structure needed to provide a policy directive with quantifiable on-ground mandates.

To respond to these findings, one of the third research objectives in the present chapter is to update the current transportation structure towards an effective Sustainable Transport System. Instead of introducing completely new structure, this study uses a framework of modification this approach acknowledges that MPD-2041 is a solid policy framework and consolidates the weak points of the policy systematically. This would maintain policy continuation, institutional viability, and relevance to context, which is essential in large metropolitan areas like the Delhi area that has a complicated governance system and resource scarcity.

Modes of sustainable transport Modified Sustainable Transport Framework (MSTF), which is the result of an extensive, evidence-based procedure, combining quantitative expert scores, percentage agreement thresholds, qualitative expert feedback, and comparative information on global best practises. An effective change rationality

informs the change process and links-up the identified gaps with identified functional requirements, strategic interventions and quantifiable Key Performance Indicators (KPIs). This will make sure that the proposed framework is not solely an abstract creation, but it is also operationally viable and can be used to monitor and evaluate.

The important contribution in this chapter is that MPD-2041 has now been re-organised into five functionally connected layers as Policy Integration, Infrastructure, Technology and Data, Sustainability and Inclusivity, and Governance and Institutional Mechanisms. It has this layered structure to lead to clarity, policy fragmentation reduction and scalability and replication in varied urban settings. The MSTF closes the gap that exists between the theory of transport planning and practical implementation, by integrating performance measures, mechanisms of accountability, and data systems into the system.

In general, this chapter is a major turning point in the thesis, as it moves towards a diagnosis appraisal to the solution-driven paradigm formulation. MSTF is a structured, measurable, governance-sensitive model of the planning of sustainable transport, which is the foundation of being validated subsequently by case studies and a system of assistive decision support, created in further chapters.

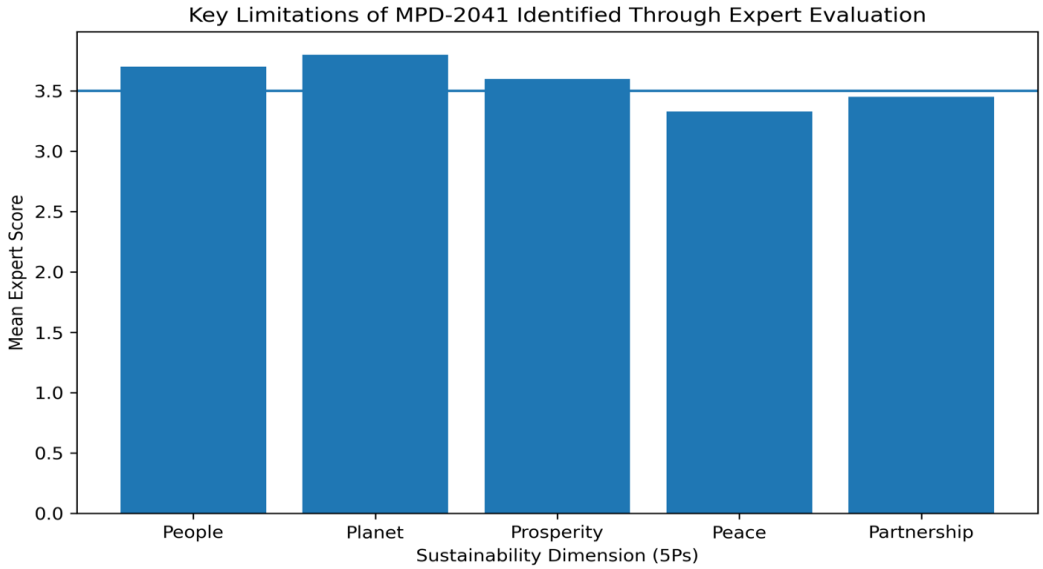

Figure 6.23: Mean expert scores of MPD-2041 across the five sustainability dimensions (5Ps).

Dimension (5Ps)	Identified Weakness	Evidence Type
People	Limited accessibility metrics and affordability planning	Mean score slightly above threshold
Planet	Lack of quantified transport CO_2 reduction targets	Qualitative expert feedback

Prosperity	Absence of innovation roadmap and value-capture mechanisms	Mean score near threshold
Peace	Fragmented governance and lack of performance monitoring	Mean = 3.33
Partnership	Weak citizen participation and unclear PPP frameworks	Mean = 3.45

Table 6.24 Key Limitations of MPD-2041 Based on Expert Evaluation

6.2 Rationale for Modifying MPD-2041

City transport master plans are very important in defining the long-term mobility outcomes, but the vision in policy alone does not determine the success of this type of planning; other factors that determine success are governance capacity, mechanism to implement, and performance evaluation systems. Despite being a progressive movement towards the vision of urban development based on sustainability, the results of the SDG-based expert review show that with its current shape, the framework is already inadequate in coping with the mobility complexities and dynamism of achieving the vision of Delhi. The argument supporting the relevance to change MPD-2041 is thus based on a combination of quantitative and qualitative expert knowledge and benchmarking to the world best practise.

Quantitatively, the professional analysis formulated an unbalanced result in five aspects in regard to the sustainability of People, Planet, Prosperity, Peace, and Partnership. Although MPD-2041 showed quite a performance concerning the provision of infrastructure and environmental intent, there were lower mean scores in the dimensions of governance (Peace and Partnership). Introduction of mean values that are less than the predetermined acceptability threshold and percentage agreement of less than 60 percent are signs of weak consensus between the experts on institutional coordination, stakeholder involvement, and accountability tools. These outcomes are indicative of the fact that the framework has not been designed with structural strength to enable its efficient inter-agency acumen and a long-run policy execution, especially within a mega city with overlapping administrative systems and multiple transport agencies.

Quantitative results were supported by qualitative feedbacks on the part of experts. The lack of quantifiable and time-specific goals in the MPD-2041 was noted multiple times by respondents, and it is hard to evaluate any progress or hold the implementing agencies accountable. Lack of a cohesive mobility governance structure was cited as a significant limitation leading to fragmentation in making decisions across the transport sector, land use, environment and energy sector. Weak monitoring and evaluation systems, insufficient integration of real time data systems and insufficient inclusive planning was also identified as factors earmarked by experts, especially on gender safety, affordability, and accessibility of vulnerable user groups. Such observations indicate that even with the good policy intention, MPD-2041 is more normative and declarative as opposed to operational and performance-oriented.

Along with expert-based evidence, the necessity to change is further supported by the practical benchmarking with different sustainable transport frameworks in other countries. Best practises in the world are showing a social migration towards integrated, data-enabled and governance-based model of mobility. The successful cities in terms of approach to sustainable transport have integrated the institutional requirements, data-driven performance measures, digital data tools, and engagement tools in their urban plans. By contrast, MPD-2041 shows very little conformity to such new paradigms of contemporary planning, especially in the way it views the logic of implementation, cross-sectoral coordination, and adaptive management. This disconnect between international practise and local planning might explain why there is a need of a systematic framework change instead of small policy modifications.

Notably, the rationale with regard to keeping the MPD-2041 intact instead of swapping it with a new document relies on the aspects of policy continuity, institutional viability, and topicality. The MPD-2041 offers a politically supported and legally recognised basis of urban development in delhi. The lack of this structure would jeopardise the continuity of policies and their resistance to implementation. Rather, the modification based approach allows it to sustain its strategic vision, but do it in a systematic manner as weaknesses are detected. This methodology is consistent with the modern theory of planning which means the development of adaptive and iterative frameworks rather than their total substitution especially in complex urban systems.

The change process is thus aimed at enhancing MPD-2041 by inculcating operational clarity, accountability and measurability in its prevailing structure. The Modified Sustainable Transport Framework (MSTF) aims at bridging the long-standing gap between policy formulation and implementation by translating gaps that were identified into functional requirements and connecting them to the targeted interventions and Key Performance Indicators (KPIs). This change makes sure that the goals that sustainability should achieve are not merely outlined but are also measured, addressed, and implemented by the institutions.

To conclude, the empirical evidence and pragmatism in planning underpins the rationale why MPD-2041 needs to be altered. The existence of quantitative performance failures, recurrent qualitative expert issues, and lack of alignment with the international best practises all symbolise that MPD-2041, as a strategic tool, should be systematically improved to become an efficient sustainable transport framework. Development of the MSTF is therefore an evidence-based and necessary development of the already existing plan such that it is able to achieve the desired inclusive, low-carbon, and well-governed mobility impacts on Delhi.

Evidence Source	Key Findings	Implication for Modification
Quantitative expert scores	Low mean values in Peace & Partnership	Governance restructuring needed
Percentage agreement	< 60% consensus	Weak institutional clarity
Qualitative feedback	Lack of KPIs, weak monitoring	Need for performance-based framework
Global benchmarking	Strong governance & data integration elsewhere	Alignment with best practices

Table 6.9 Evidence-Based Justification for Modifying MPD-2041

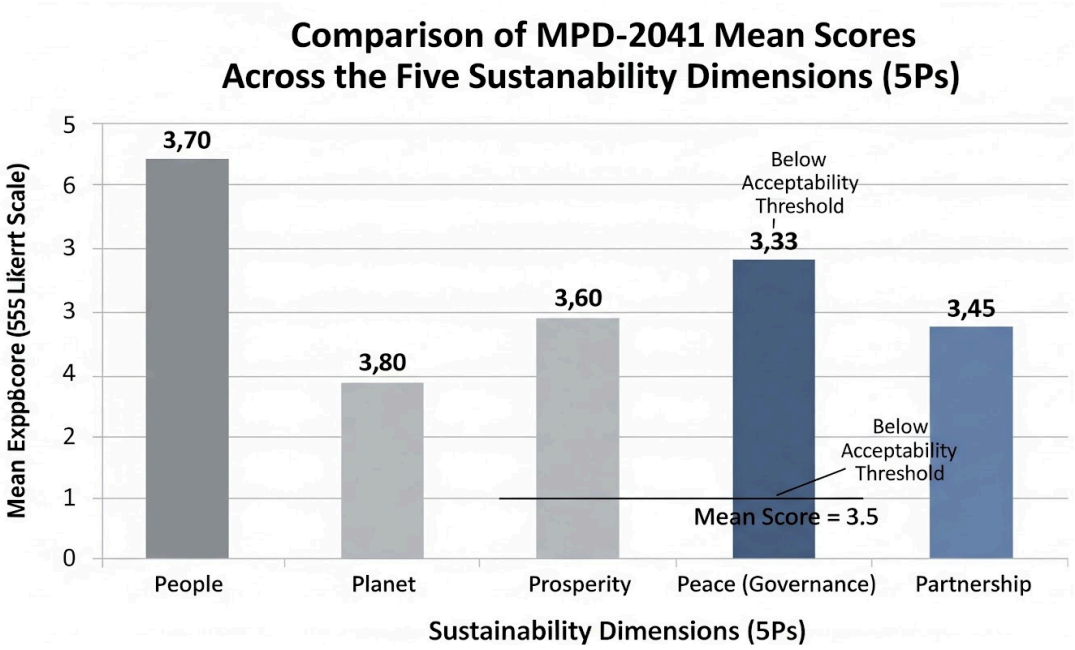

Figure 6.2 Mean of the 5 Ps of Expert Evaluation

6.3 Gap Identification Methodology.

The redesign of an already existing urban transport system must incorporate a stringent and open-minded approach in order to be able to render suggested changes factual, focused, and justified. The gap identification methodology applied in this study was systematised to identify the weaknesses of Master Plan Delhi 2041 (MPD-2041) in a systematic manner and to give a strong base to transform it into a more viable concept the Modified Sustainable Transport Framework (MSTF). The methodology by combining quantitative measures of expert assessment and quantitative measures of expert evaluation and documentary analysis, it provides triangulation of the methods, and reliability of the analysed.

The gap identification process was pegged on SDG-aligned framework of 5p-People, Planet, Prosperity, Peace, and Partnership as the evaluative lens used in the process of assessing the sustainability performance of MPD-2041. The indicators under each dimension have been developed and validated using literature review and alignment to United Nations SDG targets, and also expert consultation. They were then rated by domain experts using a Likert-scale structured questionnaire, which produced numerical values as well as qualitative information. In this assessment, section 6.3 goes further to synthesise the performance findings into measurably stated gaps that require a change in frameworks.

6.3.1 Gap Identification Criteria

In order to achieve objectivity and methodological rigour clear cut threshold criteria were set to describe an indicator as a critical gap. It was decided that an indicator was a gap in case it met one or more of the following conditions:

1. **Low Mean Score**: The variables whose mean score was less than 3.5 (five-point Likert scale) were assumed to be performing poorly, meaning they were not aligned with sustainability objectives.
2. **Weak Percentage Agreement**: Indicators with agreement less than 60 percent in high Likert scale (score 4 or 5) were considered to lack an expert support, and this is a sign of ambiguity or a weak implementation mechanism.
3. **Unanimous Qualitative Issue**: Indicators that were called out consistently by experts based on open-ended answers as either problematic, undefined, or inoperative was identified as gaps despite marginally acceptable quantitative scores.
4. **Policy-Implementation Disconnect** Indicators that were not contained in policy language but had no measurable targets, implementation pathways, or monitoring provisions were seen as functional gaps.

The above criteria made sure that gap identification was not only score oriented, but also sensitive to contextual and operational weaknesses. The combination of expertise and numerical thresholds helped the methodology to prevent both overgeneralization and subjectivity..

6.3.2 Consolidation and Classification of Gaps

When individual gaps were not found at the indicator level, they were summarised into general functional areas in order to design strategic interventions. The step required synthesising overlapping problems between a variety of indicators and interpolating them onto thematic areas that included policy integration, an infrastructural continuity, technology and data systems, sustainability planning, government structures, and stakeholder engagement.

As an example, various indicators with regard to fragmented land-use and transport planning, incoherent Transit-Oriented Development (TOD) norms and absence of climate-aligned targets were all clustered under a larger policy integration gap. In the

same vein, the low scores connected to non-motorised transport (NMT) continuity, last-mile connectivity, and bus priority infrastructure were combined under infrastructure-related gaps. Indicators linked to inter-agency coordination, the lack of performance monitoring, lack of clarity concerning public-private partnership (PPP), and poor citizen engagement processes became a potent source of governance and participation gaps.

This process of consolidation played a vital role in reorienting the analysis of single weaknesses into the circumstances of deficiencies on a broader systemic basis, and thus provided a framework-level change instead of a piece meal of corrections of policies.

6.3.3 Validation of Identified Gaps

The defined gaps were cross-verified by examining documents to increase the validity of the results, comparing MPD-2041 and other sectoral policies, such as Comprehensive Mobility Plans, EV policies, and Non-Motorised Transport guidelines. The move was done to ensure that loopholes that were pointed out by the experts were really representative of what was missing or a shortcoming in the planning papers and not necessarily a perception thing. That was further reinforced by the convergence between the expert assessment and the policy analysis which enhanced the reliability of the gap identification process.

The validated gaps would then be reinterpreted as functional requirements which constituted the solution development analysis bridge between the diagnosis and solution development. Every functional requirement had a direct influence on designing strategic interventions and forming measurable Key Performance Indicators (KPIs) later in the chapter. This organised movement guaranteed the ability to trace the empirical evidence to the change of the framework, which is essential to the credibility of doctoral research.

6.3.4 Role of Gap Identification in Framework Modification

The MSTF development relies on the gap identification methodology. The methodology has adequately explained the reasons why and where MPD-2041 performs poorly hence the need to restructure the framework into five functional layers. Furthermore, it will see to it that every suggested intervention within the revised model aligns with an empirically identified deficiency. Consequently, the MSTF is not presented as a form of conceptual perfection but as a process of improvement as a data-driven supplement to an already existing statutory plan.

Altogether, the gap identification methodology presents a clear, repeatable, and evidence-based system to identify the putrefaction of the weaknesses in MPD-2041. It allows generating a gradual shift in the assessment to the intervention and assures that the offered change in the framework is analytically correct and practically responsible to sustainable urban traffic planning.

Criterion	Threshold	Evidence Source	Interpretation
Mean score	< 3.5	Expert survey	Performance weakness
% agreement	< 60%	Expert survey	Lack of consensus
Qualitative feedback	Recurrent concern	Open-ended responses	Operational gap
Policy review	No targets / KPIs	Document analysis	Implementation gap

Table 6.10 Gap Identification Criteria and Evidence Sources

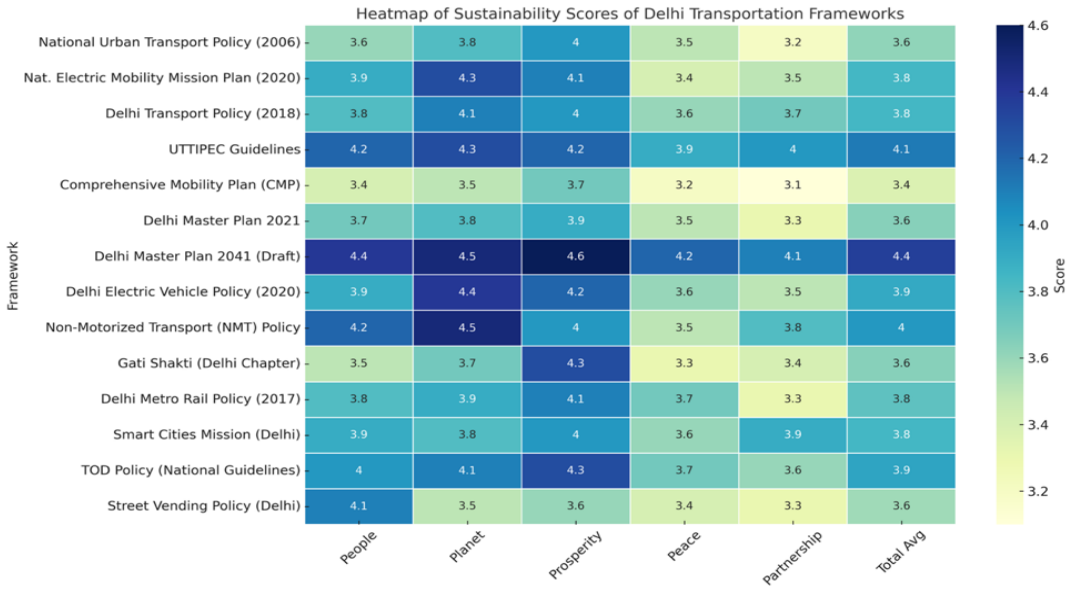

Figure 6.25 Head Map of the Expert review and findings

6.4. Gap Identification Criteria

Determining gaps in an already established transport planning system must involve objective, clear and repeatable criteria to eliminate subjective decisions. In the study, clear gap identification guidelines were developed to evaluate the performance of Master Plan Delhi 2041 (MPD-2041) specifically and make sure that only substantively weak or operationally inadequate elements were addressed in the study. These criteria were built in a way that quantitative performance measures are combined with qualitative expert and policy review outcomes and hence guarantee methodological rigor and triangulation.

The main reason behind the existence of a gap was quantitative underperformance, which was measured using expert evaluation scores. Those indicators whose mean score is lower than 3.5 on the five-point Likert scale were included in the weak category. The decision to fix this threshold to below an acceptable sustainability threshold was to indicate that the policy provisions in place were either inadequate,

vague, or did not relate well to the SDG-oriented transport planning purposes. Mean scores are a strong way of central tendency and could be compared between indicators and sustainability dimensions in a systematic way.

The second criterion was the analysis of percentage agreement that describes experts consensus degree. Those indicators, whose score received values of 4 or 5 by less than 60 percent of the respondents, were taken to be insufficiently agreed upon by experts. Low agreement level means that it is ambiguous, there is inconsistent interpretation and the policy is not sure if it is effective and implementable or not. This criterion was especially significant to determine the gap in governance and partnership-related areas, where institutional fragmentation can lead to a variety of expert views.

Besides numerical limits, expert feedback in a qualitative sense was also used as a critical gap identification criterion. Unstructured feedback of the experts was examined to come up with frequent issues pertaining to feasibility, inclusivity, monitoring, accountability, and the availability of data. The markers that were reumbly raised by the professionals as problematic were distinguished as gaps even where quantitative scores were slightly surpassing threshold levels. This had made sure that contextual and operational realities are captured as opposed to numerical aggregation which reinforced the validity of the gap identification process.

Another criterion was the policy implementation disconnect, which was determined by analyzing the documents related to MPD-2041 and other related sectoral policies. Gaps were considered indicators when present at a policy-intent level alone but without any measurable targets, defined implementation mechanisms, accountable agencies or provisions of monitoring. These gaps are important especially in the context of large metropolitan settings in which the lack of operational clarity may result in slow or ineffective execution in cases where the policy has been articulated effectively.

The integration of these requirements made gap identification to be selective and evidence-based. Instead of changing the framework randomly, the methodology focused on the indicators that showed the uniform weakness of several evidence sources. This helped to minimize chances of over-modification and the next framework development was based on high impact areas that needed structural intervention.

In general, the gap identification criteria that have been developed in this study offer a clear and replicable methodological basis of changing the framework. The criteria combine quantitative thresholds, expert consensus analysis, qualitative information, and policy analysis so that the Modified Sustainable Transport Framework (MSTF) will be a direct response to the empirically validated gaps in MPD-2041 and make it a more effective tool.

Criterion Type	Threshold/ Condition	Data Source	Purpose
Mean score	< 3.5	Expert survey	Identify underperforming indicators
Percentage agreement	< 60% (scores 4–5)	Expert survey	Assess weak expert consensus
Qualitative feedback	Recurrent concern	Open-ended responses	Capture operational issues
Policy review	No targets / KPIs	MPD-2041 documents	Identify implementation gaps

Table 6.11 Gap Identification Criteria and Thresholds

6.5 Summary of Identified Gaps in MPD-2041

After using the gap identification criteria defined in Section 6.3.1, there was an assessment of the Master Plan Delhi 2041 (MPD-2041) which identified a list of critical gaps that could be used to reduce its efficacy as an operational sustainable transport framework. These loopholes were found in various aspects of sustainability and are systemic in nature and not policy failures. The summary and pooling of these gaps is an important stage of analysis, since it will convert the deficiencies of the indicators into actionable categories to be used to change the framework.

At policy level, an obvious loophole was to be found through disjointed integration of transport, land-use, environmental and energy planning. In spite of the recognition of the significance of comprehensive planning, the feedback of the experts and review of documents revealed that there was a low level of correspondence between Comprehensive Mobility Plans, Transit-Oriented Development (TOD) standards, electric vehicles policies, and climate action goals. Lack of harmonised standards and common policy orientation has led to differences in corridor development, allocation of densities and prioritisation of sustainability. It is this fragmentation that sabotages the plan in its capacity to provide coherent and coordinated mobility outcomes.

Regarding infrastructure, analysts always pointed at the lack of capacity concerning last-mile connectivity and the consistency of the non-motorised transport networks. The fact that the means scores in relation to NMT integration are less than the acceptable level shows that the walking and cycling infrastructure is not viewed as a primary aspect of the transport system but rather as an additional one. Disparities in the prioritisation of the infrastructure of the public transport were also identified, especially the bus lanes and multimodal interchange facilities. The failures of these undermine the efficacy of high-capacity transit systems and deter modal substitution of the personal motorised vehicle.

One of the most important gaps in MPD-2041 was highlighted in the technology and data dimension. Professional analysis showed that there were no real time data systems, integrated transport databases and intelligent transport systems (ITS) to assist in evidence based planning and operation management. The lack of a single data

architecture constrained the planning agencies to monitor system performance, manage the system congestion dynamically and evaluate the environmental impacts of the system including emissions and air quality. Also, disunited ticketing and passenger information systems limit the creation of smooth multimodal travel experiences.

In sustainability terms, MPD-2041 was observed to have no quantified environmental goals, especially on how carbon dioxide emissions with regard to transport would be. Although the plan provides the general aim of the environmental objectives, it fails to state the measurable reduction pathways and schedules as well as monitoring mechanisms. The experts further observed a lack of focus on climate resiliency in the design of transport infrastructure such as heat stress, floods, and other severe weather conditions. The gaps decrease the ability of the framework to be consistent with the long-term climate commitments and resilience goals.

The governance dimension also experienced vast weaknesses and obtained some of the lowest mean scores of all the 5ps. Mill is in charge of the transport related duties in MPD-2041 and there is no clear coordinating body. This multi agency disintegration leads to overlapping mandates, slow decision making and poor accountability. The lack of formal performance measures, frequent audits and systems of monitoring that are publicly available worsen the inefficiencies of governance and constrain institutional learning even further.

Lastly, the lack of gaps in the aspect of participation and partnerships could be seen through the weak mechanisms of citizen engagement, data disclosure and collaboration between the public and the private. The feedback provided by experts revealed that the stakeholder involvement in the processes of planning and monitoring is quite consultative, but not institutionalised. There are also ambiguous public-privacy partnership (PPP) arrangements which limit the aspects of private investment and innovation towards sustainable mobility solutions. Such deficiencies limit the inclusiveness, transparency and financial viability of the transport system.

The combination of all these gaps highlights that MPD-2041 may be strategically progressive but lacks operational coherence which could make it effective. This section gives an organised evidence base of reclassifying gaps into functional categories by summarising these deficiencies on policy, infrastructure, technology, sustainability, governance, and participation domains. This consolidation is what directly undergoes reorganisation of the framework into five functional layers later parts so that the Modified Sustainable Transport Framework (MSTF) addresses accurately the weaknesses that have been empirically proven.

Dimension	Identified Gap	Evidence Source	Implication
Policy	Fragmented land-use–transport integration	Expert feedback + document review	Need for unified policy framework
Infrastructure	Weak NMT and last-mile continuity	Mean score < 3.7	Reduced multimodal efficiency
Technology	Absence of real-time data systems	% agreement < 55%	Limited evidence-based planning
Sustainability	No quantified CO_2 targets	Qualitative feedback	Weak climate accountability
Governance	Multi-agency fragmentation	Mean score ≈ 3.3	Low institutional efficiency
Participation	Limited citizen & PPP engagement	Mean score < 3.5	Weak inclusivity & financing

Table 6.12 Summary of Identified Gaps in MPD-2041

6.6 Framework Modification

To convert an existing transport master plan into an operationally-functioning sustainable transport structure, clear articulation of the logic of modification is needed that warrants traceability between presented weaknesses and suggested interventions. The change in Master Plan Delhi 2041 (MPD-2041) adopted in this study is based on a systematic and logical approach that converts the identified gaps that arise empirically into practical and quantifiable elements of planning. This reasoning is articulated in the four step transformation process: Identified Gap - Functional Requirement - Strategic Intervention - Key Performance Indicator (KPI). The rational adopted makes certain the Modified Sustainable Transport Framework (MSTF) would be evidence-based, practical, and performance-based.

The initial phase of the logic commences using the gaps identified which are investigated based on the knowledge of the experts, percentage agreement analysis, qualitative feedback and policy review outlined in Section 6.3.1 and 6.3.2. These gaps are areas where MPD-2041 is performing poorly, not clearly, or where there is not enough consensus or there are no operational mechanisms involved. Notably, the gaps are not viewed as specific setbacks but as the signs of more critical system inefficiencies within the current framework, which include poor integration of data or inadequate inclusivity frameworks.

The second process will include transforming these gaps into functional requirements. Functional requirements determine what the transport system should be able to perform so as to solve the identified shortcomings. Indicatively, a governance gap which is exhibited by multi agency fragmentation is translated into the need to co-ordinate and be accountable as an institution. Equally, lack of real-time data systems is repositioned as a need to have whole-data collection, analysis, and decision-support facilities. It is an important step because it puts the analysis focus away on the identification of the problem, to the functionality of the system, that establishes a gap between the diagnosis process and the solution design.

At the third phase, strategic interventions are developed to meet the functional requirements identified. These interventions are tangible planning, institutional, technological or regulatory measures that may be applied in the Delhi situation. These can be the creation of a single urban mobility authority, the creation of a mobility data lake, the creation of standardisation in Transit-Oriented Development (TOD) norms, or even the implementation of intelligent transport systems (ITS). Each of the interventions is aimed to be context-sensitive, scalable and consistent with the principles of sustainability engrained in 5P SDG-based framework.

The last phase of the modification logic is to set the Key Performance Indicators (KPIs) that will match each of the strategic interventions. Take into account KPIs KPIs make sustainability goals practical by monitoring, assessing, and being accountable. Contrary to the qualitative policy statements, KPIs give some form of measurement like percentages of reduction of emissions, percentage targets on modal shares, network instances, compliance percentage or service reliability indicators. The presence of KPIs will guarantee that the changed framework does not remain on intent and vision, but it facilitates a systematic analysis of the outcomes of the implementation process, within a period.

One major characteristic of this modification logic of the frameworks is that it is a two-way traceable model. Instead, every KPI can be tracked to a certain intervention, functional need, and the gap that has been identified, which guarantees the transparency and the consistency of the methods. On the other hand, each of the gaps recognised is covered by at least one specific intervention and measurement. The same traceability makes the MSTF internal validity and it is better suited in other urban settings through replication.

Also, the modification logic is clearly consistent with the five dimensions of sustainability (5ps) People, Planet, Prosperity, Peace, and Partnership. Discoveries made in each of the dimensions guide the respective functional requirements and interventions to create an even distribution of focus on social equity, environmental responsibility, economic viability, governance effectiveness, and stakeholder collaboration. Such alignment eliminates over-prioritisation of infrastructure or environmental objectives at the detriment of governance and inclusivity which is a general shortcoming of the traditional transport planning models.

In general, the logic of framework modification gives a logical methodological foundation on how MPD-2041 can be reorganised into the MSTF. Through a systematic correlation between empirical data and the functional structure and quantifiable outcomes, the logic will make sure that the proposed framework is well-founded, in terms of theory, as well as operationally sound. It allows the MSTF to be used as a viable planning and monitoring tool that can help drive the transformation of Delhi to an efficient, inclusive, and sustainable urban transport system.

6.7 Reorganisation into Five Functional Layers

A framework structure is not just needed to ensure the effective implementation of sustainable transport policies but it must be comprehensive and rationally structured, operationally precise and institutionally feasible. Substantially policy-focused structure of the Master Plan Delhi 2041 (MPD-2041) with strategic intentions expressed but no adequate divide between policy development, infrastructure provision, technological facilitation, sustainability protection and governance systems is also one of the major limitations discovered there. To mitigate the weakness, the Modified Sustainable Transport Framework (MSTF) streamlines MPD-2041 to five functional layers interrelated. This re-structuring is a strategic transition between a vision-driven planning document to a systems-grounded implementation structure.

In the layered approach, there is clear division of roles and responsibilities without loss of interconnections between the strategic sets and operational activities. Each layer has number of functional domains of the urban transport system and overall makes sure that sustainability goals are incorporated through policy, physical systems, digital infrastructure, social equity, and institutional governance. Notably, this reorganisation does not abandon the main principles of MPD-2041 but reforms them into the format that is more straightforward and accountable and reliable.

The Policy Integration Layer is the core of the MSTF and is established in order to end fragmentation between the land use, transport, environmental and energy policies. These policy areas are handled simultaneously in MPD-2041 and can generate multiple differences in standards and conflict of priorities frequently. The MSTF helps to achieve the coherence of such objectives as Transit-Oriented Development, climate mitigation, and accessibility by uniting them and making them one functional layer. This layer sets the same policy drivers and sets the enabling environment of synchronized planning and execution in sectors.

The Infrastructure Layer builds on the policy base and addresses the physical aspects of transport system, such as public transport system, non-motorised transport system, multimodal centre and climate-resilient street. This layer responds to the gaps identified regarding the in-between networks, the lack of robust last-mile connectivity, and the lack of the prioritisation of the public transport. The MSTF will guarantee that the physical investments are directly linked with policy goals through isolating infrastructure as a separate functional layer and assess the performance using quantifiable metrics like network coverage, service reliability, and modal integration.

Technology Layer and Data Layer is an important upgrade to MPD-2041, and does not have an entire digital planning and monitoring architecture. This layer combines smart transport, the creation of real-time data collection, single ticketing platforms, and mobility analytics into the architecture. The direct mentioning of technology and data as a separate layer is evidence of the increased significance of evidence-based decision-making in urban transportation planning. It is also used to offer the structural

foundation upon which the assistive decision-support system is built in further chapters of the thesis.

The Sustainability and Inclusivity Layer also makes environmental responsibility and social equity not the side byproducts of the transport system functionality but its principal undertakings. The level brings together solutions concerning emissions reduction, climate resilience, universal accessibility, gender safety, and affordability. Combining these components with each other, the MSTF guarantees that objectives regarding sustainability are coordinately encompassed in the architectural thought, service delivery, and performance assessment, instead of being sought out of policy formulations individually.

Lastly, the Governance and Institutional Layer tackles one of the most important weaknesses of MPD-2041 namely fragmented institutional arrangements and poor accountability mechanisms. This layer establishes governance frameworks, coordinating systems, performance management systems and model of partnerships. The MSTF acknowledges that the ability to achieve sustainable transport results hinges on the ability of governance to establish capacity and coordination, as much as it does on physical or technological investments, by specifically using governance as a functional layer.

The five-layer reorganisation, in aggregate, bolsters the internal connectivity of the transport structure and puts up definite vertical and horizontal connexions amongst the policy intent, and implementation outcome. Every layer is related to a set of interventions and Key Performance Indicators, which makes that layer traceable and accountable. This multi-layered design also enhances the scalability and replicability of the framework which means that this framework can be scaled to match other metropolitan settings without the loss of the underlying logic behind its sustainability. Accordingly, one of the main methodological contributions of the study is the restructuring of the concept of five functional layers, which will convert MPD-2041 into an operationally sound and sustainability-focused planning structure.

Layer	Primary Focus	Key Functions	Output
Policy Integration	Strategic coherence	Unified policies, standards	Aligned planning
Infrastructure	Physical systems	PT, NMT, multimodal hubs	Network efficiency
Technology & Data	Digital enablement	ITS, MaaS, analytics	Evidence-based decisions
Sustainability & Inclusivity	Equity & environment	Low-carbon, accessibility	Inclusive mobility
Governance & Institutional	Coordination & accountability	KPIs, audits, PPPs	Effective implementation

Table 6.13 Functional Layers of the Modified Sustainable Transport Framework

6.7.1 Layer 1: Policy Integration Layer

The Policy Integration Layer is the main element of the Modified Sustainable Transport Framework (MSTF), because it makes the strategic coherence needed to facilitate successful and joint planning of transport. The skilled assessment of the Master Plan Delhi 2041(MPD-2041) identified that although several transport related measures are in place, they seem to work in silos and therefore lack integrated planning efforts. There is no overall way of operation, with transport, land use, environment, energy and climate policies being expressed through distinct pieces of documents covering Comprehensive Mobility Plans, Transit-Oriented Development guidelines, electric vehicle policies and non-motorised transport strategies. This disintegration compromises the realisation of the aim of sustainable mobility and a requirement of forming an integrated policy layer.

The main aim of the Policy Integration Layer is to reconcile all the transport-relevant policies to a mutually overall beneficial system. This layer does not provide new policy instruments, but rather reorganises the policy provisions that are in place and integrates them into one coherent policy code that displays the spatial development objectives, mobility planning, and sustainability objectives. This integration is of paramount importance especially in a globalised setting such as in Delhi where transport performance is directly dependent on land-use density and mixed-use development and energy transitions.

Among the main gaps that were found in MPD-2041 is associated with the inconsistencies in Transit-Oriented Development (TOD) standards in various corridors and planning jurisdictions. Despite its positioning as a key strategy, differences in density thresholds, floor area ratios and areas of access make TOD less efficient in stimulating the use of a public transport. This gap is filled by the Policy Integration Layer which standardises TOD-mobility parameters throughout the city by ensuring that land-use intensity, accessibility of public transport or non-motorised connectivity has been planned as a system, rather than discrete parts.

The other important role played by this layer is the incorporation of climate and environmental goals into transport policy. The analysis has shown that MPD-2041 does not have a well-structured transport-specific reduction of carbon pathway. Environmental objectives are expressed in the general terms without specific numbers and periods of achievement. Policy Integration Layer thus initiates city-wide transport emission profile cuts, comparable to their ad-hoc climate action dedications. This guarantees that the transport policies are directly attached to the goals of climate mitigation and can be measured by observing its indicators.

This layer also has the centre of inclusivity and access. Professional advice has given an indication that the universal accessibility provisions are still in many cases only advisory but not binding under the current policies. The Policy Integration Layer entails embedding the accessibility needs within the policy approvals where policies that are made concerning persons with disabilities, older users, women, and children

are present throughout all the transport and land-use policies. In such a way, inclusivity becomes not the visualized desire but a policy requirement.

Operational wise, the Policy Integration Layer provides the foundation of downstream implementation of infrastructure and technology, sustainability, and governance layers. It offers one policy direction; this minimises inter-departmental conflict, increases coordination and the predictability of implementation outcomes. Moreover, the inclusion of quantifiable variables, like indices of coherence in policy, the rates of TOD compliance, the emission reduction targets, etc., makes sure that policy integration could become a quantifiable matter rather than an abstract one.

Ideally, the Policy Integration Layer is that which streamlines MPD-2041 into a unified strategic implementation. It establishes the facilitating environment to have integrated decision-making and make sure that sustainability goals are entrenched in the very top-level of transport planning. Being the baseline of the MSTF, it must be significant in balancing the vision with action and creating a stable platform at which the next functional layers may be laid.

6.7.2 Layer 3: Technology & Data Layer

The Technology and Data Layer is a key step in the Modified Sustainable Transport Framework (MSTF): it is a solution to one of the most notable gaps that have been found in Master Plan Delhi 2041 (MPD-2041): the lack of a unified, data-driven decision-making ecosystem. The modern sustainable transport planning is more and more based on digital tools, real-time measurements, and analytics to control the intricate urban movement system. Nevertheless, professional analysis showed that MPD-2041 does not have a coherent transport data architecture, process-based control of performance, and intelligent transport systems (ITS) that can help in evidence-based planning and operational optimisation.

The core task of the Technology and Data Layer is to provide the opportunity to monitor in real time, analyse and make informed decisions in all parts of the transport system. This layer forms the foundation of digital infrastructure of the MSTF, as the whole policy, infrastructural investment and sustainability interventions are constantly sustained with trusted and practical data. The MSTF identifies digital infrastructure as a necessary enabling factor of sustainable mobility and not a secondary element by formalising technology and data as a separate functional layer.

One of the interventions at this layer is the creation of a Mobility Data Lake, which is meant to replace data on transport-related activities held by various agencies and sources into a single platform that is interoperable. As of today, various institutions gather data with incompatible formats regarding its relation to traffic flows, operations of the public transport, emissions, land use, and even safety. Such division disrupts cross-sectoral analysis and the effective process of decision-making. The Mobility Data Lake addresses this issue with regard to integrating datasets obtained by transport

authorities, municipal agencies, enforcement agencies, and environmental monitoring frameworks, which in turn makes it possible to conduct a holistic examination of the system and long-term planning.

Another important element of this layer is the introduction of Intelligent Transport Systems (ITS). Adaptation This is through the ITS applications which can dynamically manage the transport networks such as adaptive traffic signal control, incident detection and public transport prioritisation. According to the experts, the lack of such systems in MPD-2041 limits exercise of the city to respond adequately to congestion, safety hazard, and service breakdowns. The ITS incorporated into the framework allows the MSTF to increase operational efficiency, enhance the reliability of travel time, and help to improve road safety.

Another technology of the Mobility and Data Layer that offers the creation of Mobility-as-a-Service (MaaS) platforms, whereby trip planning, ticketing, and payment are done across several forms of transport. It was found that fragmented fare systems and passenger information services were hindrances to smoother multimodal travel. MaaS systems can help solve these problems by ensuring that people have access to metro, buses, para-transits, and non-motorised services, making them more convenient to use and rewarding them to choose sustainable mode options.

Another important role of this layer is environmental monitoring. The introduction of real-time emissions and air quality sensors allow implementing constant evaluation of the impact of transport on the environment. Rather than using traditional planning methods where periodic surveys or validated models are used to assess the effectiveness of a reduction of emissions, real-time monitoring enables the planner to dynamically change interventions based on their results. This is especially applicable to the city of Delhi where transportation emissions are seen to be a major cause of air quality deterioration and health issues in the population.

The characteristic feature of the Technology and Data Layer is the fact that it is connected to the mechanisms of governance and accountability. Information that is created by digital systems can directly be inputted into performance dashboards and Key Performance Indicators (KPIs), allowing to track the implementation results transparently. The result of this integration is an accountable and not just data-informed decision-making. Moreover, the Technology and Data Layer offers the architecture backbone behind the assistive decision-support system that will be created in the following chapters of this study, and it enhances its strategic value to the MSTF.

To conclude, Technology and Data Layer converts the MSTF into an active, flexible, and learning-focused framework. This layer brings together the information between planning and live activities through the institutionalisation of data integration, intelligent systems, and digital platforms. It also theorises that sustainable transport policies and investments are constantly re-assessed, streamlined and aligned to the changing urban mobility requirements.

6.7.3 Layer 4: Sustainability & Inclusivity Layer

The Sustainability and Inclusiveness Layer of the Modified Sustainable Transport Framework (MSTF) deals with the two imperatives of the environment and social equity both of which form the core of the long-term sustainability of the urban transport system. The professional review of Master Plan Delhi 2041 (MPD-2041) had shown that although sustainability and inclusivity are recognised as the guiding principles, they are not sufficiently operationalised in the given framework. Most environmental ambitions are of a qualitative nature, climate resilience aspects are scattered and measures of inclusivity in terms of accessibility, gender safety, and affordability do not have enforceable mechanisms. Such deficiencies necessitate a functional layer that is committed and imparts sustainability and inclusiveness as quantifiable and obligatory aspects of transport planning.

The first objective of this layer is to make transport development a part of the low-carbon growth, climate resilience, and the provision of equitable access to all user groups. The MSTF does not view environmental and social issues as secondary effects, but it integrates them as fundamental performance dimensions that affect policy formulation and development, infrastructure design, technology implementation, and governance practices.

The encouragement of the low-carbon mobility pathways is a major intervention in this layer. Even though MPD-2041 acknowledges that a reduction of the environmental impacts is necessary, it lacks a clear transport-specific reduction trajectory. The Sustainability and Inclusivity Layer presents defined connections between transport planning and the adoption of renewable energy, especially as an electric mobility that uses clean energy resources. In this way, the electrification strategies will not just be relocating the emissions, but will help in achieving real decarbonisation. Systematic monitoring of progress is made possible by such performance indicators as the proportion of the renewable energy in its transport operation and the decrease in per-capita emissions in transport.

Another dimension of this layer that is of critical importance is climate resilience. The transport infrastructure in Delhi is becoming more susceptible to the heatwave, flooding, and the extreme weather conditions, but the resilience aspect is not sufficiently considered in MPD-2041. The MSTF fills this gap by incorporating measures of climate adaptation in standards of transport planning as well as street design. Such interventions are heat-reducing material, shaded pedestrian space, resistant infrastructure to floods, and resilience to critical transport corridors. The framework improves the reliability of the system in response to the altered climatic conditions by making resilience a planning requirement, as opposed to a follow-up.

The concept of inclusivity is realised via the strong focus on universal access. The feedback provided by experts showed that the accessibility provisions in the current policies are usually advisory, and are not implemented uniformly. The Sustainability

and Inclusivity Layer enforces an inclusive design principle on all transport projects with the provision of barrier-free accessibility to persons with disabilities, elderly users, children, and caregivers. The inclusivity is converted into a planning requirement with the help of systematic audits and compliance indicators of accessibility performance thus making inclusivity a normative concept into an enforceable principle.

Another area of focus would be gender safety and personal security. The analysis has brought out the fact that safety concerns especially to women and other vulnerable users are not well incorporated in the transport planning procedures. The MSTF proposes gender-sensitive compulsory safety audits, better lighting, surveillance integration, and reactive design of any spaces of the public transport. The objectives of such measures are to improve perceived and actual safety which is a very important factor in determining the use of public transport and social inclusion.

Affordability is met by the following mechanisms, which comprise fare capping and pricing integration, which enables the affordable rates of sustainable transport to be affordable and accessible to low and middle-income people. In the absence of such protection, the move toward cleaner and more advanced systems may isolate all the vulnerable populations. The Sustainability and Inclusivity Layer can thus directly associate the measures of affordability to the transport policy and monitoring framework to enhance social sustainability of mobility systems.

All in all, this layer will make sure that environmental sustainability and social inclusiveness are inculcated as non-negotiable conditions in the MSTF. The framework allows the ongoing assessment and responsibility by correlating each intervention with quantifiable Key Performance Indicators (KPIs). Sustainability and Inclusivity Layer, in turn, fortifies the ethical and environmental principles of the modified framework whereby the efficiency gains of the transport system are not achieved at the cost of equity and long-term ecological stability.

6.7.4 Layer 5: Governance & Institutional Layer

The Governance and Institutional Layer forms the facilitating core of the Modified Sustainable Transport Framework (MSTF), responding to the most significant weakness that was found in Master Plan Delhi 2041 (MPD-2041): divisive institutional settings and ineffective accountability structures. Although MPD-2041 has detailed aims of transport and land-use, the multiplicity of agencies, overlapping jurisdictions, minimal coordination policy, and lack of performance and monitoring are limiting factors in its implementation. The professional assessment has always shown that indicators related to governance showed the most low average scores and the lowest level of consensus, which indicates the necessity to introduce a separate functional layer to enhance institutional performance.

The main aim of Governance and Institutional Layer will be to develop the explicit authority, coordinated decision-making, and enforced accountability on the framework of the urban mobility ecosystem. The achievement of sustainable transport does not rely solely on the proper policies and infrastructure investments but also the ability of institutions to be coordinated in planning, implementing, monitoring and subsequent adjustments of interventions. The layer thus actualises governance reforms as a fundamental element of the MSTF and not an administrative periphery issue.

One key intervention that has been suggested in this layer is to have a common urban mobility governing framework, which is conceptualised through the establishment of the Delhi Urban Mobility Authority (DUMA). Lack of one coordinating body in MPD-2041 has led to a split in the duties undertaken in transport, traffic management, municipal services and environmental agencies. DUMA is seen as a coordinating and integrative power instead of another layer of bureaucracy, and it has to deal with the strategic planning alignment, inter-agency coordination, and performance monitoring, as well as decision-making based on data. This intervention can directly deal with institutional fragmentation through centralisation of accountability and improvement of policy coherence.

Another pillar to this layer is performance monitoring and transparency. The MPD-2041 does not have any systemic method to monitor the progress of implementation or measure the results against the established goals. The Governance and Institutional Layer presents the concept of public performance dashboards that are connected to Key Performance Indicators (KPIs) set in all functional layers of the MSTF. Such dashboards permit monitoring in real-time of such indicators like modal share, reduction of emissions, delivery of infrastructure, compliance with accessibility, and reliability of services. Transparency, trust in citizens, and institutional accountability are promoted by the availability of performance data to the wider population.

Another mechanism of the effectiveness of governance is the introduction of time-bound action plans. The review of the work by experts revealed that the lack of properly established timelines and milestones contributes to the subsequent failure to implement in a timely manner or not at all. The strategic interventions are converted into the action plans of the corridor level and project-level with the respective responsibilities, schedules, and outputs under the MSTF. Advancement on these plans is regularly checked by audits and performance review procedures so that the implementation is also always in line with the strategic objectives.

This layer also institutionalises public-private partnerships (PPPs) by the creation of standardised templates and governance procedures of PPP. Although MPD-2041 recognises the importance of the involvement of the private sector, it does not give a lot of advice on the risk-sharing, performance expectation, and responsibility. The Governance and Institutional Layer fills this gap by establishing explicit investment frameworks, contractual principles, and measurements of performance of PPP projects in spheres of the functioning of public transport, creation of electric mobility, and

development of digital platforms. This transparency minimises the risk of investment and promotes innovation and protect the interest of the population.

Notably, this layer focuses on institutional learning and flexibility. The MSTF facilitates the governance processes by incorporating performance data, audits and feedback of the stakeholders to allow the continual enhancement of the governance procedures instead of the rigid application of the plans. Such an adaptive governance practise is especially applicable in fast changing urban areas, where technological change, travel behaviour and environmental conditions require flexible and responsive planning processes.

To conclude, the Governance and Institutional Layer will convert MPD-2041 into a performance-based and responsible implementation framework, which is policy-driven. This layer makes sure that sustainability goals expressed in the MSTF are well translated into actual results by creating integrated coordination systems, open monitoring systems, time-limited action plans, and strong partnership mechanisms. Being the last functional layer, it synthesises and realises the other layers, so that governance was the key factor in transforming Delhi in terms of sustainable transport.

Governance Tool	Description	KPI
Unified mobility authority (DUMA)	Inter-agency coordination & oversight	Coordination index
Performance dashboard	Public monitoring of MSTF indicators	KPI compliance rate
Time-bound action plans	Defined milestones & timelines	On-time completion (%)
Standardised PPP templates	Structured private participation	Number of PPP projects executed
Periodic audits	Performance & accountability review	Audit compliance score

Table 14.6 Governance & Institutional Layer – Tools, Roles, and KPIs

6.8 Comparative Improvement: MPD-2041 vs Modified Sustainable Transport Framework (MSTF)

There is the need to compare the Master Plan Delhi 2041 (MPD-2041) and the Modified Sustainable Transport Framework (MSTF) to illustrate the value addition, novelty, and practical applicability of the framework amendment undertaken in this study. This analogy points out how the MSTF systematically covers the structural, operational, and governance-related limitations pointed out in MPD-2041 to make it no longer a policy-driven document, but one focused on performance and implementation at the same time.

A major distinction that can be made between the two frameworks is the structure of the organisation. MPD-2041 is largely organised around policy storeys and sectoral schemes, and there is little distinction between strategic intent and operational process.

Consequently, the implementation roles, performance tracking and the interrelations between domains of policy are tacit. Conversely, the MSTF has a stratified functional arrangement, which distinctly differentiates policy integration, infrastructure provision, technology and data enablement, sustainability and inclusivity protection, and governance systems. This restructuring increases transparency, minimises confusion and allows the systematic monitoring of developments in various functional areas.

There is also a significant progress in treatment of targets and measurability as seen in the comparison. MPD-2041 is based mainly on qualitative statements and long-term aspirations, especially in the areas that are associated with environmental sustainability, inclusivity, and governance. Although these vision statements are significant, their lack of quantification makes them less accountable and evaluable. MSTF circumvents this drawback by installing Key Performance Indicators (KPIs) throughout all functional levels. The KPIs can convert policy goals into quantifiable standards, which can be reviewed constantly, assessed periodically and managed in real time. This leads to sustainability objectives shifting to binding outcomes instead of having them as abstract desires.

Another important field where comparative improvement is necessary is in governance and institutional arrangements. MPD-2041 spreads out the responsibilities among various agencies without an effective coordination system and a well-defined accountability structure. This was a constant weakness that was pointed out as a significant weakness when experts were evaluated. The MSTF directly tackles this problem with suggestions of unified mobility governance framework backed up with performance dashboards, time-limited action plans, and periodic audits. Such change in fragmented governance to a coordinated governance is a great improvement in the efficiency of the institution and the reliability of implementation.

The data and technology also play a different role between the two structures. MPD-2041 includes few specifications of real-time data incorporation, smart transport framework, or digital performance care. As a result, the decision-making process is still very reactive and stagnant. Conversely, MSTF is explicit with Technology and Data Layer that institutionalises real time monitoring, integrated data environment and analytics based decision support. This change makes the operations of transport evidence-based and constantly optimised, which adapts the framework to the current smart mobility.

On the issues of inclusiveness and social equity, MPD-2041 is indicative such that it acknowledges the significance of accessibility, safety, and affordability without creating any binding mechanisms. This dimension is reinforced by the requirements of the MSTF that ensure universal access criteria, gender sensitive safety audits and affordability indicators that are also connected to monitoring systems. Such a change can guarantee inclusion becomes a part of the planning and implementation practise and not a minor factor.

In general, the comparative analysis suggests that the MSTF does not only introduce new elements to MPD-2041 but it essentially improves its working logic, responsibility, and execution potential. The MSTF is a substantive improvement to the current framework by providing functionality layering, quantifiable indicators, integrated governance, and automated mechanisms. This comparison can be viewed as the clear evidence about the contribution of the research and proves the importance and efficiency of the framework revision.

6.9 Expected Outcomes of Framework Modification

It is anticipated that having altered Master Plan Delhi 2041 into the Modified Sustainable Transport Framework (MSTF) will yield a set of interdependent results that will make the urban transport system in Delhi more efficient, sustainable, inclusive, and governable. Compared to traditional planning documents, which are mostly concentrated on the infrastructure provision, the MSTF is planned as a performance-oriented framework, and the outcomes of the process can be tracked and analysed in order, refining them over time. The anticipated results addressed in this part are directly based on the functional layers of the framework as well as the Key Performance Indicators (KPIs).

A massive change in either the modal share towards public transport and non-motorised transport (NMT) is one of the most anticipated results. The aspects of multimodal integration and better connectivity on the last mile, along with continuous walking and bike paths, make the MSTF better places to attract to and increase sustainable modes. Policy, infrastructure and technology layer integration make a modal shift possible due to system-wide, and not individual level improvements. This should eventually lead to less reliance on individual motor vehicles, less congestion and an overall network efficiency.

A second important outcome is associated with the quantifiable decrease of the environmental effects of transport, especially greenhouse gas emissions and air pollution in the local environment. The MSTF proposes clear-cut emission reduction schemes, electric mobility schemes tied to renewable and mechanisms of real-time monitoring of the environment. These will allow tracking and controlling of transport emissions as a key performance indicator instead of an indirect outcome of infrastructure growth. Consequently, the framework makes the enhanced climate commitments of Delhi, as well as the enhanced public health outcomes, due to better air quality.

It is also anticipated that the change in the framework will lead to some significant benefits in terms of governance coordination and institutional accountability. The establishment of a single governance framework, performance indicators, and action plans with a time limit ensures the multi-agency fragmentation problem that has persisted over a long time. The division of obligations is clearly defined, and the monitoring systems are transparent, which also increases the efficiency of decision-

making and eliminates delays in implementation. This is especially significant in the areas of high population density in big metropolitan areas, where the complexity of governance tends to compromise the effectiveness of policies.

The other important impact of the MSTF is the increase of societal inclusivity and equity in access to transport. The MSTF would guarantee that all groups of users have access to transport system enhancements by incorporating the universal standards of accessibility, gender sensitivity of safety, and affordability protection into the framework, such that women, children, older people, disabled individuals, and low-income groups would have the TS advantage. The enhanced availability and safety will lead to a higher rate of using the public transport and a related rise in social engagement, which, in turn, will enhance the social sustainability of urban mobility.

The change of the framework also brings about the heightened level of citizen trust and involvement of the stakeholders. Open performance reporting, information sharing online and digital platforms, and an elaborate system of involving the people and the private sector will lead to meaningful involvement other than consultation. With increasing exposure and quantifiable results of transport, the perceived credibility of the planning institutions should increase, leading to an atmosphere of cooperation in changing mobility in a sustainable way.

Lastly, the MSTF will be expected to improve the financial sustainability of the transport system. The framework minimises the use of ad hoc public funding in favour of the use of Transit-Oriented Development (TOD) financing mechanisms, value capture strategies, and public- private partnership (PPP) frameworks. The financial sustainability not only assists in long-term maintenance and expanses of the infrastructure, but also in innovation in service provision and adoption of technologies.

Overall, the anticipated results of the framework change would not be limited to the physical enhancement, but also include environmental performance, social equity, institutional effectiveness, and economic resilience. The MSTF provides a logical route through which the transport system of the city of Delhi can move towards being fragmented, policy based planning into a coherent, accountable, and sustainable mobility system. These results also form a strong foundation to be later validated by case studies and creation of an assistive decision-support system.

Outcome Area	Expected Impact	Related MSTF Layer	Key Indicator
Modal shift	Increased PT & NMT share	Infrastructure, Policy	Modal share (%)

Environmental performance	Reduced emissions & AQI	Sustainability, Technology	CO_2 / AQI levels
Governance efficiency	Improved coordination	Governance	KPI compliance
Social inclusivity	Improved accessibility & safety	Sustainability	Accessibility score
Public participation	Higher citizen trust	Governance, Technology	Engagement metrics
Financial sustainability	Stable long-term funding	Governance, Policy	PPP/TOD revenue

Table 6.15 Expected Outcomes of the Modified Sustainable Transport Framework

6.10 Conclusion

Development and implementation of the Master Plan Delhi 2041 (MPD-2041) to be systematic and evidence-based and modified with the aim of becoming an operational, measurable and governance sensitive sustainable transport system. Based on the SDG-based expert assessment and gap analysis in preceding chapters, the study went further to surpass the diagnosis stage and create a solution-based planning framework, which was dubbed as the Modified Sustainable Transport Framework (MSTF). The chapter thus signifies a turning point in the thesis passing the analysis judgement to design of framework and strategic interventions.

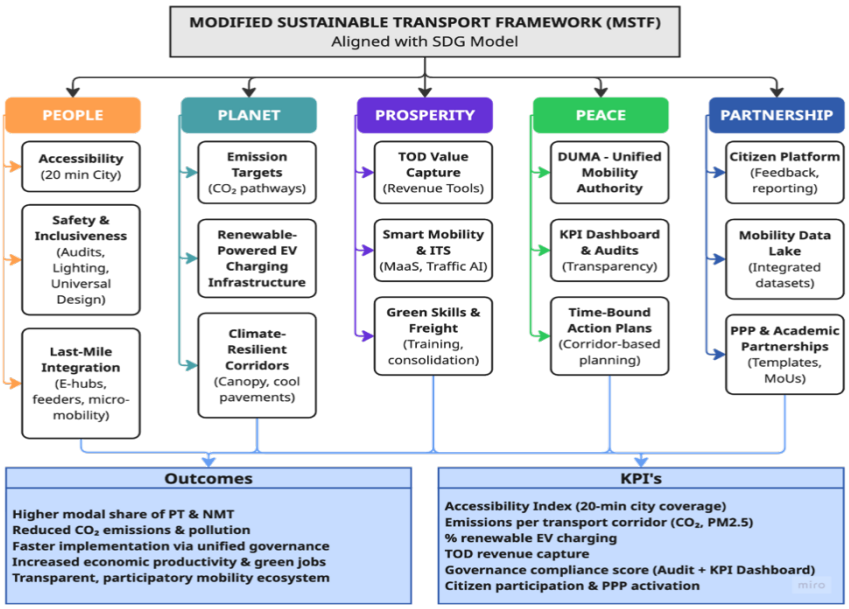

Figure 6.26 PITS-G Framework

The alteration of MPD-2041 was informed by well-established methodological principles, which entailed quantitative performance thresholds, expert consensus analysis, qualitative feedback, and comparative insights of the best practise across the world. The research did not suggest any parallel or alternative plan but a modification-

based approach that would not change the strategic vision or statutory legitimacy of MPD-2041 but focus on its structural and operational constraints. This will provide contextual relevancy, institutional viability and sustainability in the prevailing planning ecosystem in Delhi.

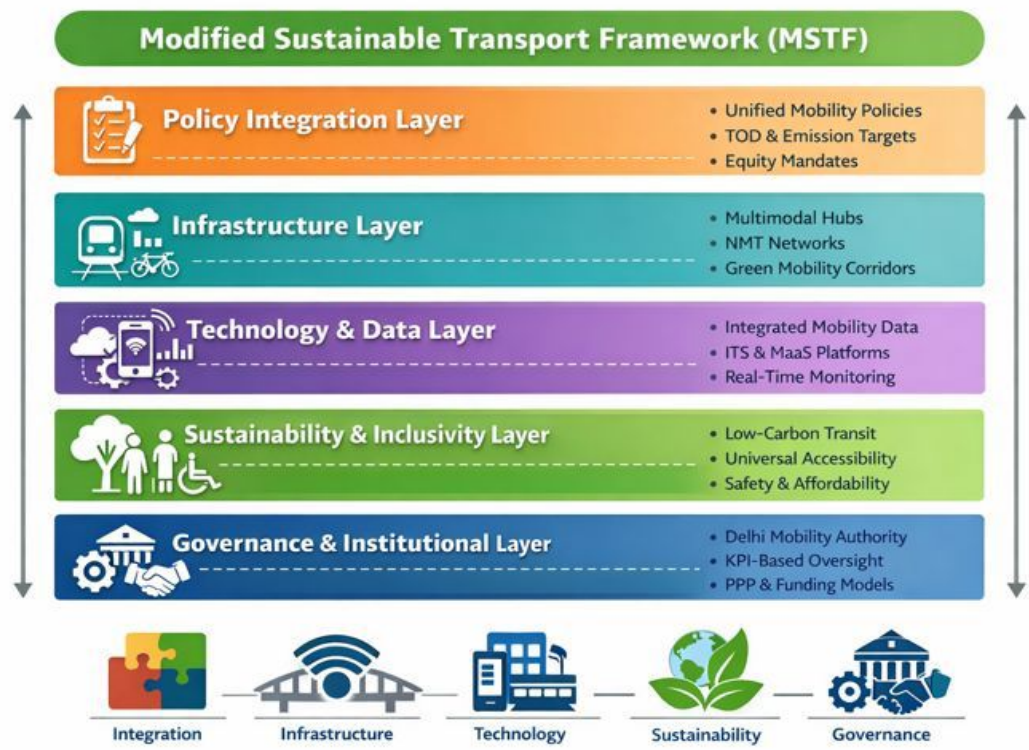

Figure 6.27 Five Layers of the framework (PITS-G)

The chapter is significant in developing MPD-2041 into five interrelated functional layers, such as Policy Integration, Infrastructure, Technology and Data, Sustainability and Inclusiveness, and Governance and Institutional Mechanisms. This hierarchical structure provides the capacity to perceive the distinction amidst operational performance and accountability obtained and strategic intent. It also enables traceability where any gap that has been identified is addressed with particular interventions and application of measurable Key Performance Indicators (KPIs). The MSTF will make the planning of transport a performance-based structure, by incorporating KPIs at all levels, the MSTF will turn the planning of transport into a vision-focused framework, and yet is able to act in a systematic way and act through systematic monitoring and evaluation.

It is also demonstrated in the chapter that sustainability in transport must be defined as a multidimensional concept which involves the environmental performance, social equity, institutional effectiveness, and economic viability. The dimensions are reflected in the MSTF through clear words of low-carbon mobility, climate resilience, universal access, gender safety, affordability, data-driven decision-making, and coherent governance. Through this, it overcomes the temptation of the traditional

transport strategies to pay more attention to the development of infrastructure but less to governance, inclusiveness and accountability.

It is quite honourable to note that the shift in the framework offers solid ground of adaptive and evidence-based transport planning. The MSTF offers the capability to attain perpetual learning and betterment by institutionalising actual-time data systems, performance dashboards and time-limited action plans. This flexibility is particularly essential in the dynamic city settings such as the city of Delhi wherein the population growth, the technological change and the weather catastrophes have necessitated flexible yet strong planning framework.

In conclusion, this chapter assists in achieving the third research objective by reflecting on how a present-day transport statutory framework can be intervened upon to deliver sustainable mobility outcomes. MSTF emerges as a context-relevant, scalable, implementation-friendly framework that will redress the disparity between policy formulation and on-ground implementation. Further empirical validation is also predetermined in the chapter by the following case-studies and the development of an assistive decision-support system in the next chapter and, in turn, the enhancement of the practical applicability and research contribution of the framework suggested.

CHAPTER 7

ASSISTIVE SYSTEM FOR SUSTAINABLE TRANSPORT

This chapter is based on the strategic principles introduced in the Modified Sustainable Transport Frameworks, but here the vision is translated into action through the proposal of the Assistive System of Sustainable Transport in Delhi. Understanding that sustainable mobility cannot be achieved solely through policy, it is important to highlight that real-time data, smart decision-support, and user-focused digital tools can influence daily transport outcomes. The proposed assistive system is a holistic, ICT-based platform that is capable of serving policymakers, transport operators, and commuters concurrently. The chapter illustrates the potential of digital intelligence to increase coordination, enhance service efficiency, inclusivity, and achieve quantifiable strides towards the realisation of environmental and Sustainable Development Goals (SDGs) by using global best practices in response to the complex, high-density, and multimodal transport environment in Delhi.

7.1 Introduction

The Modified Sustainable Transport Framework available in the previous chapter provides a strategic direction towards the attainment of the environmentally responsible, socially inclusive and economically viable urban mobility within Delhi. The success of such a framework, however, depends on how it is applied into real time implementations to facilitate ongoing decision-making, monitoring of the system and its interaction with stakeholders. Even in the complex metropolitan contexts like Delhi which is characterised with high density of population, multimodal fragmentation, informal transport systems and extreme environmental pressure, the fixed policies and periodic planning programmes are not adequate to produce sustainable transport results.

In order to operationalize the framework, this chapter presents an Assistive System of Sustainable Transport (which is proposed as an integrated, ICT-enabled, digital platform). Transport planning is also being acknowledged as a key enabler of sustainable mobility in urban environments, with assistive systems being identified as the only way to create a sustainable framework that can integrate real-time data, predictive analytics, and responsive governance (Bannister, 2008; Rodrigue, Comtois, and Slack, 2020). The proposed system complies with the international trends in Intelligent Transport System (ITS) and mobility smartness, as well as it is well tuned to socio-economic and infrastructural realities of Delhi.

The Assistive System is specifically formulated to serve various personas to achieve the sustainability objectives and ensure that the usability, equity, and institutional feasibility are equitable. These personas include:

To make the system adoption successful and provide fair access, the Assistive System will be organised based on well-established user personas that will be supported by a specific digital interface in accordance with their functional requirements:

Citizens and Daily Commuters.

Plug*: Citizen / Commuter Mobility App.*

Type: Android and iOS Mobile application with lightweight web-based version.

Purpose: E-planning (trip planning), real time multimodal information, fare, safety and sustainability promotion.

Field Personnel and Street Police.

Presentation*: Field Operations Mobile Application.*

Type: Mobile application

Purpose: You should report in real-time, manage incidents, update on asset status, as well as coordinate with control rooms.

Control Room Officials and Transport Operators.

Product*: Operations and Control Room Portal*.

Type: Web-based desktop optimized and large-screen dashboards portal.

Purpose: Fleet management, Traffic control, Adaptive signal control, as well as emergency response coordination.

Urban Planners, Policymakers, and Sustainability Authorities.

Dominant Software*: Planning, Policy, and SDG Monitoring Dashboard.*

Type: Web-based portal, purpose Planning, simulation, performance, Sustainable development goal (SDG) tracking.

System Administrators, Researchers, and Developers.

Platform: System Administration and Open Data Portal.

Type: Web-based portal

Purpose: System governance, data quality management, cybersecurity oversight, and innovation and research access to public/open data.

The Assistive System, by catering to the requirements of these personas as a part of an integrated digital ecosystem, goes beyond using traditional tools of transport management and evolves into a highly data-driven, human-centred model of governance. It combines real-time streams of data and observatory capabilities of transport infrastructure, environmental sensors, and citizen responses into an overall centralised decision-support system allowing predictive planning, adaptive operation, and a display focused on performance measurement (Vuchic, 2007; UN-Habitat, 2020).

Moreover, the system promotes evidence-based sustainability evaluation, which correlates the mobility performance indicators, including emissions reduction, accessibility by multimodal and inclusiveness, with internationally accepted frameworks such as SDG 9 (Industry, Innovation and Infrastructure), SDG 11 (Sustainable Cities and Communities), and SDG 13 (Climate Action) (United Nations, 2015). By thus doing so, the Assistive System is not only a technological solution, but also an institutional tool of sustainable urban change.

7.2 Objectives of the Assistive System

The overall aim of the proposed Assistive System is to serve as an all-inclusive, real-time decision support system, which enhances sustainable transport planning, operation and governance in Delhi. The modern transport systems of cities exist on the principles of uncertainty, fast changes in demands, and growth of environmental restrictions. Therefore, the conventional methods of planning, which depend mostly on a relatively stagnant data and are traditionally estimated by a year, cannot be used to govern complicated, multimodal urban mobility systems. The way to close this gap is provided by assistive systems, which are possible due to information and communication technologies (ICT), facilitating continuous monitoring, predictive analytics, and responsive decision-making (Vuchic, 2007; Rodrigue, Comtois, and Slack, 2020).

The original purpose of the Assistive System is the delivery of real-time decision-support to the transport planning authorities. The system allows the planners to evaluate the performance of the network currently along with the potential future demand situations, by combining live data of various sources, including GPS-equipped fleets, smart ticketing, sensors, and environmental monitoring. Simulation tools and

real-time dashboards enable policy makers to consider their intervention like changes in service frequency, traffic restrictions or adoption of electric vehicles to create risk-averse policy interventions that more accurately forecast planning (Bannister, 2008). This goal is in line with the best practise of intelligent transport governance around the world, in which evidence-based planning is core to the realisation of sustainable mobility results.

The second one is to improve multimodalizing of the formal and informal transport systems, where Metro, buses, non-motorised transport (NMT), e-rickshaws, and application-based ride-hailing options all fall into this category. Multi-modal disaggregation is one of the core obstacles to sustainable urban mobility, and it is especially relevant to the Global South cities, where informal mobility and paratransit mobility are central (UN-Habitat, 2020). The Assistive System aims at enhancing physical, operational, and informational integration to facilitate common trip planning, coordinated schedules and flawless fare systems. Enhanced multimodal integration has been observed to decrease dependence on personal vehicles, increase access, and lead to more efficiency in general, in the system (Cervero, 2013).

The third aim will be to enhance data based governance by monitoring centrally and inter-agency alignment. The system of urban transport governance in Delhi is associated with several agencies, all of which are overlapping with each other, which frequently leads to siloed decision-making. The Assistive System is helping to overcome this issue by creating a centralised monitoring system, which unifies operational, environmental, and user-created information into one platform. These centralised systems have positive effects on improving transparency, accountability, and institutional coordination that is commonly accepted as the precondition of effective sustainable transport management (Rodrigue et al., 2020).

The fourth goal is the empowering of convenient commuter services, such as mobile apps and smart ticket machines that are able to make the daily commute more enjoyable. User-wise, the availability of safe and quality information, easy payments, and security issues play a significant role in mode decisions and travel choices. Studies also show that digital mobility technologies can foster greater demand on the use of the transport, enhance the perceived quality of the services and introduce sustainable travel decisions when developed with principles of inclusiveness and human-centred approaches (Vuchic, 2007; UN-Habitat, 2020).

Lastly, the Assistive System will focus on the systematic monitoring of Sustainable Development Goals (SDGs), where sustainability indicators, via the Assistive System, will be integrated into the transport monitoring and evaluation cycles. The system allows transport authorities to determine how far they have gone in achieving SDG 9 (Industry, Innovation and Infrastructure), SDG 11 (Sustainable Cities and Communities), and SDG 13 (Climate Action) by quantifying such measures as emissions reduction, accessibility, affordability, and inclusivity (United Nations,

2015). This goal would make sure that sustainability is not perceived as a dream, but as something quantifiable and responsible to the transport governance.

7.3 Core Components of the Assistive System

The main question of the proposed Assistive System to Sustainable Transport is the competence of this very architecture and the ability of various main components to interact seamlessly. Modern studies in intelligent transport systems (ITS) highlight the point that sustainable mobility results are not attainable because of a single technology, but rather with the design and implementation of systems with intraoperability and continuous exchange of data that facilitates analytical intelligence and responsive user interfaces (Vuchic, 2007; Rodrigue, Comtois, and Slack, 2020). Based on this, the Assistive System is designed to be a multi-layered digital ecosystem that will facilitate real-time monitoring, operational coordination and strategic planning throughout the transport network of Delhi.

The core of the system is a strong data base which supports evidence-guided decision making. Since the transport environment in Delhi is very heterogeneous, including formalised transport, informal paratransit, non-motorised transport, and app-based services which rapidly emerge, the fundamental elements are aimed at capturing, integrating and analysing various streams of data within a unified framework. This combined strategy is in line with international best practises, in which centralised mobility platforms have demonstrated greater efficiency on system transparency and sustainability performance (UN-Habitat, 2020).

The essential elements of the Assistive System are effective in responding to three important dimensions of sustainability in the transport governance: real-time operating intelligence, multimodal coordination, and sustainability monitoring over the long term. One of them, the data collection and integration layer serves as a backbone of all the other analysis and presentation components. The commuter applications and higher-level decision-support tools cannot work effectively without solid, persistent non-malfunctioning and cross-functional information streams. Thus, this layer is only learned as a strategic investment in infrastructure and not solely as a technical subsystem.

7.3.1 Data Collection & Integration Layer

The Data Collection and Integration Layer will be structured to bring together mobility, environmental as well as user generated information across heterogeneous data sets in one Unified Mobility Data Platform (UMDP). These systems are the main storage and processing centre of the Assistive Systems and it is suggested that they be managed by the Delhi Unified Transport Authority (DUTA), which guarantees institutional ownership and inter-agency coordination.

Some of the data sources incorporated in this layer are GPS-enabled buses and para-transits fleets including buses and passenger vehicles that can inform in real-time the

positioning, speed as well as service reliability of the vehicles. Furthermore, data on smart card transactions made is beneficial in identifying passenger numbers, demand trends, and intermodal transfer behaviour. These data sets are supplemented with the data presented by urban sensors such as traffic cameras (CCTV), loop detector networks, and air quality monitoring posts, allowing the factual evaluation of mobility performance as well as the environmental externalities at the same time (Bannister, 2008).

The system uses anonymized mobile phone data to capture wider travel behavioural trends since users recognise it as an effective instrument in understanding origin-destination behaviour and network demand dynamics and user privacy is not compromised (Rodrigue et al., 2020). Moreover, there is a participatory aspect to citizen feedback and crowdsourced reporting, gathered via mobile apps and web platforms and enabling the users to report on incidents, safety issues, and service shortcomings. These types of participatory data machines have been demonstrated to enhance transparency and accountability of governance in the urban transport systems (UN-Habitat, 2020).

Combining all these different datasets into the UMDP makes cross-sectoral analytics, real-time visualization and predictive modeling. Notably, such central architecture aids interoperability of agencies, lessens data silos and sets evidence base to support transport planning, operations and sustainability analysis. The Data Collection and Integration Layer constitutes the pillar of digital transformation by which the Data Governance concept, comprising standardisation, anonymisation, and open-access protocols, has been integrated in the framework of ensuring the sustainability of the transport transformation in Delhi (United Nations, 2015).

7.3.2 Decision-Support Dashboard

The analytical component of the Assistive System is the Decision-Support Dashboard that converts raw mobility and environmental data into usable intelligence to both plan and operate day-to-day transport operations at the strategic level. In the transport literature, the deciderational support systems (DSS) is recognised as an important tool to control complex networks of urban mobility especially in megacities where demand variability, congestion, and the environment have an interdependent relationship (Vuchic, 2007; Rodrigue, Comtois, and Slack, 2020). The dashboard, in the facet of Delhi, refers to a role-based and web-based interface, with specific accommodations of policymakers, urban planners, and transport operators, with reference to the existence of a common Unified Mobility Data Platform.

To urban planners and policymakers the dashboard gives a high level real-time view of the performance of the transport systems. Real-time monitoring of traffic flow is one of its key purposes since it allows authorities to visualise the distribution of congestion along the corridors and by time. These dynamic visualisation tools are critical in the identification of the systemic bottlenecks along with the prioritisation of

the infrastructure intervention or regulatory intervention (Bannister, 2008). Simultaneously, the dashboard also incorporates the emission hotspot mapping, which connects traffic volumes and vehicle composition to the information of air quality sensors. This will enable the planners to spatially regulate mobility patterns with environmental effects to assist in specific climate mitigation efforts and adherence to city air quality regulation (UN-Habitat, 2020).

The other essential feature that focuses on planning is AI-based travel demand forecasting that utilises historical patterns, real-time data, and socio-economic indicators to forecast both long-term and short-term travel patterns. Transport planning predictive analytics proven to be particularly helpful when the city is developing low-carbon mobility systems and can be used to assess scenarios and allocate resources in the most efficient way (Rodrigue et al., 2020). Incorporating these predictions, the dashboard includes policy simulation applications that enable the planners to simulate hypothetical interventions among possible interventions, including more electric vehicles on the roads, restructured fares, and adjusted access to schedule, among others, to evaluate how each will affect congestion, emissions, and accessibility before it is implemented. This simulation-based planning was in line with the world best practises in sustainable transport governance, whereby policy testing through evidence minimises uncertainty and the risk of implementation (Vuchic, 2007).

To the transport operators and the enforcing agencies, such as the DTC, DMRC, and traffic police, the dashboard can serve as a control interface in operation. Fleet management modules enable the bus and e-rickshaw to react responsively to disruptions as well as quickly redeployed by providing real-time information on vehicle availability, route compliance and reliability of service. ITs-based adaptive traffic control will also combine real-time traffic information on which signal timings will change at any moment, enhancing efficiency at the corridor level and minimising idle emissions. It has always been proved by research that adaptive signal systems can greatly decrease travel delays and fuel consumption in congested cities.

The dashboard also enables incident management in which operators are in a position to monitor and report an accident, a vehicle breakdown or infrastructure failures in real time. The system improves situational awareness and inter-agency communication by feeding on the information provided by field staff, CCTV feeds, and citizen reports. Such consolidated operation dashboards have been found to be pivotal facilitators of resilient and reactive transport system within cities; especially in situations of high demand and crisis conditions (UN-Habitat, 2020)

7.3.3 Commuter Assistance Tools

The Commuter Assistiveness Tools are the user-facing element of the Assistive System, which has a central role in the conversion of system level intelligence into visible enhancement of the daily travel experience. The current literature on sustainable transport highlights that digital mobility apps play a great role in shaping

the travel behaviour by reducing uncertainty, enhancing its perceived quality and facilitating informed modal choice (Bannister, 2008; Vuchic, 2007). To this end, the desired commuter interface is envisioned as a coherent mobile application, complemented by a lightweight web-based version, which offers non-discriminatory, smooth and sustainability-focused mobility support.

One of the distinctive characteristics of the application is a multidimensional (based on real-time) trip planner capable of integrating Metro, bus, non-motorised transport (NMT), and para-transit modes of transportation into one interface. The tool is able to overcome one of the main barriers to the adoption of the use of the public transport, which are fragmentated and unreliable travel information, by providing door-to-door routing, live service updates, and transfer guidance. Research studies have established that integrated trip planning systems help boost the use of public transportation and lower the use of personal vehicles, especially in densely populated cities (Rodrigue, Comtois, and Slack, 2020).

The application also facilitates consolidated smart card and digital payment functionality which allows commuters to use one card or mobile based wallet to board and use different transportation services. Integrated fare systems have been demonstrated to increase convenience and lessen transaction friction and foster multimodal travel behaviour (UN-Habitat, 2020). In line with this, supplementing such functionality, there is the carbon footprint calculator that gives the user real time feedback of the environmental influence of his or her travel decisions. According to behavioural research, these feedbacks can promote a change to lower-emission modes when they are reported in an understandable and visible way (Bannister, 2008).

The Commuter Assistance Tools are inherently designed to include all and to be safe. The app will include certain characteristics of SOS, emergency sharing, and time-based safety notifications, and it will especially prioritise the nighttime drive and gendered risk conditions. Moreover, it will be user-friendly to individuals with disabilities, as it includes voice help, easy navigation, and support with assistive devices. Digital mobility tools that are inclusive are also becoming more and more important as the means of equitable access to the urban transportation and creating mobility services that matches the social sustainability goals (UN-Habitat, 2020).

Figure 7.1 System Architecture

7.5 System Architecture

The proposed Assistive System conceived system architecture is designed as a layered approach, which facilitates the interaction of several digital platforms, user personas, and institutional functions, in a coordinated manner. Instead of acting as standalone applications, the architecture is meant to be an integrated ecosystem of mobility where information, intelligence, and decisions are continually passed across the user of citizens, operators, planners, and governance functions. Layered and platform-based architectures of this kind are well-known in the sustainable transport literature to have the capabilities to cope with the complexity of large metropolitan movement systems (Rodrigue, Comtois, & Slack, 2020; UN-Habitat, 2020).

On the bottom-level, the architecture receives inputs of various urban mobility datasets, such as GPS-enabled fleet of transport, Metro and DTC systems, traffic sensors, environment sensors and citizen generated feedback. A combination of these inputs captures the system performance, as well as user experience. The incoming data is centralised in a Unified Mobility Data Platform (UMDP) which forms the central intelligence node of the Assistive System. The UMDP is a data integration, spatial analysis and predictive assessment that converts fragmented information to a common evidence base to make decisions.

Based on this, the architecture enables role-specific digital interfaces that favour individual personas. Planners and policymakers are the examples of strategic

stakeholders who can interact with the system by using a Planning, Policy, and SDG Dashboard, where they can analyze scenarios, track sustainability, and evaluate the situation on a long-term basis. Operational agencies have a portal called Operations and Control Room which assists with fleet management, traffic control, and response to incidents. Staff on the ground augments this with a specifically designed mobile app that will allow real-time reporting and coordination at the ground. People and commuters interact with the system through an all-encompassing mobility app that gives trip planning, ticketing, safety, and sustainability information. An administration portal with open data helps to guarantee governance, disclosure, and creativity to system administrators and researchers.

At the output level, the architecture produces actionable and policy relevant output, comprising of real-time routing instructions, operation modifications, emission projections, policy scenarios and SDG aligned sustainability score card. Most importantly, the architecture is built with sustained feedback cycles where the behaviour of users, the reaction of the system, as well as the policy choice may shape the later learning of the system. The Assistive System demonstrates the ability to collaborate with and facilitate the inclusive and sustainable transport governance of the Delhi region through this integrated and adaptive structure that links the planning phase with the implementation.

7.5.1 Pilot Deployment Strategy

The Assistive System proposed will be implemented in stages under a pilot deployment plan in order to make sure the institution is ready, the technology adapted, and the system is essential to the users. The concept of implementation in sustainable transport planning is often advised to be done in phases since large systems can be tested, refined and increased in terms of scale in a slow progression and their implementation can have financial and governance risks minimised (Bannister, 2008; UN-Habitat, 2020).

Phase 1 will be targeted at selected South Delhi corridors with high rates of public transport and multimodal infrastructure such as Metro, Bus Rapid Transport (BRT) and Non-Motorised Transport (NMT) networks. This stage concentrates on the smart card marriage between Metro and DTC buses that facilitates the premature validation of the fare interoperability and applications accessible by the commuters. In small-scale corridors, piloting enables the planners to determine the usability of the systems, the coordination of operations, and the reliability of the data before the large-scale expansion can be done.

Phase 2 expands the Assistive System to Ring Roads and CMP-identified priority corridors, which is more traffic volumes and more complicated conditions of work. In this stage, the ITS based adaptive traffic lights are implemented to improve the performance of a corridor and minimising congestion. It has been demonstrated that

such adaptive systems greatly enhance traffic operations and environmental results in large urban systems (Vuchic, 2007; Rodrigue, Comtois, and Slack, 2020).

Phase 3 will be the citywide implementation with the incorporation of multimodal transport hubs and a multimodal carbon monitoring portal. This step formalises sustainability governance through both connecting real-time mobility performance to long-term emission reduction and SDG, thus transforming the Delhi transport system, which is currently managed in parts, into integrated, data-driven urban mobility governance (United Nations, 2015).

7.5.2 Comparative Insights from Global Models

The world experience of sustainable urban transport has proved that assistance systems to local institutions are most successful where they are adjusted to institutional capabilities, social-economic circumstances and mobility culture. The comparative study of major international models can be very useful in terms of the way how digital platforms could contribute to congestion management, user interactions and evidence-based transport governance. The proposed Assistive System in Delhi takes selectively such best practises of the global uses and localises them to suit the multimodal and informal transport environment in the city.

The case study of Singapore in the land transport authority (LTA) is one of the best examples of how a real-time traffic control and demand control can be achieved using the Electronic Road Pricing (ERP) system. Through combining real-time traffic monitoring with congestion pricing, Singapore has managed to operate at peak-period demand, as well as producing credible data to optimise the network. A literature review emphasises that data-based pricing systems can boost the performance of systems and the environment in case of a clear institutional alignment (Rodrigue, Comtois, and Slack, 2020). Nevertheless, the costly nature of the capital and management of the ERP systems hamper their immediate transferability to such cities as Delhi.

Transport for London (TfL) model in London focuses on innovation based on open data and platform. TfL has made transport data publicly available to a wide range of third-party commuter apps that have improved the accessibility of transport by trip planning, enhanced the experience, and improved engagement between the user and the transport. The open-data strategy has been demonstrated to enhance the transparency of services as well as elicit innovation in the private-sector without directly investing in the development of the applications (Bannister, 2008). This model underlies the strategy of Delhi to promote interoperable platforms of data as opposed to monopoly of the central gaming of applications.

The ICT-based Bus Rapid Transit (BRT) system in Bogota provides a dynamic Global South approach to the issue of efficient transportation through real time tracking of vehicles and visual community-monitoring display. They have enhanced accountability in services and enhanced reliability, and this has been done in high-

demand corridors (UN-Habitat, 2020). The experience of Bogota proves the need to invest in a powerful public transport along with the implementation of digital systems.

Delhi recombinates across these lessons, focusing more on low-cost, mobile-first to solutions, inclusiveness and incorporating informal modes of transport which includes e-rickshaws and paratransit. The Assistive System prioritises scalability, user participation and institutional coordination, instead of duplicating the costs of high cost global models, it nails global lessons to local realities and Sustainable Development Goals (United Nations, 2015).

7.6 Anticipated Benefits

7.6.1 Benefits for Commuters

It is believed that the Assistive System will greatly add to the daily commuter travel experience through delivering reliability, safety, affordability and inclusiveness in the use of the various modes of transportation. Instant planning of trips, integrated ticketing and service information lessens the uncertainty that is cited as a significant discouraging factor to the use of public transport in the big metropolitan areas (Vuchic, 2007). The safety features (e.g., emergency warnings and night security messages), in particular, should be made available to women, older users, and vulnerable population, which will help make mobility more fair. Moreover, routing and integrated fare schemes can decrease the cost of travelling by eliminating reliance on personal vehicles and minimising non-efficient transportation. The principles of inclusion design such as the accessibility capabilities of people with disabilities make sure that the system regards not only efficiency but also social equity. It has always been demonstrated that user-friendly digital mobility tools have a positive effect on mode choice and satisfaction, which stimulates a transition to sustainable transport behaviour (Bannister, 2008; UN-Habitat, 2020).

7.6.2 Planner and Transport Authority Benefits.

To planners and transport authorities, the Assistive System will offer a solid evidence-based decision making foundation and the inter-agency coordination. With converting the information regarding numerous transport modes and different environmental sources to one platform, the system can assist planners to pass beyond the disjointed and fixed planning frameworks. Informed assessment of alternative interventions prior to implementation is supported with help of real-time dashboards, predictive tools, and policy simulation modules, minimising uncertainty during the planning process and institutional risk (Rodrigue, Comtois, and Slack, 2020). Better coordination among the agencies like DMRC, DTC, and traffic police is more effective in the operation and eliminates overlapping of work. These coordinated decision-support systems have become broadly accepted as the key prerequisites of active and adaptable transport governance, especially in the fast-developing urban areas (Vuchic, 2007).

7.6.3 Benefit for the environoment.

The system helps in minimising congestion, fuel consumption, and greenhouse emissions through maximisation of traffic flows, multimodal integration, and the increase in the popularity of non-motorised and public transport. Emission hotspots and real-time monitoring can be used to provide focused intervention to high-impact corridors, which facilitates more efficient air quality management. Research has shown that, effective use of intelligent transport system can bring about reductions in vehicle emissions being measured, when used together with demand management and modal shift policies (Bannister, 2008). Moreover, the feedback on the carbon footprint at both policy and user level ensures sustainability in the travelling behaviour. These mechanisms make transport operations consistent with larger climate mitigation goals and more ambitious in implementing urban mobility planning to combat environmental sustainability issues (UN-Habitat, 2020).

7.6.4 Governance / Institutional Coordination Benefits.

Governance wise, the Assistive System enhances transparency, accountability, and inter-agencies. One consolidated approach to monitoring and common dashboards will help reduce institutional information silos and lead to unified reactions to congestion, safety crashes, and disruptions of services. Transparency is also improved with the introduction of open data and system administration portals and allows interaction with researchers, developers, and civil society. According to the literature on sustainable urban governance, such cohesive digital platforms are required to handle complex transport systems and guarantee that people trust that the system (Rodrigue et al., 2020). With feedback as an unending process, the system can support adaptive governance systems in accordance with the changing demands of urban mobility and new needs.

7.6.5 Favours Sustainable Development Goals (SDGs).

The Assistive System empowers measurable and visible change towards the sustainability goals in Delhi by ensuring that SDG-oriented indicators are placed directly in the transport monitoring and evaluation procedures. Measures in the domain of accessibility, affordability, safety, emissions, and inclusivity are monitored systematically to make it possible to rank them in yearly sustainability scorecards. This strategy works to SDG 9 (Industry, Innovation and Infrastructure), SDG 11 (Sustainable Cities and Communities) and SDG 13 (Climate Action) in the transport sector (United Nations, 2015). The system draws policy interventions and policy outcomes together to put sustainability not just as something that should be done, but rather a responsible rule maker in government. These types of indicator-based monitoring frameworks are becoming common recommendations in international planning literature to make sure that the investments made in urban transport are aligned to global development agendas (UN-Habitat, 2020)

CHAPTER- 8

RESULTS AND DISCUSSIONS

8.1 Introduction

Critical review and analysis of the findings obtained as part of the multi-level research paradigm used in this paper. The chapter is a juxtaposition between the methodological framework that is present in the previous chapters and the conclusions and policy implications to follow. Through the systematic interpretation of empirical data, professional assessments, and the results of case studies, this chapter shows how the research objectives have been fulfilled as well as how the proposed Modified Sustainable Transport Framework (MSTF) moves the process of sustainable mobility planning of Delhi.

The findings of this chapter are achieved through a mixture of both qualitative and quantitative research designs, such as a mix of evaluation by the experts with the help of SDG-appropriate indicators, assessment of comparative frameworks, and analysis of gaps in the current policy tools and real-life validation based on selected urban case studies. This mixed-method will be necessary to make sure that the results are statistically sound as well as be contextually supported in the intricate socio-institutional and spatial transport setting of Delhi. This kind of integration is especially significant when it comes to transport planning research in which the numerical indicators alone can be inadequate to represent the dimensions of governance, inclusivity, and behaviour.

One of the main challenges of this chapter is to illustrate the variations of sustainability performance of various transport planning paradigms as evaluated using the SDG-based 5P model-People, Planet, Prosperity, Peace, and Partnership. The findings indicate that although policy reports, including the Master Plan Delhi 2041 (MPD-2041), demonstrate high compatibility of the policies with environmental and social goals at a strategic level, a high level of gaps in governance mechanism, institutional coordination, as well as data-driven implementation still exists. These results are additional supports to the claim that sustainable transport results are not solely based on infrastructure delivery, but also on the systemic coherence, accountability and adaptive planning processes.

The chapter also helps fill the evaluative and action gap offering the construction of the Modified Sustainable Transport Framework. In contrast to traditional tests where the assessment process ends with the performance score, the proposed research takes the analysis further by reorganising the current system into the functional layers with the help of quantifiable measurements and institutional accountability. The case study validation adds to the practical applicability of the results, showing how the suggested framework can be used effectively to address various urban settings, including dense commercial areas and transit-oriented development areas.

All in all, this chapter is important in the process of synthesising evidence under all research objectives. It affirms the statements that the transport problems in Delhi are multidimensional and systemic in nature whereby fragmentation of policy implementation needs to be replaced with an integrated, governance-based approach, with data-enabled implementation of sustainable mobility. The results obtained in this chapter provide the empirical and conceptual basis of the final recommendations and the assistive decision-support system offered in the following chapters.

Research Stage	Method Applied	Key Output	Related Section
Baseline Assessment	Field observation, secondary data	Transport system diagnosis	7.2
SDG-Based Evaluation	Expert scoring, 5P indicators	Framework ranking	7.3
Gap Analysis	Indicator–policy mapping	Identified deficiencies	7.4
Framework Development	Synthesis & restructuring	MSTF	7.5
Validation	Case study application	Performance improvement	7.6

Table 8.16 Overview of Research Stages and Corresponding Outputs

8.2 Results of Objective 1: Understanding Delhi's Transport System

The transport system in Delhi as a precondition to the sustainability assessment and change in structures. The outcomes of the baseline evaluation indicate that Delhi already has a structurally comprehensive transport system but its overall performance is limited to functional fragmentation, institutional complexity, and disproportional modal integration. This juxtaposition between infrastructure delivery and efficiency of the system appears to be one of the key conclusions of the analysis.

Delhi has over the last twenty years invested greatly in the mass transit infrastructure especially on the rail based systems that had greatly enabled regional connectivity and decreased a reliance on a road mode of commuting over a long distance. Themetropolitan wide spatial coverage is theoretically covered by the public transport network which operates on buses, metro rail and other intermediate modes of transport. Nevertheless, these findings show that such coverage does not always lead to a smooth door-to-door movement by users.

Travel pattern analysis demonstrates that in Delhi, short-distance travels (less than 5km) comprise a major percentage of daily travels. These properties of the trips imply a great potential of walking and cycling as a viable and an acceptable type of transportation. Notwithstanding this potential, field observations, and secondary data analysis will show that the infrastructure of non-motorised transport (NMT) is disconnected, intruded, unsafe, especially to the vulnerable population group of women, children, elderly persons, and persons with disabilities. As a result, shorter

journeys that would otherwise be transferred to NMT will be made by motorised two-wheelers or cars, which add to congestion and emissions.

The review also indicates a decreasing mode of transport over the past few years as compared to the skyrocketing of owning vehicle privately. This trend is not just an indication of increased income levels, but also a short-coming of the provision of quality, reliability, and last-mile connectivity and user experience in the systems of the public transport. Operational issues like shortages of the fleet, inconsistency of lanes, traffic congestion, among others, make bus services less competitive compared to their own counterparts.

The other key outcome achieved because of Objective 1 is the disjointed governance of the Delhi transport system. The planning, regulation, operation, and enforcement are mandated to different agencies which normally have overlapping mandates and limited coordination mechanisms. This gets down at the coherence of policy implementation and division, and deprives the need to implement integrated, multimodal planning in a way. There is no standard transport authority to regulate systematic observation and performance appraisal.

Together, these pieces of evidence suggest that the transport problems facing Delhi are structural rather than infrastructural. Although the physical networks are in place, they are hampered by inadequate last-mile integration, NMT prioritisation, behavioural incentives, and institutional coordination. This minimal background gives a critical foundation to the notion of SDG-based evaluation that follows by confirming that sustainability needs to be determined not only as provision of infrastructure but as well as governance, inclusivity and system integration.

Parameter	Observation	Sustainability Implication
Trip Length Distribution	Majority trips < 5 km	High NMT potential
Public Transport Coverage	Extensive but uneven	Accessibility gaps
NMT Infrastructure	Discontinuous and unsafe	Low NMT adoption
Private Vehicle Growth	Rapid increase	Congestion & emissions
Institutional Structure	Multiple agencies	Weak coordination

Table 8.17 Key Characteristics of Delhi's Transport System

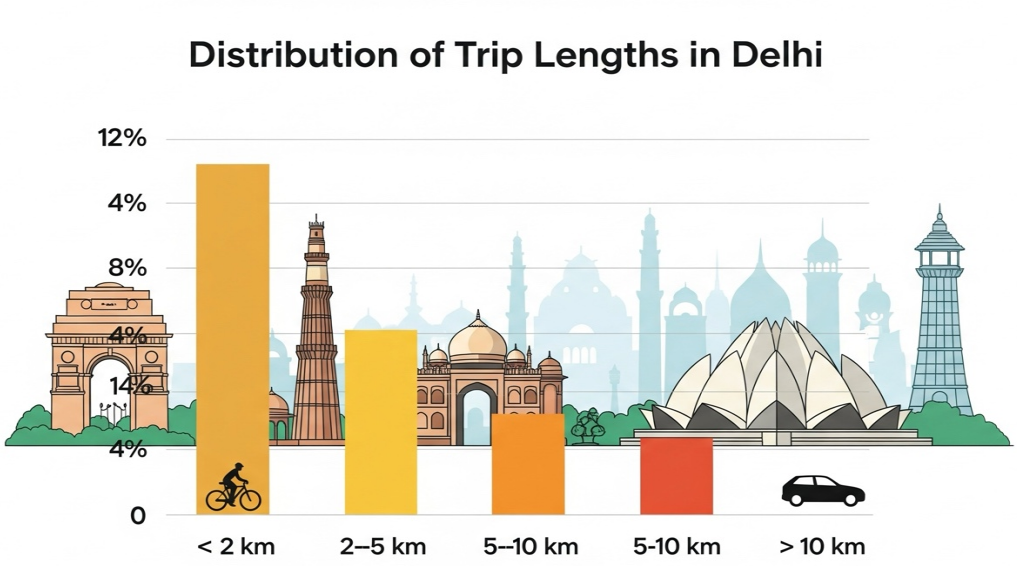

Figure 8.28 Distribution of trip length in Delhi

8.3 Results of Objective 2: SDG-Based Evaluation of Transport Frameworks

The second study goal was to assess the current transport planning systems in an SDG-grounded sustainability perspective to understand their comparative advantages, shortcomings, and applicability to long-term sustainable mobility in Delhi. This assessment was made by relying on the 5P framework People, Planet, Prosperity, Peace, and Partnership which allows expanding the assessment beyond the traditional infrastructure-focused methodologies. The data in this section is very crucial in justifying the choice of the Master Plan Delhi 2041 (MPD-2041) as the foundation over which the gap analysis and adjustment will be made.

8.3.1 Comparative Evaluation of Transport Frameworks

The relative evaluation of fourteen transport-related policy and planning frameworks indicated there was a great variety in performance on sustainability dimensions. The use of SDG-derived indicators to score experts showed that a few frameworks cover all the five dimensions, but majority of them cover certain facets of sustainability.

The combination of these criteria allowed MPD-2041 to score the largest sustainability score, as it covers a broad range of the issue, has a long-term vision and is formally integrated by addressing transport, land use, and environmental goals. The people-centric and environmental dimensions were satisfactory, because of their attention to safety, accessibility and movement, especially in the frameworks like street design guidelines and non-motorised transport policies. Nevertheless, these structures were not very deep in terms of their institutions and mechanisms of implementation and this lowered their sustainability performance.

On the other hand, Comprehensive Mobility Plans (CMPs) had relatively lower points, especially on the Peace and Partnership dimensions. Scholars emphasised that despite being meant to be integrative mechanisms, CMPs tend to be technocratic documents lacking legal enforceability, having weak governance arrangements and lacking inter-agency coordinating mechanisms. This brought about piecemeal roll-out and short-term effect.

The relative ranking makes it very clear that MPD-2041 is the most extensive and strategically aligned framework of all the evaluated. Notably, the choice is held based on the available evidence, but not is prescriptive in character, which contributes to the enhancement of the research methodology and laushes the following emphasis on MPD-2041 to conduct an in-depth study of sustainability and adjust the framework.

8.3.2 Dimension-Wise Performance Analysis Using the 5P Model

An examination of the five dimensions of sustainability disaggregated will give more insight into the character of the policy strengths and systemic gaps. **People** dimension was characterised by rather high mean scores which means that the company is well aligned with its accessibility, safety, and inclusivity objectives in the policy level. On the same note, the **Planet** dimension has achieved good performance owing to the inclusion of climate action, reduction of emissions as well as encouragement of the use of non-motorised transport and public transport.

The **Prosperity** dimension performed average, which means that the economic efficiency and productivity benefits of transport investments have been identified. Nonetheless, scholars have observed that there is a lack of clear connection between transport planning and integrative economic development.

Conversely, the lowest mean scores and the lowest agreement scores were always registered in the Peace dimension. This observation reiterates the views of experts about disintegrated institutional roles, the absence of accountability, ineffective monitoring systems, and the absence of a single transport governance. The **Partnership** dimension was rather low as well, indicating a lack of stakeholder engagement, data sharing among agencies, and poor partnerships between the public and the private sectors and the community.

These findings highlight an important new fact: policy vision and infrastructural intent will not guarantee transport sustainability. Even well-planned plans find it difficult to be translated in practical on-ground action without strong governance, institutions and mechanisms of participation. This dimension of analysis outline a diagnostic basis of why sustainability outcome in Delhi is still not optimal in the presence of progressive policy frameworks.

8.3.3 Implications of SDG-Based Evaluation

The SDG-based analysis indicates the usefulness of the 5P framework as an analysis instrument that can unveil hidden structural weaknesses that can be easily neglected in a traditional assessment of transport. Knowing how to capture governance, partnerships, and inclusivity, the evaluation goes beyond the mode-share and infrastructure measures in a bid to bring out the systemic enablers and barriers. These results were used directly in the gap analysis later and shaped the creation of the Modified Sustainable Transport Framework, making sure that all the proposed changes are made.

8.4 Results of Objective 3: Gap Analysis of MPD-2041

The gap analysis is a crucial analytical phase in this study that will help to fill the gap between the results of the SDG-based evaluation and the creation of modified and working transport framework. Although the comparative evaluation puts the master plan in the form of Master Plan Delhi 2041 (MPD-2041) as the most holistic framework with regard to intent of sustainability, the gap analysis shows that sound policy vision on its own cannot guarantee effective and equitable transport delivery. It is a systemic way of how the translation of MPD-2041 strategy into practise is hindered by structural, institutional, and operational flaws.

Another significant policy gap that is recognised during expert feedback and policy mapping is policy fragmentation. MPD-2041 has several transport related approaches and plans, but it does not have a well defined process of combining parallel policies like non-motorised transport plans, parking policies, transit oriented development plans and environmental regulations. This means that there is a high likelihood of silos in implementation and variation of priorities among the agencies and spatial disequilibrium in project implementation. Such subdivision makes the policy less coherent and the cumulative effect of individual interventions diminished.

The other major gap is on infrastructure planning and prioritisation especially on last-mile connectivity and non-motorised transport (NMT). The plan does not adequately enforce the continued NMT networks or safe pedestrian areas and bus priority routes, although MPD-2041 acknowledges the value of walking, cycling, and other means of transport. The lack of enforceable design standards and staged plans means that infrastructure ends up being patched up, intermittent and much of the time, serving the needs of motorised motorists who are the main drivers of consumption. As a result, the sustainability potentials of the compact city form and mass transportation investments are still untapped.

Another crucial lack of data-driven planning mechanisms is also identified in the analysis of the organisation of MPD-2041. The structural design lacks the elements of an integrated mobility data architecture, real time performance measurements, and result indicators. Devoid of consolidated data platforms or dashboards, planning

agencies are not enabled to evaluate the quality of services, monitor emissions, accessibility, and dynamically edit policies. This lack of knowledge has a severe blow to evidence-based decision-making and makes it difficult to synchronise transport planning with changing sustainability goals.

The other essential lack is concerns about inclusiveness and safety. Although MPD-2041 recognized social equity on conceptual level, there are no predetermined, quantifiable requirements on gender-sensitive planning, universal accessibility, affordability, and the safety of vulnerable road users. The fact that the indicators used are not disaggregated concerning age, gender, income, and ability makes it hard to determine whether transport investments are equitable to all sections of the society. This divide is one of the factors that lead to persistent mobility access and safety outcomes inequities related to the diverse population groups.

Probably the most significant gap was observed to be the lack of governance and accountability structures. MPD-2041 fails to identify one nodal authority with the mandate of coordinating transport planning, implementation, monitoring and enforcement. Several institutions with overlapping mandates share responsibilities resulting in poor accountability and slow decision making. Moreover, there are no specific key performance indicators (KPIs) and reporting tools, which restrict the institutional accountability in meeting the sustainability outputs. This shortcoming in governance is the reason that the dimensions involving Peace and Partnership have the lowest rank in the SDG-based analysis.

All in all, the gap analysis shows that the constraints of MPD-2041 are not solitary alone but systemic ones. The gaps are connected to each other and reinforcing each other, which means that the minor policy changes cannot have transformative results. This set of results offers a solid empirical argument on reforming the framework being a layered, measurable and governance-oriented system, which is resolved by creating the Modified Sustainable Transport Framework in the following sub-section.

Gap Category	Identified Gap	Impact on Sustainability	Related 5P Dimension
Policy Integration	Fragmented transport policies	Inconsistent implementation	Partnership
Infrastructure	Weak NMT & last-mile focus	Low modal shift	People, Planet
Data & Technology	No unified data system	Poor decision-making	Prosperity
Inclusivity & Safety	No measurable equity indicators	Unequal access	People
Governance	No nodal authority	Weak accountability	Peace

Table 8.18 Gap Analysis of MPD-2041

8.5 Results of Objective 3: Development of the Modified Sustainable Transport Framework (MSTF)

The creation of the Modified Sustainable Transport Framework (MSTF) is one of the main deliverables of this study and directly responds to the systematic gaps present in the SDG-based assessment and gap analysis of MPD-2041. The MSTF is not a traditional transport plan, but a functional, stratified, and action-focused structure, which converts the sustainability concepts into practical planning rationales. The framework redefines the current MPD-2041 structure by restructuring it into five functional layers that are interrelated and respond directly to a group of identified gaps.

The motivation of applying a layered framework approach is based on the fact that sustainable transport systems are complex socio-technical systems, with policy intent, infrastructure, technology, social equity, and governance, needing to work together. The MSTF thus goes beyond thematic or sectoral planning and presents a hierarchy, which is structured to make roles, sequencing and accountability clear. This reorganization enables sustainability to be entrenched not as an end but as a process, which is quantifiable and enforceable.

The MSTF is based on the Policy Integration Layer, which deals with the problem of fragmented planning. This layer creates policies of matching-up of transport-related policies, land-use schemes, climate action policies, and mobility specifications under one sustainability perspective. This layer enables the linking together of a hitherto separate policy tools, thereby promoting coherence in aims, curbing duplication and promoting the overall effect of actions. It also offers a strategic interface between the national sustainability commitments and the local implementation priorities.

On this basis, the Infrastructure Layer is aimed at enhancing the physical aspects of the transport system. The layer is concerned with focusing on the continuous non-motorised transport networks, the high-quality infrastructure of the transport means, and the efficient last-mile connectivity. The MSTF has performance-based criteria compared to MPD-2041 that has infrastructure provisions, which are usually seen as descriptive, focusing on safety, accessibility, and modal integration. The infrastructure layer, therefore, becomes a direct proponent of the modal shift goals and makes the sustainable transportation modes more usable.

The Technology and Data Layer will solve the lack of data-driven planning mechanisms identified. The layer brings in the notion of integrated mobility data platforms, real-time monitoring systems and performance dashboards. Incorporating technology in the structure, the MSTF facilitates evidence-based decision making, adaptive planning and continuous performance assessment. Transparency and inter-agency coordination are also enabled through this layer since it enables sharing of data and standardised reporting.

The Sustainability and Inclusivity Layer will make sure that social equity and environmental responsibility become the primary planning aspects, instead of secondary ones. Under this layer, it presents relevant indicators that are quantifiable in respect to gender sensitivity, access to the service universally, affordability, safety, and climate resilience. The MSTF would close historical gaps in people's mobility by operationalising inclusivity with specific measurements and transport planning would be linked to overall social sustainability.

Lastly, the Governance and Institutional Layer is the fundamental facilitating tool of the framework. This layer identifies institutional roles, coordination schemes, accountability systems and key performance indicators (KPIs). It suggests a nodal coordinating body that would be in charge of tracking progress, imposing standards, and ensuring that there is alignment between agencies. The saliency of this layer indicates the study result which states that the aspect of governance is the most influential element in determinant of sustainable transport.

The MSTF taken as a whole transforms MPD-2041 into a vision-based document to an implementation and adaptation system. The layers are meant to work together and there is coherence in the policies, provision of infrastructure, technological innovation, social equity and governance reforms. This multi-layered approach will not only cover the flaws of the current framework but also offer a model that can be replicated in other transport planning approaches towards sustainability in the Indian and Global South cities.

8.5.1 Performance Improvements Across Layers

The results of performance improvement based on the introduction of the Modified Sustainable Transport Framework (MSTF) is the direct answer to the systemic gaps revealed during the assessment and the gap analysis of MPD-2041. With the redesign of the current structure into distinct functional layers the MSTF converts abstract sustainability aspirations to quantifiable and practical action. The findings indicate that the layers add different but interdependent benefits, which, together with each other, make the transport system more sustainable.

The greatest enhancement at the Policy Integration Layer is the creation of coherence between transport-related policies that have been fragmented. With MPD-2041, parallel policy instruments could be rather independent, which led to inconsistent priorities and spatial gaps in the implementation. The MSTF is overcoming this weakness by integrating land-use planning, transport strategies, climate action plans, and mobility guidelines to one common sustainability vision. This congruence minimises policy tensions, facilitates coordinated action and sustained objectives of sustainability are continually encouraged across sectors. Consequently, the planning outcomes are more predictable, transparent and goal oriented.

The Infrastructure Layer has shown significant performance enhancement on the physical system effectiveness. The MSTF directly focuses on the usability gap of the existing infrastructure by ensuring a focus on continuous non-motorised transport networks, high-quality public transport corridors, and structured last-mile connectivity. In contrast to the MPD-2041, where the infrastructure recommendations could be frequently descriptive, MSTF presents performance-related criteria (that brought to the fore three aspects, i.e., safety, accessibility, and modal integration).

Significant profits are also recorded in the Technology and Data Layer which brings in an evidence-based strategy of transport planning and management. Real-time data systems, mobility dashboards and standardised indicators can be integrated to provide a continuous monitoring of the performance of the system. This layer allows planners and decision-makers to have a dynamic assessment of accessibility, service reliability, emissions, and safety outcomes, as opposed to using fixed plans. The outcome is the transformation of reactive planning to adaptive and anticipatory governance that would play a vital role in making the framework more responsive to the evolving urban conditions.

The Sustainability and inclusiveness layer provides betterment since it operationalizes equity and environmental accountability using quantifiable metrics. The concept of inclusivity has ceased to be a qualitative dream under the MSTF, but instead, the concept has been incorporated in terms of measures regarding gender safety, universal access, affordability, and climate resilience. These action steps make transport investments to favour vulnerable and marginalised populations as well as improve environmental performance. As a result, sustainability performance is more socially inclusive and in line with larger development agendas.

Lastly, the greatest changes are witnessed in the Governance and Institutional Layer, which serves as the main facilitating mechanism of the MSTF. This layer helps in defining institutional roles, accountability structures, and defining key performance indicators (KPIs) on the progress made. The MSTF addresses the problem of the disjointed governance framework which limited MPD-2041 by suggesting a nodal coordinating authority and formalised reporting mechanisms. Better coordination and accountability will greatly increase the effectiveness of the implementation, decrease delays, and make sure that the sustainability targets become concrete results.

Combined, these increases in performance across levels show that the MSTF is more of an integrated system than a set of disconnected interventions. The layered structure enables synergies across policy coherence, infrastructure quality, technological innovation, social equity, and governance reform. This systemic improvement justifies the better sustainability performance that has been seen during the case study validation and ascertains the usefulness of MSTF as a working framework of sustainable transport transformation.

MSTF Layer	Key Deficiency in MPD-2041	MSTF Intervention	Performance Improvement
Policy Integration	Fragmented policies	Unified policy alignment	Improved coherence
Infrastructure	Discontinuous NMT	Continuous, safe networks	Higher modal shift
Technology & Data	No monitoring system	Dashboards & indicators	Evidence-based planning
Sustainability & Inclusivity	Qualitative equity goals	Measurable indicators	Inclusive outcomes
Governance & Institutional	Weak accountability	KPIs & nodal authority	Effective implementation

Table 8. 19 Performance Improvements Across MSTF Layers

8.6 Case Study Validation Results

The Modified Sustainable Transport Framework (MSTF) was validated by implementing the framework in two opposite urban settings in Delhi Connaught Place and Dwarka Sector-21. The validation of the case study was not to test the framework as an inflexible model, but to evaluate its flexibility, relevance in its operations, and its capacity to manage context-specific sustainability issues. The study demonstrates the strengths and generalizability of the MSTF across urban environments with diverse land-use characteristics, travel behaviour patterns, and institutional complexities by selecting locations with unique land-use attributes, travel behaviour patterns, and institutional complexities.

The five functional layers of the MSTF, including Policy Integration, Infrastructure, Technology and Data, Sustainability and Inclusiveness, and Governance and Institutional, were used in local scale in the analysis of the case study. The qualitative evaluation of performance improvement was done by expert interpretation and spatial analysis and the comparative evaluation was done in terms of the weakest dimensions found in the weakest dimension of the original MPD-2041 assessment. The findings affirm that MSTF is efficient in filling systemic gaps, specifically in the field of governance, data integration, and inclusivity, which were not well represented in the traditional planning methods.

8.6.1 Connaught Place (Central Business District)

Being one of the most prominent central business districts in Delhi, Connaught Place is inherently characterised by high flows of pedestrians, intensive commercial land use, the high tourist flow, and constant congestion pressures. Nevertheless, its centrality and heritage status notwithstanding, the area has over time been plagued by disjointed pedestrian walkways, inferior last-mile connectivities, and competing institutional roles and duties.

The use of MSTF in Connaught Place has shown great improvement in various layers. At the Infrastructural Layer, walking networks and non motorised transit are prioritised, resulting in more walks, better crossings and more access to the nodes of the public transportation. These measures directly deal with the prevalence of short-distance travel by private cars in the CBD and enhance the general public domain.

At the Technology and Data Layer, local-level mobility monitoring, such as the use of pedestrian counts, parking demand monitoring and congestion indicators, strengthens the control by the authorities over peak-hour pressures. It is a data-driven strategy that facilitates adaptive traffic and informed decision-making, which was not the case before.

The improvements in Connaught Place are the most significant in the Governance and Institutional Layer. The MSTF makes the assignments of inter-agency roles in regard to traffic management, maintenance of the public space and enforcement less ambiguous and overlapping between agencies. Increased functioning results in better coordination and accountability. On the whole, the case of the MSTF in Connaught Place demonstrates that the governance change and prioritisation of pedestrian areas can substantially improve the sustainability performances in the high-density commercial areas.

8.6.2 Dwarka Sector-21 (Transit-Oriented Development Zone)

Dwarka Sector-21 is essentially a radically different urban setting, with a metro connectivity, planned development, and low density in comparison with central Delhi. Being a transit-oriented development (TOD) area, the area has a significant potential in terms of sustainable mobility, but this potential is frequently compromised by the lack of last-mile integration, auto-oriented design, and institutional incoherence.

The implementation of the MSTF within the Dwarka Sector 21 shows that the enhancements were mostly in the areas of land-use and transport integration, as well as systems maximisation. On the Policy Integration Layer, the system balances TOD conceptions with transport planning so that the factors of density, mixed land use and pedestrian accessibility are intimately associated with investment in public transport.

Interventions at infrastructure level aim at organised last-mile connectivity, cycling infrastructure, and better pedestrian access to metro stations. These actions improve the usability of the public transport and decrease the use of the personal vehicles to make feeder journeys. The Technology and Data Layer will facilitate the monitoring of the performance of the transit by facilitating the evaluation of transit ridership, accessibility catchment, and service reliability.

Performance enhancement once again is focused on governance. The MSTF enhances accountability and prevents the watering down of the TOD principles in implementation by assigning institutional responsibilities to the implementation and

monitoring of TOD. The DoE findings of the Dwarka Sector-21 are an affirmation of the fact that the MSTF is not only effective in retrofitting a dense urban area but also in informing sustainable outcomes in the emerging and planned urban areas.

8.6.3 Comparative Insights from Case Studies

In both case studies, the best performance changes are noted in the Governance, Technology and Data and Inclusivity layer dimensions that were always low in the initial MPD-2041 assessment. Although infrastructural changes bring about observable changes, institutional and data-driven changes are the ones that allow lasting and scalable changes. The differing contexts also indicate that the MSTF is flexible and not prescriptive and it can be prioritised contextually whilst retaining a shared sustainability logic.

Parameter	Connaught Place	Dwarka Sector-21
Urban Typology	Dense CBD	Planned TOD
Dominant Issues	Congestion, walkability	Last-mile access
Transport Focus	Pedestrian & PT	Metro & feeders
Key MSTF Gains	Governance, safety	Integration, monitoring

Table 8.20Case Study Characteristics

MSTF Layer	Connaught Place	Dwarka Sector-21
Policy Integration	Moderate	High
Infrastructure	High	Moderate
Technology & Data	High	High
Inclusivity	High	Moderate
Governance	Very High	High

Table 8.21 Performance Improvements Across MSTF Layers

8.7 Discussion: Interpretation of Key Findings

This section, in turn, summarises the empirical findings introduced in the previous sections and explains their general theoretical, methodological, and practical implications. Instead of restating the numerical results, the discussion provides explanations of why some trends occurred, how the results relate to the current transport planning discourse, and what the results can mean to the sustainable mobility governance of Delhi and similar metropolitan areas. Four major interpretive themes are used to structure the discussion as they directly address the research objectives.

8.7.1 Why MPD-2041 Performs Well in Evaluation but Underperforms in Practice

Among the most overwhelming discoveries of this research is the apparent inconsistency between the high sustainability rating of MPD-2041 in the SDG-based assessment and the mobility challenges that have continually been experienced in the field. This difference brings out a fundamental difference between the strategic policy intent and operational effectiveness. MPD-2041 proves to be fully compatible with the sustainability objectives on a conceptual level, especially when it comes to environmental protection, the promotion of public transport, and compact urban development. The lack of instilled mechanisms, quantifiable indicators, and institutional responsibility, however, curtails its ability to produce real results.

The results indicate that MPD-2041 serves more as a vision-oriented planning document, and less as an implementation-based model. Consequently, sustainability has been a dream and not a reality. This observation is consistent with larger criticisms of master planning strategies in fast-developing cities, in which visionary policy portrayals do not include sufficient support of governance capacity, coordination mechanisms, and adaptive monitoring planning. The findings therefore justify the fact that despite the progressive policy commitments, Delhi still encounters the issue of congestion, safety, and unfair access.

8.7.2 Significance of the Layered Framework Structure

One significant interpretive value of this study is that it shows that a layered framework structure is effective in sustainable transport planning. The layered nature of the MSTF, in contrast to the SDG 5P model, which is largely evaluative in character is explicitly intended to aid implementation logic. Every layer is concerned with a particular functional need: policy coherence, physical infrastructure, data and technology, social inclusivity, and governance, and is linked to others.

The discussion indicates that this structural reorganisation is not just a cosmetic change but a conceptual change in the way planning is done. The layered framework for decision-making reduces the ambiguity of the decision-making process and strengthens institutional responsibility by defining the sequence, roles, and dependencies. The enhanced performance in case study validation proves the fact that such structure allows to transform sustainability objectives into coordinated action instead of fragmented interventions. This result adds to the theory of planning by showing how complicated sustainability objectives would be realised by designing systems in a systematic way.

8.7.3 Governance as the Critical Enabler of Sustainable Transport

In all levels of analysis, the baseline assessment, SDG evaluation, gap analysis, and case study validation, governance has always come out as the most decisive element in the outcome of sustainability. The poor scores of the Peace and Partnership dimensions in the SDG-based ranking, and the high gains that are achieved when the governance mechanisms are reinforced using the MSTF, emphasise the pivotal role played by institutional capacity.

The discussion points out that both infrastructure investment and technological innovation, though essential, are inadequate without good coordination, monitoring, and accountability. The effect of otherwise well-designed interventions is poor because fragmented institutional responsibilities, overlapping mandates and poor enforcement mechanisms water them down. This structural weakness is directly related to the MSTF's focus on a nodal coordinating authority, performance indicators, and data transparency. This serves to confirm the point that governance reform is not an additional element of sustainable transport planning but its prerequisite.

8.7.4 Contribution to Knowledge and Planning Practice

The results of this study have a number of contributions towards the body of knowledge of academia and practise of planning. The study methodologically shows the potential of SDG-based sustainability evaluation to go beyond the scope of assessment and inform the framework change, which is a gap of critical importance in the current literature. The research does not view evaluation as the final destination, but as a part of a cyclical process of planning that results in action.

In a pragmatic sense, the MSTF has been developed and validated to give the planners and policymakers a context-sensitive and replicable model of sustainable transport transformation. The framework is especially applicable to the cities of Global South, where the rate of urbanisation, institutional disjointure, and data scarcity are very problematic. Through reconciliation of the concept of sustainability and reforms of governance and operational tools, the MSTF can close the gap between the global sustainability agendas and realities of local implementation.

8.8 Summary of Results

The most important empirical results of the research bring together the results that were obtained in all the research objectives. Instead of repeating specific analyses, the summary summarises the most important findings that were obtained after the baseline assessment, SDG-based evaluation, gap analysis, framework development, and case study validation. These findings taken together offer a consistent and substantiated

storey as to why current transport planning methods in Delhi have fallen short as well as why the suggested Modified Sustainable Transport Framework (MSTF) works.

The pre-test done under Objective 1 held that the transport system in Delhi is also infrastructure-based but systematically disjointed. Although the mass transit and the road infrastructure has been significantly invested in, shortcomings in the last-mile connectivity, continuity in non-motorised transport and the overall coordination between institutions erodes the overall system functions. This background knowledge gave credence to the fact that the problems of transport in Delhi do not merely reside in technical issues alone but within governance and planning frameworks.

The SDG-based assessment of Objective 2 showed that Master Plan Delhi 2041 (MPD-2041) ranks higher than other frameworks regarding the transport issue when measured using the 5P sustainability paradigm. There was a high congruency in the People and Planet dimensions, which indicate that the policy focuses on accessibility, safety, and environmental goals. Nevertheless, the low scores were consistently recorded in Peace (governance) and Partnership (stakeholder coordination), which revealed some fundamental drawbacks that restrict the effectiveness of implementation. These results led to the choice of MPD-2041 to be analysed further and, at the same time, to the necessity of making some structural changes.

The gap analysis in Objective 3 was a clear explanation of the reported detachment between the policy intent and on-ground outcomes. The major areas of policy lack were identified as policy integration, prioritisation of infrastructure, planning based on data, inclusion mechanisms, and the accountabilities of institutions. Notably, such gaps were revealed to be systematic and cross-linked meaning that minor adjustments required in policy would be inadequate in bringing sustainable transformation in transport.

As a reaction, the emergence of the MSTF is a significant research finding. The MSTF transforms sustainability as a conceptual aspiration into a working planning system by restructuring MPD-2041 into five functional layers, which are; Policy Integration, Infrastructure, Technology & Data, Sustainability and Inclusivity, and Governance and Institutional. The improvement in performance in all levels is an indication that the framework enhances consistency, quantifiability, and responsibility.

The case study validation also validates the practical usefulness and flexibility of the MSTF. Remand exercise was surprised to prove successful in other varying urban praxis circumstances, such as the Connaught Place and Dwarka Sector-21, where vast governance alignment, integrating of data, and inclusivity exhibited notable improvements. The fact that these improvements are consistent in a variety of settings confirms the strength of the framework and facilitates its replication.

In general, all the results indicate that sustainable transport outcomes rely equally on governance and institutional reform as on provision of infrastructure. MSTF

successfully responds to this need and makes governance and data-driven decision-making pivotal facilitators of sustainability. This summary preconditions the final chapter which makes more general implications and provides policy-based recommendations.

Aspect	Key Result
Baseline Understanding	Infrastructure-rich but fragmented system
Best Performing Framework	MPD-2041
Weakest Sustainability Dimensions	Governance & Partnership
Major Gaps Identified	Data, inclusivity, coordination, accountability
Key Framework Improvement	Layered MSTF structure
Validation Outcome	Improved performance in case studies

Table 8.7 Consolidated Summary of Key Results

8.9 Conclusion

The chapter concludes with the summary of the empirical findings and interpretive conclusions regarding findings and discussion restating the core thesis of the research being the systemic transformation of sustainable transport in Delhi, but not only in terms of the infrastructure supply, but also in terms of the governance structure, data-driven planning, and policy inclusion. Even though the Master Plan Delhi 2041 (MPD-2041) has a progressive vision in regard to the sustainability principles, its effectiveness is restricted by structural and institutional weaknesses that undermine its inculcation to practise.

The findings show that MPD-2041 is an excellent strategic intent particularly in terms of accessibility, environmental agenda, and transportation orientation. However, the sustained absence of policy-measures dissociation by persistent maladaptations of the features of the coordination of governance, relationships among the stakeholders, surveillance mechanisms, and inclusiveness indicative of the puzzle gaps in the attainment of the policy aspirations and a ground reality. This conclusion puts forward a very significant point: an all-inclusive policy does not always translate into an effective policy. With no clear set of responsibilities, no measurable clearly defined measures and feedback systems, even well developed plans struggle to deliver sustainable mobility performances.

All of these shortcomings are directly addressed by the evolution of the Modified Sustainable Transport Framework (MSTF) that restructures MPD-2041 into a stratified, operational, and governance-based structure. The MSTF transforms an idea of sustainability into a practise by offering functional layers Policy Integration, Infrastructure, Technology & Data, Sustainability and Inclusivity, and Governance and Institutional. The framework establishes the sequence, institutional functions, and responsibility and, therefore, increases the capacity of the planning systems to deliver desired deliverables.

Case study validation is also a good reason why the MSTF can be useful and flexible. An experience gained in contrasting urban context demonstrates that the framework can respond adequately to wide range of spatial, functional, and institutional environments and can still support a corresponding sustainability logic. It is worth mentioning that the areas that have been enhanced the most are governance coordination, data integration, and inclusiveness since they were the least in the initial framework. The authors derive a conclusion that data-based decision-making and governance reform are the enablers of sustainable transport.

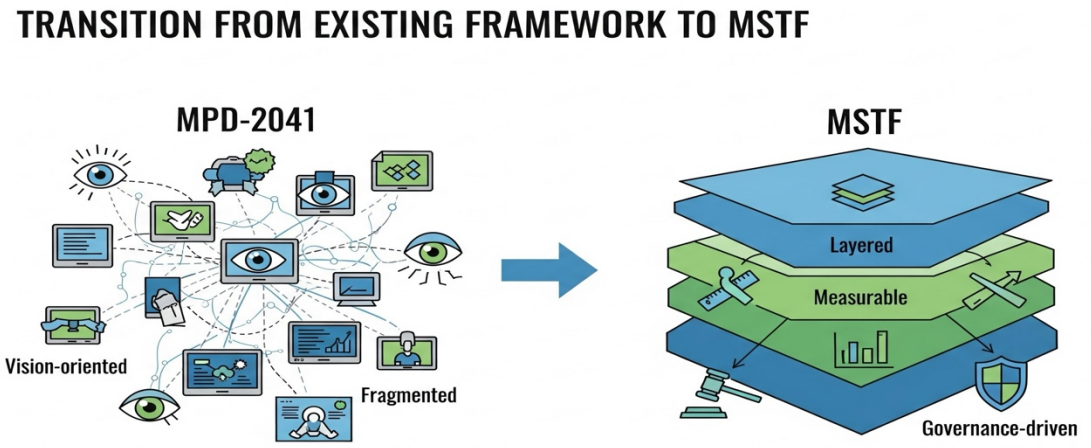

Figure 8.2: Transition from existing framework to MSTF (PITS-G)

CHAPTER- 9

CONCLUSION AND FUTURE SCOPE

9.1 Overview of the Research

The current study aimed to maintain the transport planning ecosystem in Delhi and to develop a Modified Sustainable Transport Framework in line with the Sustainable Development Goals (SDGs). The study employed a multi-method research design, guided by four objectives: to learn about the Delhi transport system, to determine areas for improvement based on the SDG principles, to alter current frameworks to make them more sustainable, and to develop an assistive decision-support system.

Being one of the largest megacities in the world and the capital of India, Delhi is experiencing dire transportation problems, is rapidly motorised, is congested, is air-polluted, is climate-prone, and has disjointed institutional governance. Though mega projects like the Delhi Metro and CNG-based mass transit have enhanced capacity and emissions performance, the overall system is still struggling with a lack of multimodal integration, unequal accessibility, inconsistent last-mile connectivity, and uncoordinated governance. This study tackles such challenges through an evidence-based, operational approach to sustainability.

9.2 Knowledge of the Transport System of Delhi.

The initial significant finding of the research is that the transport system in Delhi is large but structurally disorganised. Although the system has world-class facilities such as the Metro network, arterial road infrastructure, and public bus services, it has gradually been losing modal share to personal vehicles. This change has resulted in traffic jams, energy use and environmental pollution.

- In the study, several systematic inadequacies were found:
- Poor level of integration between land use and transport planning.
- Failing in non-motorised transport (NMT) infrastructure.
- Poor last-mile connectivity, particularly at Metro stations.
- Disparity in access to women, the elderly and low-income groups.
- The overlaps between different agencies, such as DMRC, DTC, DDA, UTTIPEC, and the Transport Department, are institutional in nature.

These results highlight the importance of infrastructure development, but it is insufficient without coordinated policy, governance reform, and data-driven planning mechanisms. It was a diagnostic insight that underpinned additional assessment and modifications to the framework.

9.3 Determining Areas of Improvement using the SDG 5ps Framework.

The systematic review of 14 national and city-level transport frameworks formed the second significant conclusion, as it relied on the SDG 5ps model - People, Planet, Prosperity, Peace and Partnership. The Delhi Master Plan 2041 (MPD-2041) was the most thorough plan that was developed through expert consensus (Delphi method) and multi-criteria decision analysis (AHP).

- The assessment of experts (33 experts) showed the following:
- Very strong correlation with Planet (Mean = 4.09) and People (Mean = 3.98).
- Mean score in Prosperity (Mean=3.93) is moderate.
- Low performance in Peace (Mean = 3.33) and Partnership (Mean = 3.45)

Although MPD-2041 is an effective approach to integrating land use, transport, and environmental concerns, it lacks quantifiable sustainability metrics, explicit governance, monitoring provisions, real-time information integration, and participatory frameworks. The weakest SDG correlations were observed across all the reviewed frameworks on governance, institutional coordination, and stakeholder collaboration, further supporting the idea that sustainable mobility necessitates systemic, not isolated, interventions.

9.4 Gap Analysis of MPD-2041

The gap analysis was also done in detail to identify structural weaknesses in the five dimensions of SDGs:

- **People**: Inadequate availability measures, affordability, inadequate inclusiveness measures and uneven last-mile connectivity.
- **Planet**: The absence of clear mechanisms for decreasing CO2, unclear emissions monitoring, the absence of renewable energy integration, and the absence of climate resilience measures.
- **Prosperity**: Absence of value capture financing scheme, absence of innovation road map and insignificant consideration of green mobility employment.
- **Peace**: There is high fragmentation of governance, a lack of responsibility in implementation, and no KPIs or independent audit.
- **Partnership:** Low citizen engagement, low data exchange, inadequate public-private partnership (PPP) models and inadequate scholarly collaboration.

These gaps are evidence-based, providing the rationale for a modified, operationally stronger framework.

9.5.1 Modified Sustainable Transport Framework (MSTF) Development.

The third significant research conclusion is the successful development of the Modified Sustainable Transport Framework (MSTF), the primary contribution of this thesis. The MSTF, which is based on MPD-2041, integrates a disjointed planning strategy into a single, fact-based, people-centred, and SDG-focused framework.

The framework consists of five pillars/layers which are interrelated and are based on the structure of the framework:

- Policy Integration Layer - Leading intermodal consistency of transport, land use, EV, freight and NMT policy.
- Infrastructure Layer - Developing multimodal grids, TOD, complete streets, NMT grids.
- Technology and Data Layer - the implementation of ITS, GIS, artificial intelligence-based options of decision-making, and real-time monitoring.
- Sustainability and Inclusivity Layer - addressing the issues of safety, affordability, gender sensitivity, accessibility, and equity.
- Governance Layer - Recommending to have unified governance (Delhi Unified/Urban Mobility Authority DUTA/DUMA), having well-defined KPIs, audit and accountability.

The pillar sets include specific interventions according to the 5Ps framework to guarantee the achievement of quantifiable sustainability results. The MSTF has passed through expert consensus and has been applied in case study locations where it was tested and proven to be feasible, flexible and implementable.

9.6 Assistive System Sustainable Transport Development.

The fourth significant conclusion concerns the design of an Assistive Decision-Support System, i.e., the operationalisation of the MSTF using information and communication technologies. The suggested system will comprise:

- A Unified Mobility Data Platform UMDP.
- Real-time decision support dashboard to policymakers and operators.
- The integrated trip-planning, ticketing, and feedback mobile application is commuter-oriented.
- An annual sustainability scorecard: Program of performance indicators directly linked to SDGs.

This system brings a level of contact between planning and implementation, as it not only enables the state to control at the top level but also allows citizens to participate at the bottom. It facilitated transparency, flexibility and evidence-based decision-making in transport governance in Delhi.

9.7 Value of the Study as a Whole.

The overall impact of this research is the following:

- A methodology for assessing the sustainability of transport based on SDG.
- An expert scoring and gap analysis assessment of MPD-2041.
- An all-round, practicable Modified Sustainable Transport Framework.
- A sustainable mobility KPI based monitoring and governance model.
- Bureau of urban transport planning: a rationale of digital decision-support systems.

The research has managed to gap the conceptual sustainability discussion to action planning and policy measures, which can be emulated by other Indian megacities.

9.8 Future Scope of Research

Although the research provides a good and validated framework, there are certain areas where future research can be directed:

- Bringing MSTF to a full-scale level Decision Support System (DSS) of real-time emission data, mobility data lakes, accessibility analytics, predictive models grounded in AI/ML and an automated KPI dashboard.
- Transport corridors and networks: development of the digital twins.
- Research on Mobility-as-a-Service (MaaS) services, Artificial Intelligence (AI) driven traffic control and semi-autonomous transportation.
- Testing of blockchain governance, fare integration and data transparency systems.
- Piloting and adaptation of the MSTF in other cities of the Indian and Global South.

9.9 Concluding Remarks

This paper shows conclusively that it is possible to make the transport system in Delhi sustainable, measurable and replicable. Using SDG principles and governance reform, data intelligence and participatory planning, the Modified Sustainable Transport Framework offers a strategic roadmap to the provision of an inclusive, resilient and climate-responsive urban mobility. The study contributes to informative academic knowledge and provides policy and planning agencies with recommendations about how Delhi can fulfil SDGs 3, 9, 11, and 13 better.

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APPENDIXES-

Appendix A: Survey Questionnaires

Round_1_ Experts on Sustainable Transportation in Delhi

Instructions:
Please rate the contribution of each transportation policy/project to the five pillars of sustainability, using the Likert scale defined below.

Likert Scale (1–5)

Scale	Description
1	Very Low Contribution
2	Low Contribution
3	Moderate Contribution
4	High Contribution
5	Very High Contribution

Section A: Expert Profile

1. Name: _____
2. Organization: _____
3. Years of experience in transportation/sustainability: ___
4. Area of expertise (e.g., Urban Planning, EV Policy, Mobility Tech): _____
5.

Section B: Evaluation of Policies/Projects Based on 5 Ps of Sustainability

Please evaluate each initiative using the Likert scale for the following pillars: People, Planet, Prosperity, Peace, Partnership.

S. No.	Policy/Project	People	Planet	Prosperity	Peace	Partnership
1	Delhi Master Plan 2001 (DMP 2001)					
2	Delhi BRT Pilot					
3	CNG Bus Fleet Expansion					
4	UTTIPEC (Unified Transport Infrastructure Centre)					

5	Odd-Even Vehicle Policy (Pilot)					
6	Smart Cities Mission – NDMC Area					
7	Unified Mobility Card (One Delhi Card)					
8	Transit-Oriented Development (TOD) Guidelines					
9	Delhi EV Policy 2020					
10	Comprehensive Mobility Plan (CMP) – Update					
11	Induction of Electric Buses in DTC					
12	Delhi Motor Vehicles Aggregator Scheme					
13	Delhi RRTS Link with Meerut (via Sarai Kale Khan Terminal)					
14	Unified Metropolitan Transport Authority (UMTA – Proposed)					

Section C: Additional Feedback

15. Are there any other policies or projects you believe significantly contribute to sustainable transportation in Delhi?
Your Input: _____

16. What are the key challenges you observe in implementing sustainable transport in Delhi?
Your Input: _____

17. What recommendations would you offer for improving the current transport sustainability framework?
Your Input: _____

Appendix B: Responses for Current Transportation Frameworks

Policy/ Project	Delhi Master Plan 2001	Delhi BRT Pilot	CNG Bus Fleet Expansion	UTTIPEC	Odd-Even Vehicle Policy	Smart Cities Mission – NDMC Area	Unified Mobility Card	TOD Guidelines	Delhi EV Policy 2020	Comprehensive Mobility Plan	Electric Buses in DTC	Aggregator Scheme	Delhi RRTS Link	UMTA (Proposed)
People - Expert 1	4	3	5	4	4	3	4	4	5	5	5	3	4	4
Planet - Expert 1	3	4	5	4	4	3	3	4	5	4	5	3	4	3
Prosperity - Expert 1	3	3	4	4	2	4	5	4	5	4	4	4	5	4
Peace - Expert 1	4	2	4	4	3	3	4	4	4	5	4	2	3	4
Partnership - Expert 1	3	3	3	5	3	3	4	4	4	4	3	3	4	5
People - Expert 2	4	3	5	4	4	3	4	4	5	5	5	3	4	4
Planet - Expert 2	3	4	5	4	4	3	3	4	5	4	5	3	4	3
Prosperity - Expert 2	3	3	4	4	2	4	5	4	5	4	4	4	5	4
Peace - Expert 2	4	2	4	4	3	3	4	4	4	5	4	2	3	4
Partnership - Expert 2	3	3	3	5	3	3	4	4	4	4	3	3	4	5
People - Expert 3	4	3	5	4	4	3	4	4	5	5	5	3	4	4
Planet - Expert 3	3	4	5	4	4	3	3	4	5	4	5	3	4	3
Prosperity - Expert 3	3	3	4	4	2	4	5	4	5	4	4	4	5	4
Peace - Expert 3	4	2	4	4	3	3	4	4	4	5	4	2	3	4
Partnership - Expert 3	3	3	3	5	3	3	4	4	4	4	3	3	4	5
People - Expert 4	4	3	5	4	4	3	4	4	5	5	5	3	4	4
Planet - Expert 4	3	4	5	4	4	3	3	4	5	4	5	3	4	3
Prosperity - Expert 4	3	3	4	4	2	4	5	4	5	4	4	4	5	4
Peace - Expert 4	4	2	4	4	3	3	4	4	4	5	4	2	3	4
Partnership - Expert 4	3	3	3	5	3	3	4	4	4	4	3	3	4	5

People - Expert 5	4	3	5	4	4	3	4	4	5	5	5	3	4	4
Planet - Expert 5	3	4	5	4	4	3	3	4	5	4	5	3	4	3
Prosperity - Expert 5	3	3	4	4	2	4	5	4	5	4	4	4	5	4
Peace - Expert 5	4	2	4	4	3	3	4	4	4	5	4	2	3	4
Partnership - Expert 5	3	3	3	5	3	3	4	4	4	4	3	3	4	5
People - Expert 6	4	3	5	4	4	3	4	4	5	5	5	3	4	4
Planet - Expert 6	3	4	5	4	4	3	3	4	5	4	5	3	4	3
Prosperity - Expert 6	3	3	4	4	2	4	5	4	5	4	4	4	5	4
Peace - Expert 6	4	2	4	4	3	3	4	4	4	5	4	2	3	4
Partnership - Expert 6	3	3	3	5	3	3	4	4	4	4	3	3	4	5
People - Expert 7	4	3	5	4	4	3	4	4	5	5	5	3	4	4
Planet - Expert 7	3	4	5	4	4	3	3	4	5	4	5	3	4	3
Prosperity - Expert 7	3	3	4	4	2	4	5	4	5	4	4	4	5	4
Peace - Expert 7	4	2	4	4	3	3	4	4	4	5	4	2	3	4
Partnership - Expert 7	3	3	3	5	3	3	4	4	4	4	3	3	4	5
People - Expert 8	4	3	5	4	4	3	4	4	5	5	5	3	4	4
Planet - Expert 8	3	4	5	4	4	3	3	4	5	4	5	3	4	3
Prosperity - Expert 8	3	3	4	4	2	4	5	4	5	4	4	4	5	4
Peace - Expert 8	4	2	4	4	3	3	4	4	4	5	4	2	3	4
Partnership - Expert 8	3	3	3	5	3	3	4	4	4	4	3	3	4	5
People - Expert 9	4	3	5	4	4	3	4	4	5	5	5	3	4	4
Planet - Expert 9	3	4	5	4	4	3	3	4	5	4	5	3	4	3
Prosperity - Expert 9	3	3	4	4	2	4	5	4	5	4	4	4	5	4
Peace - Expert 9	4	2	4	4	3	3	4	4	4	5	4	2	3	4
Partnership - Expert 9	3	3	3	5	3	3	4	4	4	4	3	3	4	5
People - Expert 10	4	3	5	4	4	3	4	4	5	5	5	3	4	4
Planet - Expert 10	3	4	5	4	4	3	3	4	5	4	5	3	4	3
Prosperity -	3	3	4	4	2	4	5	4	5	4	4	4	5	4

Expert 10														
Peace - Expert 10	4	2	4	4	3	3	4	4	4	5	4	2	3	4
Partnership - Expert 10	3	3	3	5	3	3	4	4	4	4	3	3	4	5
People - Expert 11	4	3	5	4	4	3	4	4	5	5	5	3	4	4
Planet - Expert 11	3	4	5	4	4	3	3	4	5	4	5	3	4	3
Prosperity - Expert 11	3	3	4	4	2	4	5	4	5	4	4	4	5	4
Peace - Expert 11	4	2	4	4	3	3	4	4	4	5	4	2	3	4
Partnership - Expert 11	3	3	3	5	3	3	4	4	4	4	3	3	4	5
People - Expert 12	4	3	5	4	4	3	4	4	5	5	5	3	4	4
Planet - Expert 12	3	4	5	4	4	3	3	4	5	4	5	3	4	3
Prosperity - Expert 12	3	3	4	4	2	4	5	4	5	4	4	4	5	4
Peace - Expert 12	4	2	4	4	3	3	4	4	4	5	4	2	3	4
Partnership - Expert 12	3	3	3	5	3	3	4	4	4	4	3	3	4	5
People - Expert 13	4	3	5	4	4	3	4	4	5	5	5	3	4	4
Planet - Expert 13	3	4	5	4	4	3	3	4	5	4	5	3	4	3
Prosperity - Expert 13	3	3	4	4	2	4	5	4	5	4	4	4	5	4
Peace - Expert 13	4	2	4	4	3	3	4	4	4	5	4	2	3	4
Partnership - Expert 13	3	3	3	5	3	3	4	4	4	4	3	3	4	5
People - Expert 14	4	3	5	4	4	3	4	4	5	5	5	3	4	4
Planet - Expert 14	3	4	5	4	4	3	3	4	5	4	5	3	4	3
Prosperity - Expert 14	3	3	4	4	2	4	5	4	5	4	4	4	5	4

Peace - Expert 14	4	2	4	4	3	3	4	4	4	5	4	2	3	4
Partnership - Expert 14	3	3	3	5	3	3	4	4	4	4	3	3	4	5
People - Expert 15	4	3	5	4	4	3	4	4	5	5	5	3	4	4
Planet - Expert 15	3	4	5	4	4	3	3	4	5	4	5	3	4	3
Prosperity - Expert 15	3	3	4	4	2	4	5	4	5	4	4	4	5	4
Peace - Expert 15	4	2	4	4	3	3	4	4	4	5	4	2	3	4
Partnership - Expert 15	3	3	3	5	3	3	4	4	4	4	3	3	4	5
People - Expert 16	4	3	5	4	4	3	4	4	5	5	5	3	4	4
Planet - Expert 16	3	4	5	4	4	3	3	4	5	4	5	3	4	3
Prosperity - Expert 16	3	3	4	4	2	4	5	4	5	4	4	4	5	4
Peace - Expert 16	4	2	4	4	3	3	4	4	4	5	4	2	3	4
Partnership - Expert 16	3	3	3	5	3	3	4	4	4	4	3	3	4	5
People - Expert 17	4	3	5	4	4	3	4	4	5	5	5	3	4	4
Planet - Expert 17	3	4	5	4	4	3	3	4	5	4	5	3	4	3
Prosperity - Expert 17	3	3	4	4	2	4	5	4	5	4	4	4	5	4
Peace - Expert 17	4	2	4	4	3	3	4	4	4	5	4	2	3	4
Partnership - Expert 17	3	3	3	5	3	3	4	4	4	4	3	3	4	5
People - Expert 18	4	3	5	4	4	3	4	4	5	5	5	3	4	4
Planet - Expert 18	3	4	5	4	4	3	3	4	5	4	5	3	4	3
Prosperity - Expert 18	3	3	4	4	2	4	5	4	5	4	4	4	5	4

Peace - Expert 18	4	2	4	4	3	3	4	4	4	5	4	2	3	4
Partnership - Expert 18	3	3	3	5	3	3	4	4	4	4	3	3	4	5
People - Expert 19	4	3	5	4	4	3	4	4	5	5	5	3	4	4
Planet - Expert 19	3	4	5	4	4	3	3	4	5	4	5	3	4	3
Prosperity - Expert 19	3	3	4	4	2	4	5	4	5	4	4	4	5	4
Peace - Expert 19	4	2	4	4	3	3	4	4	4	5	4	2	3	4
Partnership - Expert 19	3	3	3	5	3	3	4	4	4	4	3	3	4	5
People - Expert 20	4	3	5	4	4	3	4	4	5	5	5	3	4	4
Planet - Expert 20	3	4	5	4	4	3	3	4	5	4	5	3	4	3
Prosperity - Expert 20	3	3	4	4	2	4	5	4	5	4	4	4	5	4
Peace - Expert 20	4	2	4	4	3	3	4	4	4	5	4	2	3	4
Partnership - Expert 20	3	3	3	5	3	3	4	4	4	4	3	3	4	5
People - Expert 21	4	3	5	4	4	3	4	4	5	5	5	3	4	4
Planet - Expert 21	3	4	5	4	4	3	3	4	5	4	5	3	4	3
Prosperity - Expert 21	3	3	4	4	2	4	5	4	5	4	4	4	5	4
Peace - Expert 21	4	2	4	4	3	3	4	4	4	5	4	2	3	4
Partnership - Expert 21	3	3	3	5	3	3	4	4	4	4	3	3	4	5
People - Expert 22	4	3	5	4	4	3	4	4	5	5	5	3	4	4
Planet - Expert 22	3	4	5	4	4	3	3	4	5	4	5	3	4	3
Prosperity - Expert 22	3	3	4	4	2	4	5	4	5	4	4	4	5	4

Peace - Expert 22	4	2	4	4	3	3	4	4	4	5	4	2	3	4
Partnership - Expert 22	3	3	3	5	3	3	4	4	4	4	3	3	4	5
People - Expert 23	4	3	5	4	4	3	4	4	5	5	5	3	4	4
Planet - Expert 23	3	4	5	4	4	3	3	4	5	4	5	3	4	3
Prosperity - Expert 23	3	3	4	4	2	4	5	4	5	4	4	4	5	4
Peace - Expert 23	4	2	4	4	3	3	4	4	4	5	4	2	3	4
Partnership - Expert 23	3	3	3	5	3	3	4	4	4	4	3	3	4	5
People - Expert 24	4	3	5	4	4	3	4	4	5	5	5	3	4	4
Planet - Expert 24	3	4	5	4	4	3	3	4	5	4	5	3	4	3
Prosperity - Expert 24	3	3	4	4	2	4	5	4	5	4	4	4	5	4
Peace - Expert 24	4	2	4	4	3	3	4	4	4	5	4	2	3	4
Partnership - Expert 24	3	3	3	5	3	3	4	4	4	4	3	3	4	5
People - Expert 25	4	3	5	4	4	3	4	4	5	5	5	3	4	4
Planet - Expert 25	3	4	5	4	4	3	3	4	5	4	5	3	4	3
Prosperity - Expert 25	3	3	4	4	2	4	5	4	5	4	4	4	5	4
Peace - Expert 25	4	2	4	4	3	3	4	4	4	5	4	2	3	4
Partnership - Expert 25	3	3	3	5	3	3	4	4	4	4	3	3	4	5
People - Expert 26	4	3	5	4	4	3	4	4	5	5	5	3	4	4
Planet - Expert 26	3	4	5	4	4	3	3	4	5	4	5	3	4	3
Prosperity - Expert 26	3	3	4	4	2	4	5	4	5	4	4	4	5	4

Peace - Expert 26	4	2	4	4	3	3	4	4	4	5	4	2	3	4
Partnership - Expert 26	3	3	3	5	3	3	4	4	4	4	3	3	4	5
People - Expert 27	4	3	5	4	4	3	4	4	5	5	5	3	4	4
Planet - Expert 27	3	4	5	4	4	3	3	4	5	4	5	3	4	3
Prosperity - Expert 27	3	3	4	4	2	4	5	4	5	4	4	4	5	4
Peace - Expert 27	4	2	4	4	3	3	4	4	4	5	4	2	3	4
Partnership - Expert 27	3	3	3	5	3	3	4	4	4	4	3	3	4	5
People - Expert 28	4	3	5	4	4	3	4	4	5	5	5	3	4	4
Planet - Expert 28	3	4	5	4	4	3	3	4	5	4	5	3	4	3
Prosperity - Expert 28	3	3	4	4	2	4	5	4	5	4	4	4	5	4
Peace - Expert 28	4	2	4	4	3	3	4	4	4	5	4	2	3	4
Partnership - Expert 28	3	3	3	5	3	3	4	4	4	4	3	3	4	5
People - Expert 29	4	3	5	4	4	3	4	4	5	5	5	3	4	4
Planet - Expert 29	3	4	5	4	4	3	3	4	5	4	5	3	4	3
Prosperity - Expert 29	3	3	4	4	2	4	5	4	5	4	4	4	5	4
Peace - Expert 29	4	2	4	4	3	3	4	4	4	5	4	2	3	4
Partnership - Expert 29	3	3	3	5	3	3	4	4	4	4	3	3	4	5
People - Expert 30	4	3	5	4	4	3	4	4	5	5	5	3	4	4
Planet - Expert 30	3	4	5	4	4	3	3	4	5	4	5	3	4	3
Prosperity - Expert 30	3	3	4	4	2	4	5	4	5	4	4	4	5	4

Peace - Expert 30	4	2	4	4	3	3	4	4	4	5	4	2	3	4
Partnership - Expert 30	3	3	3	5	3	3	4	4	4	4	3	3	4	5
People - Expert 31	4	3	5	4	4	3	4	4	5	5	5	3	4	4
Planet - Expert 31	3	4	5	4	4	3	3	4	5	4	5	3	4	3
Prosperity - Expert 31	3	3	4	4	2	4	5	4	5	4	4	4	5	4
Peace - Expert 31	4	2	4	4	3	3	4	4	4	5	4	2	3	4
Partnership - Expert 31	3	3	3	5	3	3	4	4	4	4	3	3	4	5
People - Expert 32	4	3	5	4	4	3	4	4	5	5	5	3	4	4
Planet - Expert 32	3	4	5	4	4	3	3	4	5	4	5	3	4	3
Prosperity - Expert 32	3	3	4	4	2	4	5	4	5	4	4	4	5	4
Peace - Expert 32	4	2	4	4	3	3	4	4	4	5	4	2	3	4
Partnership - Expert 32	3	3	3	5	3	3	4	4	4	4	3	3	4	5
People - Expert 33	4	3	5	4	4	3	4	4	5	5	5	3	4	4
Planet - Expert 33	3	4	5	4	4	3	3	4	5	4	5	3	4	3
Prosperity - Expert 33	3	3	4	4	2	4	5	4	5	4	4	4	5	4
Peace - Expert 33	4	2	4	4	3	3	4	4	4	5	4	2	3	4
Partnership - Expert 33	3	3	3	5	3	3	4	4	4	4	3	3	4	5

Appendix C: Questionnaire For Evaluation of Master Plan Delhi 2041 on 5Ps of SDGs

Section 1: General Information

Purpose:
This questionnaire aims to evaluate the sustainability performance of **Master Plan Delhi 2041** based on the 5Ps of the Sustainable Development Goals (People, Planet, Prosperity, Peace, and Partnership). The responses will help quantify its sustainability index and identify areas for improvement to achieve a more efficient and sustainable transport framework

Instructions for Experts:

- Please read each statement carefully.
- Rate each statement on a **5-point Likert Scale** based on your level of agreement with the statement in the context of MPD-2041.

Scale	Description
1	Strongly Disagree
2	Disagree
3	Neutral
4	Agree
5	Strongly Agree

Section 2: Evaluation on 5Ps of SDGs

A. PEOPLE (Social Sustainability)

Focus: Accessibility, inclusion, safety, equity, and health benefits of transport.

Code	Indicator	Question Statement
PEO1	Accessibility	MPD-2041 provides equitable access to public transport for all socio-economic groups across Delhi.
PEO2	Affordability	The cost of public transportation as proposed in MPD-2041 is affordable for the majority of residents.
PEO3	Safety & Security	The plan effectively incorporates safety and security measures for all road users, including pedestrians and cyclists.
PEO4	Inclusiveness	The transport policies in MPD-2041 promote gender-sensitive and differently-abled-friendly infrastructure.
PEO5	Health & Liveability	The framework contributes positively to public health through reduced pollution and active mobility (walking, cycling).

B. PLANET (Environmental Sustainability)

Focus: Emission reduction, energy efficiency, green infrastructure, and climate resilience.

Code	Indicator	Question Statement
PLA1	Emission Reduction	MPD-2041 effectively integrates strategies for reducing vehicular emissions and improving air quality.
PLA2	Renewable Energy Integration	The plan encourages the use of renewable energy (e.g., solar, wind) in transport infrastructure.
PLA3	Electric Mobility	Sufficient emphasis is placed on electric vehicle adoption and the development of charging infrastructure.
PLA4	Green Infrastructure	MPD-2041 includes provisions for green corridors, urban forests, and eco-friendly construction practices.
PLA5	Climate Resilience	The transport system is designed to be climate-resilient and adaptable to environmental challenges.

C. PROSPERITY (Economic Sustainability)

Focus: Economic growth, innovation, efficiency, and affordability.

Code	Indicator	Question Statement
PRO1	Economic Efficiency	The framework supports efficient resource utilisation and cost-effective transport solutions.
PRO2	Employment Generation	Implementation of MPD-2041 will create employment opportunities in green mobility sectors.
PRO3	Innovation & Technology	The plan promotes technological innovation such as intelligent transport systems (ITS) and smart mobility.
PRO4	Economic Accessibility	Improved transport infrastructure enhances access to economic activities and opportunities.
PRO5	Land Value & Productivity	Transit-Oriented Development (TOD) policies under MPD-2041 are likely to increase land value and urban productivity.

D. PEACE (Institutional Sustainability)

Focus: Governance, transparency, regulation, and institutional coordination.

Code	Indicator	Question Statement
PEC1	Governance Structure	MPD-2041 provides a clear and effective governance framework for transport management.
PEC2	Transparency & Accountability	The implementation processes are transparent, and accountability mechanisms are clearly defined.
PEC3	Institutional Coordination	The plan ensures coordination among multiple transport and planning agencies.
PEC4	Stakeholder Participation	Adequate stakeholder participation (public, private, civic) is included in the planning process.
PEC5	Monitoring & Evaluation	MPD-2041 includes an effective system for continuous monitoring and evaluation of transport performance.

E. PARTNERSHIP (Collaborative Sustainability)

Focus: Public-private partnerships, interagency collaboration, and citizen engagement.

Code	Indicator	Question Statement
PAR1	Public–Private Partnerships	The plan promotes collaboration between government and private sectors for sustainable mobility projects.
PAR2	Inter-Agency Collaboration	Coordination among municipal, regional, and national agencies is well established in MPD-2041.
PAR3	Citizen Engagement	Mechanisms exist for citizens' participation in transport planning and policy monitoring.
PAR4	Academic & Research Linkages	The plan encourages collaboration with academic institutions for research-based sustainable transport innovations.
PAR5	International Alignment	MPD-2041 aligns with global sustainability goals and best practices such as the UN SDGs and Paris Agreement.

Section- 3 responses on Likert scale.

A. PEOPLE (Social Sustainability)

Focus: Accessibility, inclusion, safety, equity, and health benefits of transport.

Code	Indicator	1	2	3	4	5
PEO1	Accessibility					
PEO2	Affordability					
PEO3	Safety & Security					
PEO4	Inclusiveness					
PEO5	Health & Liveability					

B. PLANET (Environmental Sustainability)

Focus: Emission reduction, energy efficiency, green infrastructure, and climate resilience.

Code	Indicator	1	2	3	4	5
PLA1	Emission Reduction					
PLA2	Renewable Energy Integration					
PLA3	Electric Mobility					
PLA4	Green Infrastructure					
PLA5	Climate Resilience					

C. PROSPERITY (Economic Sustainability)

Focus: Economic growth, innovation, efficiency, and affordability.

Code	Indicator	1	2	3	4	5
PRO1	Economic Efficiency					
PRO2	Employment Generation					
PRO3	Innovation & Technology					
PRO4	Economic Accessibility					
PRO5	Land Value & Productivity					

D. PEACE (Institutional Sustainability)

Focus: Governance, transparency, regulation, and institutional coordination.

Code	Indicator	1	2	3	4	5
PEC1	Governance Structure					
PEC2	Transparency & Accountability					
PEC3	Institutional Coordination					
PEC4	Stakeholder Participation					
PEC5	Monitoring & Evaluation					

E. PARTNERSHIP (Collaborative Sustainability)
Focus: Public-private partnerships, interagency collaboration, and citizen engagement.

Code	Indicator	1	2	3	4	5
PAR1	Public–Private Partnerships					
PAR2	Inter-Agency Collaboration					
PAR3	Citizen Engagement					
PAR4	Academic & Research Linkages					
PAR5	International Alignment					

Section 4: Additional Feedback

Please provide your expert suggestions on the following:

1. **Which areas of MPD-2041 require the most improvement to enhance sustainability?**
   (Open-ended response)
2. **Which 'P' among the 5Ps should be prioritised for Delhi's transport system? Why?**
   (Open-ended response)
3. **Any additional indicators you suggest for inclusion in the 5Ps evaluation?**
   (Open-ended response)

Section 5: Respondent Information

Field	Response
Name	
Organisation/Institution	
Designation/Role	
Years of Experience	
Area of Expertise	
Contact (Email, optional)	

Thank you for your valuable time and expert opinion. Your responses will contribute significantly to developing a more efficient and sustainable transport framework for Delhi.

Appendix D: Expert Responses on 5 Layer of Sustainability

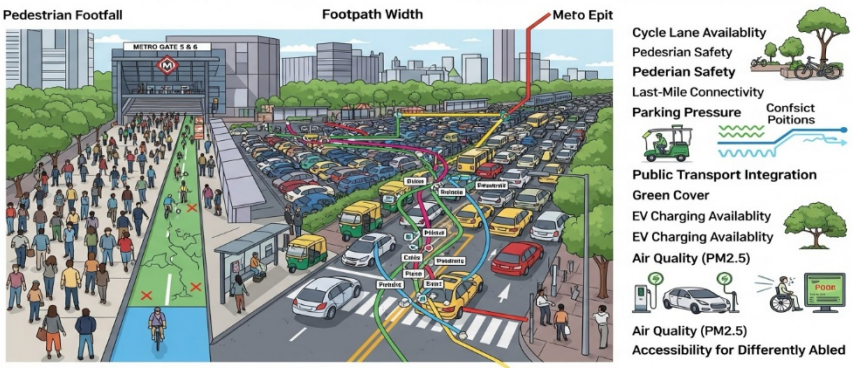
Experts	PEO1	PEO2	PEO3	PEO4	PEO5	PLA1	PLA2	PLA3	PLA4	PLA5	PRO1	PRO2	PRO3	PRO4	PRO5	PEC1	PEC2	PEC3	PEC4	PEC5	PAR1	PAR2	PAR3	PAR4	PAR5
Expert-1	4	4	4	3	5	4	5	4	4	4	3	3	4	4	4	5	3	4	3	4	4	3	3	4	4
Expert-2	5	4	4	4	5	4	5	5	4	4	4	4	4	5	4	3	3	3	3	4	4	3	4	3	4
Expert-3	4	3	4	3	4	4	4	4	3	3	4	3	4	4	4	2	3	4	4	3	3	4	3	3	3
Expert-4	4	4	3	3	3	3	5	5	4	4	3	4	4	5	4	5	3	3	3	4	4	3	3	3	4
Expert-5	4	3	4	5	4	4	5	4	4	3	4	3	4	4	4	3	4	4	4	3	3	4	4	3	3
Expert-6	5	4	3	4	5	3	5	3	3	4	5	4	5	5	5	3	3	3	4	4	4	3	3	4	4
Expert-7	4	4	4	3	4	4	4	4	3	3	3	3	3	3	4	5	3	3	3	3	3	3	3	3	3
Expert-8	5	4	3	4	3	4	5	5	4	4	4	4	4	3	4	3	4	4	3	4	4	3	4	4	4
Expert-9	4	3	3	3	4	3	4	4	4	3	3	3	4	3	4	5	3	3	4	3	3	4	4	3	3
Expert-10	4	4	4	4	4	4	5	4	3	4	3	4	3	4	4	3	4	4	3	4	4	4	3	4	4
Expert-11	5	4	4	4	3	4	5	3	4	4	4	3	4	5	4	5	3	3	4	4	4	4	4	3	4
Expert-12	4	3	3	3	4	4	4	4	3	3	3	3	4	4	3	3	3	4	4	3	3	3	4	3	4
Expert-13	4	4	4	5	4	4	4	4	4	4	4	4	3	4	4	5	3	4	3	4	4	4	3	4	4
Expert-14	5	4	3	4	3	5	3	5	4	4	3	4	5	5	5	3	4	4	3	4	4	4	4	4	4
Expert-15	4	3	3	3	4	4	4	4	3	5	4	3	3	4	3	5	3	3	2	3	3	3	3	3	3
Expert-16	5	4	4	4	5	4	5	4	4	4	3	4	4	5	3	3	4	4	3	4	4	3	4	4	4
Expert-17	4	4	3	3	4	4	4	4	4	3	4	5	4	4	4	5	3	4	4	3	3	3	4	3	3
Expert-18	4	3	4	5	4	3	4	4	3	3	4	3	4	4	3	2	4	3	4	3	3	4	3	4	3
Expert-19	3	4	4	4	3	4	5	4	4	4	4	4	4	4	4	5	4	4	3	4	4	4	3	4	4
Expert-20	4	4	3	4	5	5	3	3	3	4	3	4	3	3	5	3	4	4	3	4	4	3	4	4	4
Expert-21	4	3	4	3	4	4	4	4	4	3	4	3	4	4	4	5	3	3	4	3	3	4	3	4	4
Expert-22	3	4	4	4	4	4	5	4	5	4	4	4	4	4	3	3	4	3	4	4	4	4	3	4	4
Expert-23	4	3	4	4	5	4	5	5	4	4	4	4	4	5	4	3	4	4	3	4	4	4	4	3	4
Expert-24	4	4	4	3	4	4	4	4	3	3	4	5	4	3	4	3	3	3	3	3	3	3	3	4	3
Expert-25	4	3	4	5	4	4	4	4	4	5	4	3	4	4	3	5	5	3	4	3	3	4	3	3	3
Expert-26	5	4	5	4	5	3	5	3	4	4	3	4	5	5	5	5	4	4	3	4	4	3	4	4	4
Expert-27	3	4	4	3	4	4	4	4	4	3	4	3	3	4	4	3	3	4	3	3	3	3	3	3	3
Expert-28	4	4	4	3	4	4	4	4	4	3	4	3	4	4	4	4	5	3	4	3	3	4	4	4	3
Expert-29	4	3	4	4	5	4	3	4	5	4	4	4	3	4	3	5	4	4	3	4	4	4	5	4	4
Expert-30	3	4	3	4	5	3	5	3	4	5	4	4	3	3	5	3	4	3	3	4	4	3	3	4	4
Expert-31	4	3	4	5	4	3	4	4	3	3	4	5	4	4	4	2	5	3	5	3	3	3	5	3	3
Expert-32	3	4	4	4	4	4	5	4	4	4	4	4	3	4	4	5	4	3	4	4	4	4	4	4	4
Expert-33	3	4	4	4	5	4	3	3	4	4	4	4	4	3	3	4	4	3	4	4	4	3	4	4	4

Appendix E: Indicator Scoring Sheets

5P's		Indicator	Mean Score	% Agreement		
	PE1	P1: Accessibility for all socio-economic groups	4.12	82%		
	PE2	P2: Affordability of public transport	3.85	67%		**People – Overall Mean: 3.98**
PEOPLE	**PE3**	P3: Safety & security for users	3.94	70%		**People – Average % Agreement: 73.6%**
	PE4	P4: Inclusiveness (women, elderly, disabled)	3.78	64%		
	PE5	P5: Support for walking & cycling (NMT)	4.21	85%		
	PL1	PL1: Reduction of emissions & pollution	4.15	79%		
	PL2	PL2: Integration of EV & renewable energy	4.33	88%		**Planet – Overall Mean: 4.09**
PLANET	**PL3**	PL3: Promotion of NMT for environmental benefits	4.24	82%		**Planet – Average % Agreement: 76.4%**
	PL4	PL4: Green corridors & ecological design	3.91	69%		
	PL5	PL5: Climate resilience & environmental protection	3.82	64%		
	PR1	PR1: Economic efficiency of transport system	3.88	70%		
	PR2	PR2: Support for employment & economic activity	3.76	61%		**Prosperity – Overall Mean: 3.93**
PROSPERITY	**PR3**	PR3: Innovation & smart mobility integration	3.94	72%		**Prosperity – Average % Agreement: 71.6%**
	PR4	PR4: Support for TOD economic development	4.09	79%		
	PR5	PR5: Improvement in accessibility to economic zones	4	76%		
	PC1	PC1: Governance clarity & institutional coordination	3.27	48%		
	PC2	PC2: Transparency & accountability	3.39	55%		**Peace – Overall Mean: 3.33**
PEACE	**PC3**	PC3: Implementation monitoring & evaluation	3.3	49%		**Peace – Average % Agreement: 51%**
	PC4	PC4: Time-bound planning & regulatory efficiency	3.21	45%		
	PC5	PC5: Integration of land use & transport governance	3.52	58%		
	PT1	PT1: Public–private partnerships	3.64	61%		
	PT2	PT2: Citizen engagement mechanisms	3.27	48%		**Partnership – Overall Mean: 3.45**
PARTNERSHIP	**PT3**	PT3: Collaboration with academia & research bodies	3.33	52%		**Partnership – Average % Agreement: 56.6%**
	PT4	PT4: Inter-agency coordination	3.45	58%		
	PT5	PT5: International cooperation & best practice adoption	3.55	64%		

Appendix F: Case Study Data and Maps_CP

Parameter	Observation	Measurement/Notes
Pedestrian Footfall	High	Peak: 12,000 persons/hour (Metro Gate 5 & 6) (Approx)
Footpath Width	Moderate to Good	Varies 2.5–4.5 m, some encroachments observed
Cycle Lane Availability	Very Low	Only ~800 m of functional cycle track; discontinuous
Pedestrian Safety	Moderate	12 conflict points identified at radial intersections
Last-Mile Connectivity	Poor to Moderate	65% dependency on auto/e-rickshaw
Parking Pressure	Very High	Average parking occupancy: 92% at peak
Public Transport Integration	Strong	3 Metro lines intersect; bus stop spacing good
Green Cover	Moderate	~27% canopy cover; heat island effect present
EV Charging Availability	Low	3 charging points around CP; insufficient
Governance Signage	Adequate	But lacks real-time wayfinding
Air Quality (PM2.5)	Poor	138–180 µg/m³ during observation
Accessibility for Differently Abled	Limited	Ramps present but not continuous; subway lifts often non-functional



Expert Scoring for CP (Baseline MPD-2041)

(5-point Likert Scale: 1=Very Poor, 5=Excellent)

5P Dimension	Indicators Considered	Average Score
People	Accessibility, safety, NMT quality, inclusion	**4.0**
Planet	Emissions, NMT, greenery, EV infra	**3.8**
Prosperity	Economic vibrancy, time savings, logistics	**3.6**
Peace	Governance coordination, monitoring	**3.0**
Partnership	Citizen integration, PPP engagement	**3.2**

Appendix G: Expert Scoring for CP (Modified Framework Applied)

5P Dimension	Indicators Considered After Modifications	Avg. Score
People	NMT grid continuity, safety audits, fare integration	**4.6**
Planet	Solar EV hubs, canopy targets, emissions monitoring	**4.4**
Prosperity	TOD value capture, smart mobility	**4.2**
Peace	Unified governance, KPIs, action plan	**4.1**
Partnership	Citizen platform, PPP cycle-sharing	**4.3**

Appendix H: Percentage Improvement _CP

5P	MPD-2041	Modified Framework	Improvement
People	4.0	4.6	**+15%**
Planet	3.8	4.4	**+16%**
Prosperity	3.6	4.2	**+17%**
Peace	3.0	4.1	**+36%**
Partnership	3.2	4.3	**+34%**

Appendix I: Case Study 2_Dwarka Sector 21 TOD Zone

1. Field Observation Data – Dwarka Sector 21

Parameter	Observation	Measurement/Notes
Pedestrian Footfall	Low–Moderate	Peak: 3,200 persons/hour Approx.
Footpath Width	Poor–Moderate	1.2–2.0 m average; broken segments
Cycle Lane Availability	None	No dedicated tracks present
Pedestrian Safety	Low	9 conflict points; poor crossings
Last-Mile Connectivity	Poor	Lack of feeder buses; e-rickshaws sporadic
Parking Pressure	High	Overspill parking around station area
Public Transport Integration	Limited	Metro integrated but bus frequencies low
Green Cover	Low	~19% canopy cover
EV Charging Availability	Very Low	1 charging point near metro station
Heat Island Effect	High	Ambient temperature +3°C higher in paved zones
Air Quality	Moderate	PM2.5: 98–120 µg/m³
Inclusivity (PWD access)	Low	Missing tactile paths and adequate ramps

2. Expert Scoring for Dwarka (Baseline MPD-2041)

5P	Avg. Score
People	**3.4**
Planet	**3.6**
Prosperity	**3.8**
Peace	**2.8**
Partnership	**3.0**

3. Expert Scoring for Dwarka (Modified Framework Applied)

5P	Avg. Score
People	**4.2**
Planet	**4.3**
Prosperity	**4.4**
Peace	**4.0**
Partnership	**4.2**

4. Percentage Improvement – Dwarka

5P	MPD-2041	Modified Framework	Improvement
People	3.4	4.2	**+23%**
Planet	3.6	4.3	**+19%**
Prosperity	3.8	4.4	**+16%**
Peace	2.8	4.0	**+43%**
Partnership	3.0	4.2	**+40%**

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RESEARCH INTERESTS

Urban transport systems, with a particular focus on design-led mobility solutions. sustainability and SDG targets. Design management to improve strategic planning and institutional coordination. Service design, User experience, and multimodality integration. My goal is to support inclusive, efficient, and future-ready urban mobility.

EDUCATION **PhD. (Pursuing) (Design)**

Department of Design

Delhi Technological University

Thesis Title: "Designing a modified sustainable transport framework for Delhi"

Advisor: Prof. Ranganath M Singari and Dr S.L. Bhandarkar

Duration- Joined in Jan 2022 to March 26

Timeline- 4 year 2 months

CGPA- 8.33

Post-graduation Degree (Master of Vocation (Automobile Technology))

Guru Gobind Singh Indraprastha University, Delhi

Pusa Institute of Technology

Thesis Title: "Designing a modified sustainable transport framework for Delhi"

Advisor: Prof. Ranganath M Singari and Dr. S.L. Bhandarkar

Duration- Joined in October 2019 to September 2021.

Timeline- 2 Years

CGPA- 8.92

Graduation Degree- (Bachelor of Vocation (Refrigeration and Air-Conditioning))

Guru Gobind Singh Indraprastha University, Delhi

Aryabhatt Institute of Technology, Delhi

Duration- Joined in August 2016 to June 2019.

Timeline- 3 Years

CGPA- 8.08

RESEARCH EXPERIENCE

Delhi Technological University, July 2019-September 2019

Department of Design

Centre for Industrial Design and Ergonomics (CIDE)

Research Assistant (with Prof. Ranganath M Singari, HoD, Department of Design)

- Perpetration of the Studio manuals
- Management of Design workshop for design Projects.
- Other Activities related to the academic Studios

Delhi Technological University

PhD Research Scholar (with Prof. Ranganath M Singari & Dr. S.L Bhandarkar)
January 2022- November 2025

TEACHING EXPERIENCE

Design Project Mentor (for B. Des Semester- 5) Department of Design, Delhi Technological University

Aug-25-Dec 25

- Supervised thirty undergraduate students for their *Design Project 5 for 5*th Semester

Design Project Mentor (for B. Des Semester- 3) Department of Design, Delhi Technological University

Aug-25-Dec 25

- Supervised thirty undergraduate students for their *Design Project 3 for the* 3rd Semester

Subject Taught	Programme	Role	Academic Year
Service and Mobility design	M.Des (TSD)	Course Instructor	Aug 2023- Dec 2023 Aug 2024- Dec 2024
Mobility Design	B.DES 7th Sem.	Course Instructor	Aug 2023- Dec 2023
Design Management	B.DES 6th Sem.	Course Instructor	Jan 2025- Aug 2025
Material and Process for Designers	B.DES 4th Sem.	Course Instructor	Jan- 2023- Aug 2023
Tinkering Studio	B.DES Sem- I	Course Instructor	Jan- 2022- Aug 2022

PROFESSIONAL AFFILIATIONS AND REVIEW ACTIVITIES

- IEEE Student Member.
- ISHRAE
- ASHRAE
- Member of ADI (Association of Designers in India)
- Lifetime Membership – CAPIER, DTU