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SPATIAL PARAMETERS FOR MULTIMODAL INTEGRATION AT METRO STATIONS A CONDUCIVE CASE STUDY OF METRO STATIONS IN DELHI

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ABSTRACT

Urban public transit contributes to the multisector growth of a developing economy and is an essential component of sustainable urban development. Public transit has seen considerable upsurge in ridership over the past decade. In order to make public transportation more appealing to regular commuters than private automobiles, the current infrastructure in the majority of India's metropolitan cities must be modernized in a sustainable way. The Delhi Metro was designed with an identical objective in consideration, anticipating the increasing concern over traffic in and around the Delhi region, and after being implemented, it significantly reduced the number of individual vehicles on the road. Delhi Metro operates within the framework of the citywide multi-modal integrated transportation system, reinforced by other modes such as buses and IPT. It is the lifeline of Delhi's urban transit system. This research paper aims to study numerous aspects of multimodal integration at metro stations in order to increase the passengers' comfort and convenience. Convenient transitions in a multimodal transportation system are greatly aided by station amenities like the physical infrastructure, which includes the parking space, transfer area, metro ridership data, pedestrian network, cycling facilities, feeder shelter, taxi stands (IPT Stands), etc. Furthermore, it intends to promote walkability by establishing a high-quality public realm that is both welcoming and secure for anyone to use. This research is centered around Delhi Metro stations on the Yellow line. An extensive inventory of the station area and a commuter travel time questionnaire were used to evaluate the current state of affairs. Several standards of design were analyzed to optimize the output of research. The inferences yield specific recommendations and modifications for the present system, in addition to identifying several best practices that could be reiterated across all stations.

Keywords: Public Transit System, Multimodal Integration, Physical Infrastructure, Convenient Transition, Spatial Allocation

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1. INTRODUCTION

1.1. URBAN GROWTH AND TRANSIT CHALLENGES

Urban areas in developing nations are rapidly expanding to accommodate population growth and infrastructural demands. As GDP increases, cities are pressured to enhance their amenities, including public transit systems. In India, particularly in urban centers like Delhi, the rise in motor vehicle ownership has outpaced the development of public transit infrastructure. Delhi, with a population of approximately 16.8 million (Census of India, 2011), represents a significant case study; despite housing only 1.4% of India's population, it accounts for nearly 7% of the nation's motor

vehicles (Singh, 2005). This paper examines the multimodal integration of Delhi's transit system, focusing on the Delhi Metro's line haul mode.

1.2. COMPONENTS OF A MULTIMODAL TRANSIT SYSTEM

A comprehensive multimodal transit system includes four key components: access leg, egress leg, line haul leg, and transfer stages. Effective integration of public, personal, and non-motorized transport (NMT) modes is essential for seamless connectivity (Krygsman et al., 2001). Public modes consist of metro rail, light rail, monorail, BRT, buses, and IPT modes such as tempos and autos. Personal transport includes four-wheelers and two-wheelers, while NMT encompasses walking and cycling. Integrating these modes ensures efficient city-wide transit connectivity.

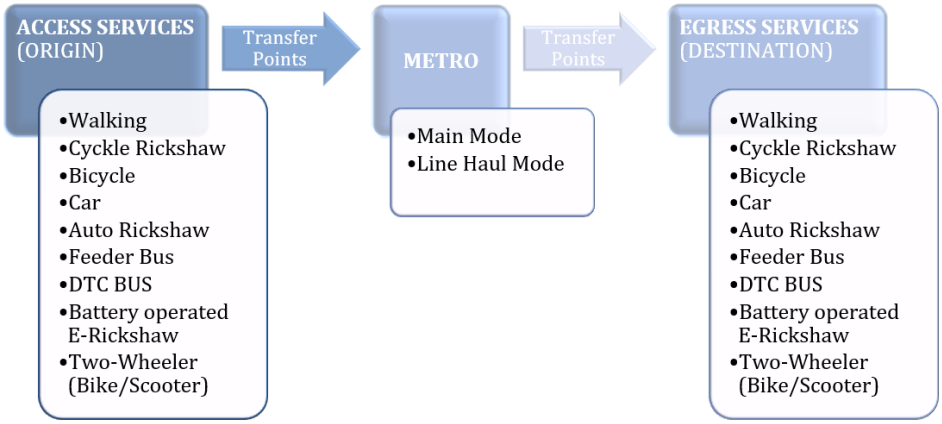

Figure 1: Structure of a Multi-Modal Trip,
Source: Author

2. NEED OF STUDY

2.1. URBAN TRANSPORTATION DEMAND AND ISSUES

Indian cities are experiencing unprecedented growth in transportation demand due to population increases, motorization, and economic development. This surge has led to road congestion, delays, and higher pollution levels. Overcrowded streets also contribute to increased accident rates. Key issues include imbalanced modal splits, insufficient infrastructure, and inefficient utilization of resources.

2.2. STUDY OBJECTIVES AND APPROACH

This study identifies gaps in multimodal integration and aims to propose a comprehensive approach to establishing a city-wide integrated transit system. The research objectives include:

- Identifying key components for a multimodal transportation system.
- Ensuring efficient access to metro stations via all transport modes, with a focus on public and non-motorized transport.
- Designing safe, attractive station environments and providing e-mobility options.
- Defining processes for integration, including preparation, planning, and design.

3. RESEARCH DESIGN

This methodology explores and enhances multimodal integration at Delhi's metro stations, particularly in Phase-III of the metro corridor. It combines quantitative and qualitative methods to assess spatial parameters and propose improvements for integrating various transportation modes.

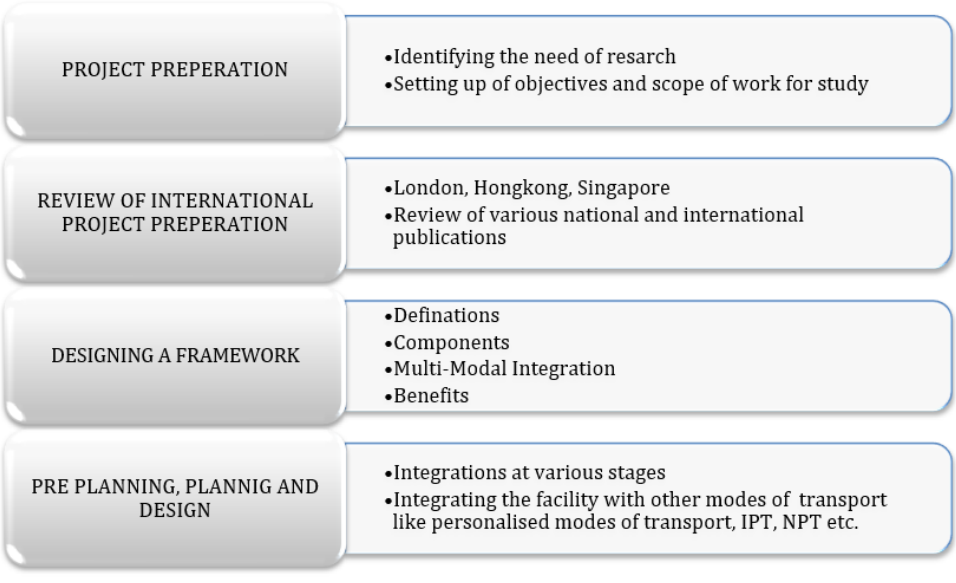

Figure 2: Research Methodology,

Source Author

3.1. RESEARCH DESIGN

A mixed-methods approach is used:

- **Quantitative Analysis:** Evaluates spatial and operational aspects of metro stations and their connections with other transport modes.
- **Qualitative Analysis:** Gathers insights on user experiences and integration effectiveness.
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3.2. DATA COLLECTION

- **Primary Data:** Includes field surveys and observational studies at selected metro stations to understand commuter experiences and interactions between transport modes.
- **Secondary Data:** Involves reviewing relevant literature and analyzing policy documents to gather existing knowledge on multimodal integration.

3.3. DATA ANALYSIS

- **Quantitative Analysis:** Utilizes GIS for spatial mapping and statistical software for analyzing survey data.
- **Qualitative Analysis:** Employs thematic analysis of interview and observation data, and compares case studies from other cities.

3.4. INTEGRATION AND RECOMMENDATIONS

- Integration of Findings: Combines quantitative and qualitative results to identify issues and propose improvements.
- Recommendations: Develops strategies for better multimodal integration based on the analysis.

3.5. CONCLUSION

- **Summary:** Highlights key findings and their implications for enhancing metro station integration.
- **Future Research:** Suggests areas for further study to expand on the current findings.

3.6. ETHICAL CONSIDERATIONS

Ensures informed consent, confidentiality of data, and addresses potential biases to maintain research integrity.

4. IDENTIFICATION OF STUDY AREA

Delhi, the National Capital of India, features a well-developed public transit system that continues to undergo significant improvements. Despite these advancements, challenges persist in optimizing the integration and efficiency of the system. The Delhi Metro, a cornerstone of Delhi's transit infrastructure, is the focus of this analysis, particularly its violet and yellow lines.

The Yellow Line (Line 2), spanning 49.02 km, connects Samaypur Badli in Delhi to Millennium City Centre in Gurgaon (Delhi Metro Rail Corporation, n.d.). This line is notable for its integration with multiple metro lines, including the Red, Blue, Pink, and magenta lines, and links with major railway stations like Old Delhi and New Delhi (Delhi Metro Rail Corporation, 2023). This extensive connectivity facilitates seamless travel across the Delhi-NCR region and enhances accessibility to key urban and suburban areas. The Violet Line (Line 6) extends 46.34 km from Kashmere Gate in New Delhi to Raja Nahar Singh in Ballabhgarh, with 34 stations along the route (Delhi Metro Rail Corporation, n.d.). It serves as a vital link, providing access to South Delhi, Central Delhi, and the satellite town of Faridabad (Delhi Metro Rail Corporation, 2023). The line's strategic connections and extensions improve mobility within Delhi and its neighboring areas.

Since its inception in 2002, the Delhi Metro has undergone two phases of expansion, with Phases 3 and 4 planned for the next decade (Delhi Metro Rail Corporation, 2023). This research evaluates the current metro infrastructure and operational practices to identify best practices and strategies for future expansions. By focusing on these lines, the study aims to enhance the understanding of multimodal integration and inform the development of more effective transit solutions in Delhi.

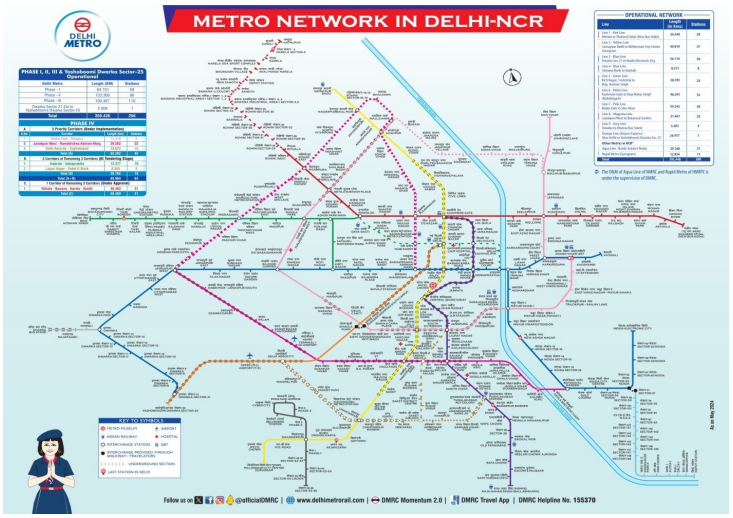

Figure 3: Network Map of Delhi Metro routes, Available at: https://www.delhimetrorail.com/network_map (Retrieved 23 August 2021)

5. LITERATURE REVIEW

5.1. CHALLENGES IN MULTIMODAL TRANSPORTATION

This research synthesizes data from primary and secondary sources to explore challenges in multimodal transportation, focusing on egress and transitions between modes. Sun et al. (2007) highlight the importance of optimizing transfer points to enhance efficiency and reduce costs, considering factors such as area size and operational requirements.

5.2. FACTORS INFLUENCING TRANSFER OPTIONS

The attractiveness of transfer options depends on accessibility and integration within the transport network (Maxwell, 2003). Factors such as cost integration, comfort, and safety are critical (Hidalgo, 2009; Atkins, 1990; Kumar et al., 2011; Guo and Wilson, 2011). Efficient use of existing modes is vital for improving system efficiency in cities like Delhi (Naveen Eluru et al., 2012).

5.3. INTERNATIONAL PRACTICES AND INSIGHTS

Studies underscore the importance of information services and well-planned routes for passenger decision-making (Sharfuddin et al., 2000). Network integration and fare integration are key factors influencing commuter willingness (Chowdhury and Ceder, 2013). International examples, such as the Trans Bay Transit Centre in San Francisco, illustrate successful multimodal hubs (Stutzki and Knowles, 2018).

5.4. INFERENCESS FROM LITTERATURE REVIEW

Effective multimodal transportation systems require optimized transfer points, integrated networks, and user-friendly facilities. Factors influencing passenger decisions include accessibility, safety, comfort, and information availability. Strategic planning and local management are essential for enhancing urban mobility and addressing transportation challenges.

6. MULTIMODAL URBAN TRANSIT SYSTEM

6.1. CONCEPT AND GOALS OF MULTIMODAL INTEGRATION

Multimodal integration refers to the strategic coordination of various transportation modes—such as walking, cycling, personal vehicles, intermediate public transport, and mass transit—with seamless connections between them. The objective is to optimize each mode's contribution to the transportation network, viewing them as complementary rather than competitive. Effective public transit systems require intermodal integration to enhance overall efficiency and attractiveness (Hasan et al., 2021).

6.2. BENEFITS OF INTEGRATION

The goal is to increase public transit usage by facilitating easier transitions between modes within transport hubs. This improves accessibility to destinations solely via public transport, enhancing user experience and reducing transfer complexities and costs (Rocha et al., 2021). Urban rail systems, including suburban trains and metros, cater to commuters beyond walking distance, relying on feeder services such as buses, auto rickshaws, and taxis. Effective integration of these modes is crucial for maximizing overall benefits (UNDP, 2019).

6.3. GLOBAL APPROACHES TO MULTIMODAL INTEGRATION

Different strategies are employed globally to optimize transportation networks through multimodal integration:

- **Cycling to Public Transport Facilities**

Utilizing bicycles for commuting between railway stations and transit hubs, a concept known as "Bike-and-Ride." Some transport modes allow bicycles onboard, enabling cycling at both ends of the journey.

Public bike rental programs in certain cities facilitate access to and from train stations.

- **Automobile to Public Transport Facilities**

Cars, though primarily used individually, serve in multi-modal contexts for short-distance travel to stations, airports, and bus stops, with "park and ride" facilities.

- Bus to Public Transport Facilities

Major cities integrate bus networks with rail routes, extending access beyond direct rail connections.

Feeder buses synchronized with train and metro schedules enhance passenger access and operational efficiency.

- Transfer Facilities

Recent efforts focus on improving transfer facilities to streamline intermodal journeys.

Intermodal stations combining rail, road, and air transport services aim to simplify transfers between different modes.

7. BENEFITS OF MULTIMODAL TRANSPORT INTEGRATION

Various stakeholders are involved in multi-modal transit hub projects, including transit operators, agencies, and commuters. Multi-modal integration offers several prospective benefits to these stakeholders:

Prospective benefits to Transit Operators and Agencies:

- Increased profit and productivity: Multi-modal integration can lead to higher numbers of travelers using the system, thereby increasing fare revenue and overall profitability.
- Reduced dependency on civic services: Integration can potentially lessen the need for additional support from municipal or government bodies.
- Enhanced attractiveness: Transit hubs with integrated services can create a more appealing environment for travelers, potentially leading to increased ridership.
- Optimized resource allocation: By consolidating services at hubs, operators can reallocate resources to improve service frequency and efficiency.
- Reduced operational oversight: Integrating feeder services at hubs can simplify route monitoring and management.

Prospective benefits for Travelers:

- Improved accessibility:
- Multi-modal hubs offer a highly accessible and user-friendly environment, accommodating different mobility needs.
- Time savings:
- Travelers can save time by easily switching between modes of transport at a single hub rather than traveling to multiple locations.
- Increased transport options:
- Hubs provide a variety of transport routes and services, giving travelers more flexibility in choosing their preferred mode of transportation.
- Enhanced comfort:
- Intermodal hubs offer better interchange facilities, ensuring a smoother transition between different modes of transport.
- Environmental benefits:
- Integration reduces duplication of routes, leading to decreased pollution and environmental impact.
- Traffic improvement:
- By encouraging the use of public transport, multi-modal integration can help alleviate traffic congestion in urban areas.
- Economic advantages:
- Less congested transport corridors can lead to economic benefits such as improved local business productivity and reduced infrastructure maintenance costs.

8. ACHIEVING MULTIMODAL TRANSPORT INTEGRATION

Route Rationalization and Bus Feeder Systems (Packirisamy, 2016)

- Urban areas developing rail systems like metros and light rail often aim to shift commuters from private vehicles to rail transit.
- In many cities, buses play a crucial role as feeder services to rail transit networks.

- For instance,
- Singapore has successfully maintained bus routes as feeders to other transport modes despite expanding its rail system (Luk and Olszewski, 2003).
- Conversely, cities like Bangkok face challenges with high fare differentials between buses and sky trains, resulting in overcrowded buses and underutilized sky trains (Townsend and Zacharias, 2010).

Integrated Ticketing (Puhe, et. Al. 2014)

- Integrated ticketing allows passengers to use a single ticket across multiple transportation modes or operators.
- Smart ticketing systems store passenger authorization electronically, enhancing convenience and reducing fare evasion (Turner and Wilson, 2010).
- Benefits for transit operators include increased revenue, flexibility in fare schemes, and improved data collection for better service planning.
- For travellers, integrated ticketing offers convenience, time savings, and reduced complexity in fare payments (Blythe, 2004).
- Societal benefits include improved traffic flow, reduced pollution, and economic advantages from increased public transport usage.

Transfer Facilities

- Efficient transfer facilities are crucial for seamless intermodal journeys, minimizing walking and waiting times.
- Features like covered walkways, clear signage, and weather protection enhance user experience and accessibility.
- Well-designed transfer points contribute to overall transport efficiency and passenger satisfaction.
- Land-use Planning
- Strategic land-use planning around transport hubs promotes modal integration and enhances accessibility.
- Development activities near hubs attract residents and businesses, supporting transit-oriented development (Wang, 2022).
- For instance; Bayappanahalli Intermodal Hub in Bangalore, integrating metro, buses, and railways with amenities like bicycle lanes and parking facilities.

Private Vehicle Management / Restraint

- Managing private vehicle usage is essential for effective multimodal transport.
- For instance, Measures like Park and Ride facilities in the USA and congestion pricing in Singapore incentivize public transport use and reduce traffic congestion. These strategies aim to balance private vehicle access with sustainable urban mobility solutions.

9. CURRENT SCENARIO OF MULTI-MODAL INTEGRATION IN PHASE-III METRO CORRIDOR, DELHI

In developing new station areas for Phase III of the Metro corridor, strict adherence to UTTIPEC's Multi-modal Integration and Connectivity Guidelines is crucial. These guidelines emphasize the seamless integration of various transportation modes—metro, buses, bicycles, and pedestrian pathways—to enhance urban mobility effectively. Equally

important is the retrofitting of existing metro stations to incorporate these integrated components systematically. This initiative requires clear timelines and structured programs for planning and implementation to ensure improved accessibility, efficiency, and reduced reliance on private vehicles within metro stations.

- **Integration Goals:** Ensure seamless connectivity between metro, buses, bicycles, and pedestrian pathways.
- **Retrofitting Initiative:** Implement systematic upgrades to existing metro stations to integrate multimodal components.
- **Planning and Implementation:** Establish clear timelines and structured programs for effective execution of integration plans.
- **Objectives:** Enhance accessibility, efficiency, and convenience for metro users while promoting sustainable urban transport solutions.
- **Walkability and Public Realm:** Improve pedestrian infrastructure and create a safe, comfortable public environment around metro stations.
- **Station Area Plans:** Develop comprehensive plans tailored to each station's urban context and functional role.
- **Infrastructure Assessment:** Evaluate capacity and readiness of station areas for development and enhancement.

The primary objective is to create a zone around each Phase III Metro Station (spanning 50-300 meters) that provides essential facilities and amenities as per UTTIPEC's multimodal integration checklist. This approach aims to facilitate efficient, convenient, and safe intermodal connectivity for all metro users. Key considerations include seamless transitions between different modes of transportation to complete travel trips seamlessly and affordably. The project also focuses on optimizing the organization and spatial allocation of para-transit and intermediate public transport modes to maximize convenience and operational efficiency.

Enhancing walkability and creating a high-quality public realm are integral to the project's design principles. By improving pedestrian infrastructure around metro stations, the project aims to encourage more sustainable travel choices and reduce reliance on individual vehicular trips. The comprehensive station area plans and movement strategies are tailored to maximize the transit system's effectiveness within each station's urban context and functional role. This involves identifying specific station typologies and envisioning their development in terms of character and urban form.

Furthermore, the project includes an assessment of each station area's infrastructure capacity, development of urban design concepts, accessibility plans, and transit/station improvement strategies. These efforts are geared towards creating integrated, user-friendly environments that support efficient urban transit and contribute to sustainable urban development goals.

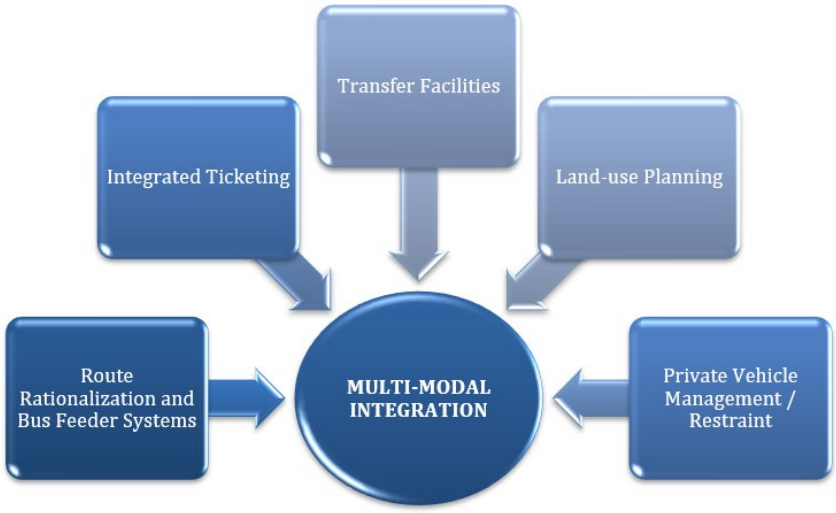

Figure 4: Elements of Multi-Modal Integration, Source: Author

10. CASE STUDY OF CHHATARPUR-MMI

The project launched the design for the first multi-modal integration at the Chattarpur Metro Station in South Delhi, adhering to the UTTIPEC Street Design Guidelines and Metro Station Checklist.

This new, world-class metro station sees over 20,000 daily visitors, many of whom need different last-mile connectivity options to complete their journeys. The pilot design for multi-modal integration at Chattarpur aims to create a convenient, modern, safe, and universally accessible environment, free of barriers, enabling people to connect seamlessly to various transport modes such as public buses, feeder buses, non-motorized transportation, and other para-transit options. This initiative is expected to enhance connectivity to and from the metro station, potentially converting many short vehicle trips into more sustainable transport modes. Special attention is given to designing the entire facility as a 'pedestrian-first' zone, ensuring climate comfort and shade.

Chattarpur Metro Station serves a catchment area of about 7 km, with nearly 19,000 people relying on para-transit modes like metro feeder buses, Garammin Seva, and auto rickshaws. Inefficient plaza planning leads to underutilized space and activity congestion at three key points, disrupting smooth pedestrian movement. Improved design and organization are necessary to enhance flow and accessibility.

The design strategy aims to transform a chaotic and congested transportation area into a well-organized and efficient hub. The current state of the area, marked by unregulated movement of buses, autos, and pedestrians, highlights the urgent need for improved infrastructure. The envisioned transformation focuses on creating a structured space with designated zones for various transportation modes and pedestrian movement. This new design features clear pathways, green spaces, and modern amenities, intending to enhance both functionality and aesthetics.

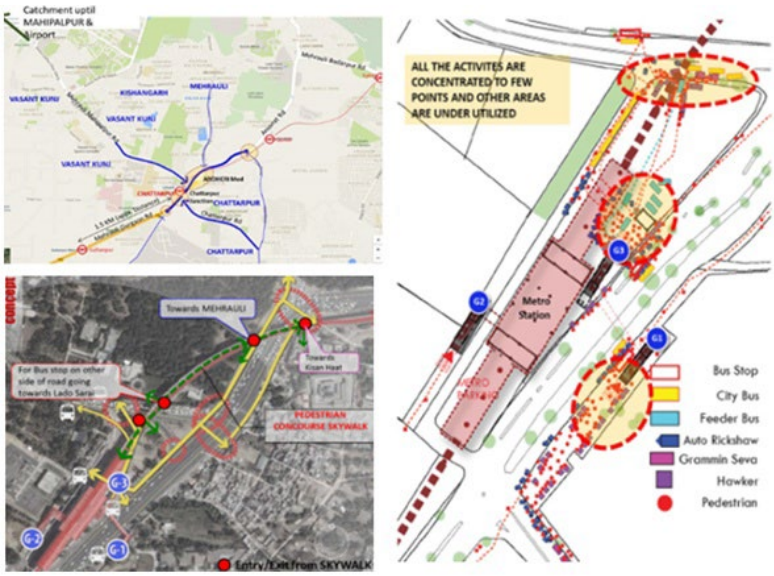

Figure 5: Existing city context, Available at: https://oasisdesigns.org/mmichattarpur.asp

11. KEY FEATURES

- **Garammin Seva Stand:** A designated area for Garammin Seva vehicles, ensuring a systematic and organized space for these local transport services, enhancing their accessibility and efficiency.
- **Auto Stand:** A specific zone for auto-rickshaws, providing a dedicated space to reduce congestion and streamline their operations, making it easier for commuters to find and hire autos.
- **Hawker's Zone:** An allocated area for street vendors, helping to organize their stalls and maintain order within the transportation hub while still supporting local businesses.
- **Cycle Stand:** A secured spot for bicycles, encouraging eco-friendly transportation options and offering a safe place for cyclists to park their bikes.

- **Public Toilet:** New restroom facilities that aim to improve sanitation and convenience for commuters and visitors, enhancing the overall experience of the transportation hub.
- **Bus Bay:** A dedicated area for buses to pick up and drop off passengers, improving the flow of bus traffic and ensuring safer boarding and alighting for passengers
- **Pedestrian Plaza:** A spacious area for pedestrians to walk and gather, designed to be safe and accessible, promoting smooth pedestrian movement within the hub.
- **Internal Multimodal Lane:** A lane designed for multiple types of transportation, facilitating seamless integration and transition between different modes of transport within the hub.
- **Food Plaza:** A designated space for food vendors and small eateries, offering a variety of food options for commuters and enhancing the overall environment with dining facilities.
- **Metro Substation and Showroom:** An area reserved for metro-related facilities, including a substation to support metro operations and a showroom that could potentially display metro-related products or services.
- **Existing and Proposed Parking Areas:** Parking zones for different types of vehicles, both existing and new, to accommodate the parking needs of commuters, including night parking for buses, thus reducing on-street parking congestion.
- **Pedestrian Concourse:** A wide, elevated walkway or passageway for pedestrians, allowing for easy and safe movement across different parts of the hub, reducing conflicts with vehicular traffic.
- **Seating Areas:** Comfortable and strategically placed seating arrangements for commuters to rest while waiting for their transportation, enhancing the comfort and usability of the hub.
- **Plaza Pump Room:** A utility area for essential services, including water pumps and other infrastructure necessary for maintaining the facilities within the hub.
- **Foot Over Bridge:** An elevated pedestrian bridge that allows people to cross busy roads or areas within the hub safely, improving connectivity and pedestrian safety.

The detailed site plan on the right provides a comprehensive layout of the proposed transportation hub. It includes designated areas for Garammin Seva stands, auto stands, and cycle stands to streamline vehicle organization. The plan also features a pedestrian plaza and a food plaza, enhancing the hub's usability and comfort for commuters. Proposed toilets and seating areas are strategically placed to improve convenience. The inclusion of a pedestrian concourse and a foot over bridge aims to ensure safe and efficient pedestrian movement. Additionally, the plan addresses parking needs with both existing and proposed parking spaces, including night parking for buses. Overall, the image conveys a strategic and well-thought-out approach to revamping a critical transportation area, focusing on improving order, safety, and commuter experience.

Figure 6: MMI Strategies at Chattarpur Metro Station, Available at: https://oasisdesigns.org/mmichattarpur.asp

Figure 7: Section through Plaza, Available at: https://oasisdesigns.org/mmichattarpur.asp

Figure 8: Current developments at Chattarpur MMI, Available at: https://oasisdesigns.org/mmichattarpur.asp

12. CASE STUDY OF NEHRU PLACE METRO STATIO- MMI, NEW DELHI

Figure 9: Existing city context, Available at: https://oasisdesigns.org/nehruplacemetrostation.asp

Nehru Place is the largest electronic market in Asia and a key commercial hub in South Delhi. The metro station serves as a crucial transportation link for the area, designed to be a destination with facilities for auto rickshaws, car parking, and drop-off spaces. The open plaza serves as a relaxation and interaction spot for metro users and commercial visitors.

Figure 10: MMI proposal at Nehru Place metro station, Available at: https://oasisdesigns.org/nehruplacemetrostation.asp

Nehru Place Metro Station is undergoing revitalization with several strategic plans aimed at enhancing the area and improving the overall user experience. One of the key initiatives is to increase the plaza area by reducing the existing parking space, which will allow for better pedestrian connectivity and a more expansive public space.

To further activate the plaza, new commercial developments are being proposed. These developments are designed to bring more activity and engagement to the area, making it a vibrant commercial hub. Additionally, dedicated drop-off zones for auto rickshaws and cars will be created, providing greater convenience for commuters and visitors.

Further plans include enhancing the vibrancy of the plaza with additional commercial spaces, ensuring that the area remains lively and attractive. A significant feature of the revitalization is the incorporation of a water body, fountain, and LED screen. These elements are intended to bring joy and create a distinct identity for Nehru Place, transforming it into a unique and enjoyable destination for all.

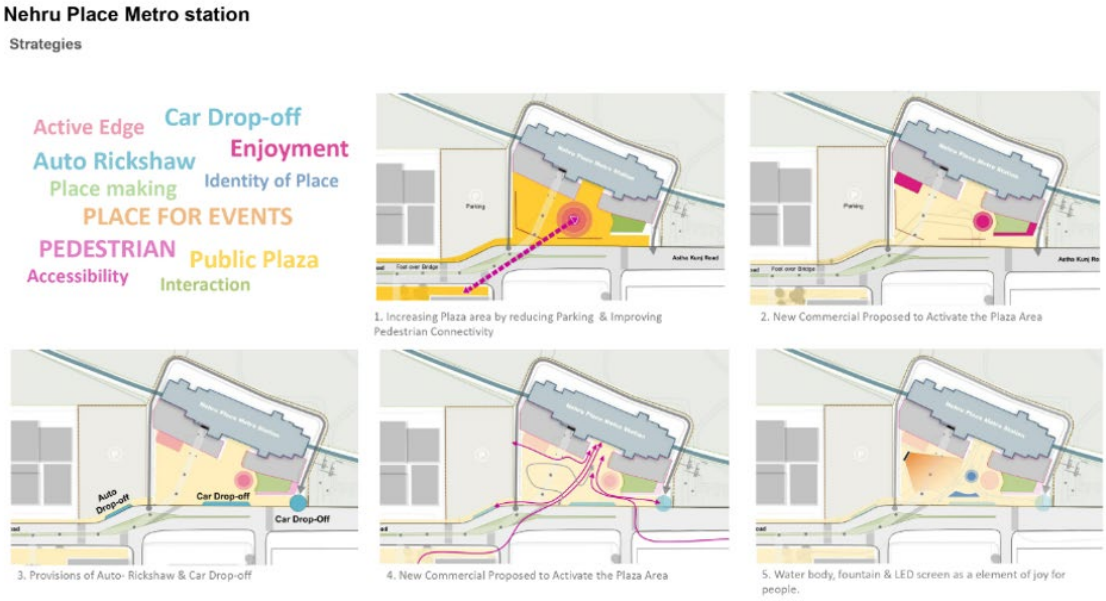

Figure 11: MMI strategies at Nehru Place metro station, Available at: https://oasisdesigns.org/nehruplacemetrostation.asp

The image provides an overview of the strategies for enhancing Nehru Place Metro Station and its surrounding area. Here is the summary:

13. KEY STRATEGIES

Figure 12: Current MMI work in progress at Nehru Place Metro Station, Available at: https://oasisdesigns.org/nehruplacemetrostation.asp

- **Active Edge:** Enhancing the perimeter with active commercial use.
- **Car Drop-off:** Dedicated areas for car drop-off to improve accessibility.
- **Auto Rickshaw Provision:** Provision for auto rickshaw services.
- **Recreational facilities:** Creating spaces that bring joy to visitors.
- **Placemaking:** Developing the area into a well-defined, attractive destination.
- **Gathering Spaces:** Allocating areas for hosting small events.
- **Pedestrian Friendly:** Improving pedestrian connectivity and comfort.
- **Public Plaza:** Creating a large, inviting public space.
- **Interaction Zones:** Designing areas that encourage social interactions.

14. INFERENCES

Based on the case studies of Chattarpur and Nehru Place Metro Stations, several critical inferences can be drawn about multimodal integration at metro stations:

- Enhanced Connectivity and Accessibility:

Seamless integration between various transport modes—such as metro, para-transit, and pedestrian infrastructure—plays a pivotal role in improving last-mile connectivity. This reduces the complexities associated with transit transfers, making commuting more efficient and convenient (Jain, Tiwari & Rao, 2020).

- Station Retrofitting and New Developments:

Retrofitting older metro stations to incorporate modern multimodal features is essential for keeping pace with growing urban mobility demands. Both case studies demonstrate that well-organized spaces and pedestrian-friendly environments enhance the overall commuter experience (Oasis Designs Inc., 2023).

- Public Realm and Pedestrian Infrastructure:

The transformation of transit hubs into pedestrian-first spaces, as seen in Chhatarpur and Nehru Place, highlights the importance of walkability and vibrant public realms. This shift encourages sustainable transport choices and creates more livable urban environments (Gehl, 2010).

- Environmental and Economic Benefits:

Multimodal integration not only alleviates traffic congestion and reduces emissions but also supports local economies. The incorporation of commercial developments at Nehru Place showcases how transit hubs can stimulate economic activity in surrounding areas (Cervero, 1998).

- Optimization of Resources:

The consolidation of various transport services at these hubs ensures efficient use of resources, streamlining operations, and enhancing service delivery. Coordinated schedules between feeder services and the metro system demonstrate this optimization (Litman, 2013).

15. CONCLUSION

This study, along with the case studies of Chattarpur and Nehru Place Metro Stations, highlights the essential role of spatial design and multimodal integration in improving urban mobility, in line with UTTIPEC's guidelines. Both stations exemplify how strategic planning can transform congested, inefficient transit areas into well-organized, user-friendly hubs (UTTIPEC, 2010).

16. KEY FINDINGS

- Enhanced Connectivity and Accessibility:

Both stations demonstrate that integrating various transport modes—metro, para-transit, and pedestrian pathways—significantly enhances the ease of transitioning between these systems. The decision to expand the public plaza at Nehru Place by reducing parking areas exemplifies how space can be reallocated to improve pedestrian experience and create more engaging public spaces.

- Station Retrofitting and New Developments:

Retrofitting existing stations, as seen at both Chattarpur and Nehru Place, proves essential to meeting the growing needs of urban commuters. The deliberate zoning of transport modes, the creation of pedestrian-first environments, and the development of new commercial spaces highlight the role that such stations can play in becoming not only transit hubs but also community centres.

- Public Realm and Pedestrian Infrastructure:

The success of these stations lies not only in their ability to manage transport but also in their transformation into welcoming public spaces. Nehru Place's enhanced plaza and Chhatarpur's pedestrian-focused design illustrate how improving the public realm contributes to increased footfall and encourages more sustainable transportation options, reducing reliance on private vehicles.

- Environmental and Economic Benefits:

Beyond their functional improvements, these stations contribute to broader environmental and economic goals. The reduction in traffic congestion and the promotion of non-motorized transport help reduce emissions, contributing to a more sustainable urban environment. Economically, the integration of commercial spaces, as in Nehru Place, revitalizes the station area and stimulates local businesses, demonstrating how transportation hubs can have a far-reaching impact on urban economies.

17. IMPLICATIONS FOR PRACTICE

- Urban Planners and Transport Authorities should prioritize clear zoning for various transport modes and improve the public realm around metro stations. Nehru Place's expanded pedestrian plaza and commercial enhancements offer a model for creating vibrant, active spaces that serve both commuters and the surrounding community.

- **Retrofitting Initiatives:**

The retrofitting of existing stations with multimodal components, as seen at both Chhatarpur and Nehru Place, must be scaled up across Delhi's metro network, ensuring they meet the growing demands of urban commuters.

18. FUTURE RESEARCH

- Further studies could explore the impacts of similar multimodal hubs on surrounding neighbourhoods and local economies.
- Technology Integration: Leveraging smart technologies to enhance commuter flow and improve coordination between transit modes should be a key area for future development.

In conclusion, Chattarpur and Nehru Place Metro Stations illustrate the transformative potential of thoughtful multimodal integration. By addressing not just transit efficiency but also the surrounding public realm, these projects create spaces that are functional, sustainable, and socially vibrant. These case studies serve as models for future metro station developments, reinforcing the idea that well-integrated transit hubs can significantly enhance urban mobility while contributing to a more sustainable and connected city.

CONFLICT OF INTERESTS

None.

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