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FEASIBILITY OF METRO NEO SYSTEM IN TIER-2 CITIES

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TRANSPORT PLANNING AND LOGISTICS MANAGEMENT

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By

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Declaration

I **Azeem Akhtar**, Scholar No. **2022MTPLM012** hereby declare that the thesis titled **"Feasibility of Metro Neo System in Tier-2 Cities"** submitted by me in partial fulfilment for the award of **Master of Planning**, at School of Planning and Architecture, Bhopal, India, is a record of bonafide work carried out by me. The matter/result embodied in this thesis has not been submitted to any other University or Institute for the award of any degree or diploma.

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Signature of the Student

Date: _______________

Certificate

This is to certify that the declaration of **Azeem Akhtar** is true to the best of my knowledge and that the student has worked under my guidance in preparing this thesis.

RECOMMENDED

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Signature of the Guide
Dr. Mohit Dev

ACCEPTED

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Prof. Saurabh Popli
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Abstract

Along with the growth of population, Indian cities (concerning their spatial area) are also growing at a very fast speed, attracting citizens from rural areas, the cities are experiencing a direct need for improvement and increment of infrastructure, which includes housing, Public transportation, Road infrastructure, water, electricity, sewage, etc.

Large cities in India including Delhi, Mumbai, Bengaluru, Chennai, etc. have been experiencing urban growth for a very long time and have been dealing with increasing population and increment in necessary public infrastructure in their way. To counter the attraction towards tier-1 cities, it is very necessary to attract people towards tier-2 also, along with their existing growing population and urban growth, they need better and extended infrastructure to cater to the needs of upcoming growth of the city.

Tier-2 cities in India need Public transportation as much as tier-1 cities, more cities are experiencing the need for metro rail to meet their day-to-day mobility requirements. While cities like Delhi and Bengaluru have seen success in the Metro rail transit system, on the other hand, some tier-2 Indian cities like Lucknow, Nagpur, and Jaipur have failed to meet their daily passenger requirement.

After observing this scenario, some other tier-2 Indian cities are looking for the possibilities of implementing the Metro Neo system for their need for public transportation. Metro Neo is a Light Rail Transit concept for a PHPDT up to 10000. It is a hybrid of Bus and Rail with a dedicated route at grade, elevated, or underground. Metroneo runs on an overhead electric power supply line and has rubber tires. The length of the coach is 18-25 meters, depending upon the requirement. Metro Neo has lesser construction as well as functioning costs as compared to other Rail-based transit systems. MoHUA has also issued guidance for the construction of Metroneo projects in November 2020.

My research will focus on the feasibility of implementing the Metro Neo system in tier-2 cities, the study will target critical differences in Rail-based transit systems based on their technicality, budget, and feasibility of construction.

सारांश

भारतीय शहरों की आबादी तेजी से बढ़ रही है, जिससे उनके क्षेत्रफल में भी वृद्धि हो रही है। ग्रामीण क्षेत्रों से आने वाली जनसंख्या के कारण शहरों में बुनियादी ढांचे के विकास की सख्त जरूरत है, जिसमें आवास, सार्वजनिक परिवहन, सड़क अवसंरचना, जल, बिजली, सीवेज आदि शामिल हैं।

दिल्ली, मुंबई, बेंगलुरु, चेन्नई जैसे बड़े शहर लंबे समय से शहरीकरण का अनुभव कर रहे हैं और बढ़ती आबादी और सार्वजनिक बुनियादी ढांचे की आवश्यकता से जूझ रहे हैं। टियर-1 शहरों की ओर रुझान को कम करने के लिए, टियर-2 शहरों को भी आकर्षक बनाना आवश्यक है। साथ ही, उनकी बढ़ती आबादी और शहरी विकास के लिए बेहतर और विस्तृत बुनियादी ढांचे की आवश्यकता है।

भारत के टियर-2 शहरों को भी टियर-1 शहरों के समान ही सार्वजनिक परिवहन की आवश्यकता है। यातायात की दैनिक आवश्यकताओं को पूरा करने के लिए अधिक शहर मेट्रो रेल की मांग कर रहे हैं। हालांकि दिल्ली और बेंगलुरु जैसे शहरों में मेट्रो रेल परिवहन प्रणाली सफल रही है, वहीं दूसरी ओर लखनऊ, नागपुर और जयपुर जैसे कुछ टियर-2 शहर दैनिक यात्री आवश्यकताओं को पूरा करने में विफल रहे हैं।

इस परिदृश्य को देखते हुए, कुछ अन्य टियर-2 भारतीय शहर सार्वजनिक परिवहन की अपनी आवश्यकता के लिए मेट्रो नियो प्रणाली को लागू करने की संभावनाओं की तलाश कर रहे हैं। मेट्रो नियो 10000 तक की यात्री क्षमता के साथ एक लाइट रेल ट्रांजिट अवधारणा है। यह बस और रेल का एक संकर है, जिसमें समतल, ऊंचा या भूमिगत समर्पित मार्ग होता है। मेट्रो नियो एक ऊपरी विद्युत आपूर्ति लाइन पर चलती है और इसमें रबर के टायर होते हैं। कोच की लंबाई आवश्यकता के अनुसार 18-25 मीटर होती है। मेट्रो नियो की निर्माण और रख-रखाव लागत अन्य रेल-आधारित परिवहन प्रणालियों की तुलना में कम है। मोहुआ ने नवंबर 2020 में मेट्रो नियो परियोजनाओं के निर्माण के लिए पहले ही दिशा-निर्देश जारी कर दिए हैं।

मेरा शोध टियर-2 शहरों में मेट्रो नियो प्रणाली को लागू करने की व्यवहार्यता पर केंद्रित होगा। यह अध्ययन उनकी तकनीकी विशेषताओं, बजट और निर्माण की व्यवहार्यता के आधार पर रेल-आधारित परिवहन प्रणालियों में महत्वपूर्ण अंतरों का लक्ष्य रखेगा।

Table of Content

List of Figures

List of Tables

List of Annexures

Abbreviations

MRTS	Mass Rapid Transit System
BRTS	Bust Rapid Transit System
LRT	Light Rail Transit
CMP	Comprehensive Mobility Plan
DPR	Detailed Project Report
MoHUA	Ministry of Housing and Urban Affairs
MoUD	Ministry of Urban Development

1. INTRODUCTION

In today's urban landscape, the need for robust and efficient public transport (PT) systems is undeniable. This is recognized by policymakers, experts, and citizens alike, driven by a common goal: to create sustainable and liveable cities. Reducing traffic congestion, pollution, and accidents are crucial factors, but the importance of PT extends beyond these immediate benefits.

The United Nations Sustainable Development Goals (UN SDGs) provide a global framework for achieving a sustainable future, and urban development is a key component. SDG 11 specifically focuses on "Sustainable Cities and Communities," highlighting the role of accessible and inclusive cities that foster innovation, economic growth, and talent attraction. Within SDG 11, Target 11.2 directly addresses urban transport, emphasizing the need for "safe, affordable, accessible and sustainable transport systems for all." This target prioritizes improving road safety and expanding public transport options, with particular attention to the needs of vulnerable populations.

1.1 Background

India is on the cusp of a significant urban transformation. Over the next two decades, the nation's urban population is projected to double. Currently, a substantial portion (nearly 30%) of this urban population resides in smaller cities with populations under 500,000 (MoHUA, 2019). This rapid urbanization trend coupled with India's commitment to the UN SDGs underscores the critical need for sustainable urban development strategies.

While there is broad agreement on the importance of investing in quality public transport, challenges arise when translating this consensus into action. Metro rail systems, for example, receive significant support and investment. However, implementing measures that prioritize public transport on existing roads, such as dedicated bus lanes and optimized junctions, often faces opposition due to concerns about increased car traffic congestion.

This presents a dilemma. Many existing metro systems in India are operating at significantly lower passenger volumes than initially projected (25-35% of ridership). Since ridership directly impacts both revenue generation and overall project benefits, these systems haven't achieved their intended outcomes. Efforts to improve bus systems have largely focused on technology upgrades and electric bus adoption, neglecting broader performance improvement strategies. Consequently, public transport ridership continues to decline in most cities, while private vehicle use (motorbikes and cars) continues to rise. These trends leave a significant portion of the population, particularly those who cannot afford private transportation, vulnerable to the dangers of congested roads and conflicts with motorized traffic.

The challenge for Indian cities, therefore, lies in developing a comprehensive and well-considered policy framework that ensures access to a high-quality public transport system for all citizens. This thesis explores the feasibility of the Metro Neo system as a potential solution for addressing these challenges in India's Tier-2 cities.

1.2 Need of the Study:

1. Tier 2 cities require a public transport system as much as any big city.
2. On congested roads in smaller cities, Can Metroneo be an option as Public Transport?
3. Seeing the success of the Metro system in some Indian cities, Metro Neo could be a good alternative where PHPDT and road width are less.

1.3 Utility of the Study:

1. Can be helpful for the authorities of the target city as well as other similar kind cities
2. Explore opportunities to integrate the Metro Neo system with smart city initiatives, such as intelligent transportation systems and digital infrastructure.

1.4 Research Framework

The research framework of my thesis is as follows:

1.4.1 Aim:

To assess if Metro Neo could be a suitable public transport option for tier 2 cities.

1.4.2 Objectives:

1. To analyze the performance of existing public transportation systems, including metro rail, in tier-2 cities.
2. To analyze the novelty of Metro Neo over other MRTS.
3. Compare the budgetary considerations of Metro Neo with other transit systems proposed in the selected city.

1.4.3 Research Question:

Can Metroneo be a suitable MRTS for a tier-2 city concerning Route alignment, Space availability, Demand, and Budget?

This research explores the feasibility of the Metroneo system as a Mass Rapid Transit Solution (MRTS) for tier-2 cities in India. The inquiry focuses on four key aspects: route alignment, space availability, passenger demand, and budgetary constraints. Firstly, the study will analyze how effectively Metroneo's route flexibility can adapt to existing urban layouts and connect critical origin-destination points within tier-2 cities. Secondly, the research will assess the space requirements of Metroneo compared to conventional metro systems, evaluating its suitability for cities with limited land resources. Thirdly, the investigation will determine if the passenger capacity of Metroneo aligns with the projected ridership growth in tier-2 cities. Finally, the study will examine the economic viability of Metroneo for tier-2 cities, considering construction costs, operational expenses, and potential ridership fares. By comprehensively evaluating these factors, this research aims to determine whether Metroneo offers a practical and sustainable MRTS solution for the evolving transportation needs of tier-2 cities in India.

1.4.4 Scope of Work:

Demand and ridership analysis: Conduct a thorough study of existing and projected transportation demand in the target city to determine the potential ridership for a Metro Neo system. Before Metro Neo takes its first spin in any city, it needs a thorough ridership check-up. This means diving deep into existing and future travel patterns, studying how people move, and figuring out how many might hop on board. This analysis is crucial to ensure the system isn't a shiny ghost train, but a bustling, well-loved ride.

Comparison of Metro Neo system with other MRTS systems: There can be various kinds of studies that need to be done to compare this transportation system with other already working transportation systems in India. The aspects in which there is a need for requirement are:

1. System Capacity and Reach

2. Cost and Infrastructure

3. Integration and Accessibility

4. Overall Suitability

1.4.5 Limitations of Study:

No completed project yet to support the study: Right now, Metro Neo is more of a vision than a reality. There's no finished project humming along yet, no trains whisking passengers through Tier-2 streets. So, studying its effectiveness is like peeking at the blueprint of a building before the first brick is laid. It's exciting, and full of potential, but still needs careful planning and construction before we can truly assess its impact.

Limited research available on the topic: Unfortunately, navigating Metro Neo's potential is like venturing into uncharted territory. Research on this specific system is still scarce, making it hard to predict its success with absolute certainty. We're flying blind in some areas, relying on educated guesses and comparisons with another system, which also means there's an exciting opportunity to be pioneers, to pave the way for a whole new era of urban mobility in Tier-2 cities.

1.4.6 Methodology:

The methodology in the table is part of the process of development of my thesis in various stages which involves:

Table 1 Research methodology

Research Methodology					
Objectives		**Task -1 Data Collection**	**Task -2 Analysis**	**Task -3 Result**	
Objective -1	To Analyse the performance of existing public transportation systems, including metro rail, in tier-2 cities.	- Annual Reports of Metro Rails across India - Papers related to BRTS systems - Find the articles/News related to the performance of MRTS systems worldwide	- Reasons for the success or failure of BRTS - Compare the worldwide performance of LRT and Metro Rail - Projected ridership data vs. actual ridership (Metro Rails in India)	- Finding the actual percentage of ridership for the metro in tier-2 cities	
		Task -1 Site Selection	**Task -2 Data Collection**	**Task -3 Analysis**	**Task -4 Results**
Objective -2	To analyze the novelty of Metro Neo over other MRTS.	- Selecting a tier -2 city to support the research of Metro Rail Under construction or functional	- Selection of an existing proposed metro route - Finding the width of ROW, space requirement, Route Alignment of the existing corridor	- Possible ways of changing existing route Differences in space requirements	- The most efficient route alignment, at grade, elevated, or underground
		Task -1 Data Collection	**Task-2 Demand**	**Task-3 Analysis**	**Task-4 Results**
Objective -3	Compare the budgetary considerations of Metro Neo with other transit systems proposed in	- From the existing Metro DPR of Agra: Forecasted Demand for Metro Acquired land Infrastructural	- Assess the actual demand of the corridor, from the provided Agra metro DPR for the horizon year	- Comparing the capital cost, land acquisition cost, - Operation and Maintenance	- Which system is more viable for the long term concerning cost?

	the selected city.	needs of Metro Capital Cost for metro O&M cost for metro		costs for Metro and Metroneo - Calculating the fare box and non-fare box revenue generation for both - Calculating the future cash flow for both.	-Analysing the result on the performance indicator matrix.

The table outlines the methodology for my thesis on the feasibility of the Metro Neo system in tier-2 cities. Here's a breakdown of the research process divided into three objectives:

Objective 1: To analyze the performance of existing public transportation systems in tier-2 cities, including metro rails

- Collect data on the performance of existing public transportation systems in tier-2 cities across India. This data will likely include ridership figures, operational costs, and customer satisfaction ratings.
- Analyze how well metro rails perform in tier-2 cities specifically. Here, I'll likely look at factors such as ridership compared to forecasts, reasons for the success or failure of metro projects in tier-2 cities, and a comparison of metro rail performance in tier-2 cities versus tier-1 cities.
- Sources for this data will include annual reports of metro rail companies in India, research papers on BRTS (Bus Rapid Transit System) systems around the world, and news articles about the performance of metro rails in various Indian cities.

Objective 2: Analyse the feasibility of Metro Neo systems in tier-2 cities

- To assess feasibility, there will be a need to compare Metro Neo with other Mass Rapid Transit Systems (MRTS). This might involve collecting data on capital costs, land acquisition costs, operation and maintenance costs, and fare revenue generation (both ticket sales and non-fare box revenue) for both Metro Neo and other MRTS options.
- There will be a need to select a tier-2 city as a case study. Here, factors to consider when choosing a city could be existing public transportation infrastructure, projected population growth, and urban sprawl.
- Once I have selected the city, I will find data on the specific proposed metro route. This could include the width of the right-of-way, space requirements for stations, and possible route alignments (elevated, at-grade, or underground).

Objective 3: Compare the budgetary considerations of Metro Neo with other transit systems in the selected tier-2 city

- Using the data from objective 2, I will calculate the total project cost for a Metro Neo system in your chosen city. This would likely include construction costs, land acquisition costs, and rolling stock costs.
- Then repeat this process to calculate the total project cost for another transit system, such as a conventional bus rapid transit system.
- Then assess the forecasted demand for passengers along the proposed Metro Neo corridor in your chosen city. This data might be available from existing Metro DPRs (Detailed Project Reports).
- Finally, compare the feasibility of Metro Neo versus the alternative transit system based on factors such as total project cost, ridership forecasts, and future cash flow projections.

By following this methodology, my thesis will be able to shed light on whether or not Metro Neo systems are a viable option for improving public transportation in tier-2 cities

2. LITERATURE STUDY

2.1 About Metro Neo

It is a hybrid of Bus and Rail with a dedicated route at grade, elevated, or underground. Metroneo runs on an overhead electric power supply line and has rubber tires. The corridor can be upgraded to a Light Rail Transit system in the future. (MoHUA, 2019)

Figure 1 Graphical representation of Metro Neo Coach

2.1.1 Standard Specifications of Metro Neo:

1. The alignment shall be decided after a thorough study and considering various factors ex: availability of Right of Way (ROW), speed, conflict with road traffic, safety, and cost.
2. The Metro Neo system shall have a dedicated path separating the road traffic from the Metro Neo lane. For segregation with road traffic, continuous plinth /fencing/kerb shall be provided.
3. The Right-of-Way (ROW) for the Metro Neo system shall be 8.0 meters for both UP & DN lanes combined. Metro Neo lane shall be suitably designed & constructed to accommodate the guidance system and considering the duty cycle of operation of Metro Neo on a dedicated path.
4. In case the road width does not permit, an At-grade single-lane Metro Neo system can be provided on a particular road and other lanes can be provided

on a parallel road. The road width occupied by the At-grade single-lane Metro Neo system shall be 4 meters.

5. Platform width shall be a minimum of 1.12 meters for the side platform and a minimum of 4 meters for the island platform.
6. Platforms may be planned in a staggered manner on alternate sides for Up and Down lanes to reduce the actual road space.
7. Lighting, Passenger Information System, CCTV, Automatic Ticket Vending Machine, Add Value Machine, Ticket Validator, Signage, etc. at stations shall be provided bare minimum and where necessary. AFC gates, Platform screen doors, X-ray baggage scanners, and DFMD are not needed at the Metro Neo stations.
8. Metro Neo platform roof can be optimized to 1/3rd of the platform length instead of providing a roof in the entire platform length.
9. Accessibility to Metro Neo station shall be made free-flowing, convenient, and safe by the implementation of an accessibility plan for the area around the station. The accessibility plan shall include a properly designed pedestrian crossing with mandatory traffic calming measures & signage/signal, improvement in footpaths and area around the stations, last mile connectivity, etc. The accessibility plan should not lead to bigger stations. (MoHUA, 2019).

Literature Review

Table 2 Literature Review

SN	Name of the Document	Author & year	Findings	Learning Outcomes
1	Standard Specifications of Metro Neo	MoHUA, 2020	Civil structure of Metro Neo, At grade and Elevated structure, Technology used for running the system	Differentiate between the structural specifications of Metro Neo with other MRTS

2	A framework for selecting an appropriate urban public transport system in Indian cities	Geetam Tiwari, Deepti Jain (2022)	Transportation needs of Indian cities based on their population and size, Performance of Metro systems in Indian cities	The suitable transportation options for a city concerning its size and population, Ridership Analysis
3	A Case Study on Indore BRTS with Reference to Other Indian Cities	Jayati Singh, Harivansh Kumar Chaudhary, Akash Malik (2022)	The current situation of BRTS in Indian cities, BRTS running status in Delhi, Pune and Indore	Barriers faced by BRTS system, Types of BRTS corridors and their advantages and Disadvantages.
4	An Update on Curb Guided Bus Technology and Deployment Trends	David Phillips, 2006	History and Technology of Kerb Guided bus systems worldwide	Specifications of Kerb guided bus system, Worldwide usage over time
5	Debunking the myths around optically-guided buses (Trackless trams)	Wong, Y. Z., 2018	Technology and worldwide practices of Optical guided bus system	Differences between various guided bus systems concerning their advantages and disadvantages
6	Alternatives analysis report for Jammu MRTS	RITES, 2020	Alternative Analysis for the feasibility of MRTS in the city of Jammu between Metro Rail and Light Rail.	Method of finding the cost difference between two transportation systems, Performance evaluation parameters
7	Detailed project report for Metro Neo project in Dehradun	UKMRC, 2021	Actual size specifications of Metroneo	Differences in various actual site parameters of Metro and Metroneo

Mass Rapid Transit System (MRTS)

A mass rapid transit system (MRTS) is a high-capacity public transport system which may be a rail/bus that carries a large number of passengers across the urban area and urban regional areas faster & comfortably.

- MRTS is a network of trains or buses that operate on fixed routes with designated stations.
- It's typically electric-powered and can be underground (subway), elevated, or at ground level.
- These systems are designed to move large numbers of people quickly and efficiently. (MoUD, 2017).

Why we need it:

- Reduced traffic congestion: By providing a convenient alternative to cars, MRTS helps reduce traffic jams on roads. This means shorter commutes for everyone, not just those using the MRTS.
- Environmental benefits: Electric-powered MRTS produce less air and noise pollution compared to cars.
- Accessibility: MRTS makes it easier for people who don't own cars or can't drive to get around. This improves access to jobs, education, and other opportunities.
- Economic development: Well-developed MRTS systems can encourage development along transit corridors, boosting property values and economic activity.(MoUD, 2017).

Benefits of Mass Rapid Transit Systems

Urban Mass Rapid Transit Systems not only enable efficient and swift movement of people but also positively impact economic growth and overall quality of life. This leads to increased income and various societal benefits, such as decreased external costs resulting from reduced traffic congestion, road and parking expenses, transportation costs, and per capita traffic accidents. Mass Rapid Transit Systems tend to diminish per capita vehicle ownership and usage while promoting a more 2

Compact and walkable development pattern, which yields developmental advantages for society. The reduction in travel costs and time subsequently reduces the production costs of goods and services, thereby significantly enhancing the city's competitiveness. A notable contribution is the substantial decrease in per capita pollution emissions, leading to a reduction in various chronic diseases and resulting in significant public health benefits. (MoUD, 2017)

Options of Mass Rapid Transit Systems (MRTS)

I. **Rail-based MRT** - Rail-based transit systems are networks of vehicles moving on fixed rails, designed to transport people within or between cities. Here's a breakdown of the different types:

A. Metro Rail - They operate on exclusive tracks, either elevated or underground, that completely separate them from other traffic. This allows metros to weave through a city's core at high speeds and with exceptional frequency, thanks to advanced control systems. While the most expensive mass transit option to build, metros deliver the ultimate in speed and service, making them invaluable for large and busy cities. Metro rail is a fully segregated rail-based transit system, operating at ground level, elevated, or underground. It boasts high capacity, accommodating 40,000 –80,000 passengers per hour per direction (PPHPD).

Figure 2 Image of a Metro Rail

B. Metrolite/Light Rail Transit (LRT) - While the term "light rail" might imply a similar size to trams, light rail systems have some key differences. Light rail typically operates on a completely separate track system, often elevated or underground, with advanced controls. Trams, on the other hand, may share some street space with regular traffic. Light rail can have short sections at street level but generally offers a more separated experience.

Figure 3 Image of a Light Rail

C. Monorail - A train that glides on a single, elevated track snaking through a city or an amusement park. That's a monorail. Unlike regular trains that hug two parallel rails, monorails find balance on a single beam. These can be built overhead, on the ground, or even underground. Popular in busy areas and tourist hotspots, monorails transport passengers in medium-sized wagons. They offer a quieter ride than traditional trains thanks to rubber tires on concrete tracks. Since they're separated from other traffic, monorails avoid congestion and offer a smooth journey. An interesting safety feature is their design: straddle beam monorails can't derail unless the track itself suffers a major breakdown. So, next time you see a sleek train gliding on a single rail, you'll know it's a monorail, a unique mode of transportation offering an efficient and scenic ride.

Figure 4 Image of a MonoRail

D. Tramways - Tramways are rail-based systems that typically operate at ground level and share the road with other vehicles. Tram vehicles run on fixed rails at grade in shared right of way. Vehicles are usually lighter and shorter than mainline and rapid transit trains. Today, most trams use electrical power, usually fed by a pantograph sliding on an overhead line; older systems may use a trolley pole or a bow collector.

Figure 5 Image of a Tram

ii. Bus-based MRT

A. Bus priority: Bus priority is a dedicated corridor for buses which is built in the middle of the ROW, this corridor is entirely dedicated to buses, and no other traffic is permitted inside the corridor. There are many dedicated BRTS currently functional worldwide as well as in India. This dedicated stretch of road runs down the center of the existing right-of-way (ROW), typically separated by barriers or curbs, and is solely for the movement of buses. By eliminating interference from cars and other vehicles, bus priority corridors significantly improve efficiency.

These corridors aren't a novel concept. Dedicated Bus Rapid Transit Systems (BRTS) are already up and running in many cities worldwide, including several in India. These BRTS corridors often go beyond just separated lanes. They might boast features like platform-level boarding stations for quicker passenger access, intelligent traffic management systems, and even high-capacity buses. The result? Faster commutes, improved reliability, and a more attractive public transport option. (Jaiswal et al., 2012)

The benefits extend beyond the passenger experience. By prioritizing buses, these corridors can significantly reduce traffic congestion on regular roads. This translates to cleaner air, as fewer idling vehicles spew out pollutants. Additionally, with more people opting for buses, the overall demand for car usage comes down, easing parking woes and creating a more breathable city environment.

Cities like Ahmedabad, and Indore have a successful network of BRT corridors whereas else cities like Delhi and Bhopal have not been successful in running such corridors for a long run. (Harsha, 2022)

Figure 6 Image showing bus priority corridor

B. Lane Marked: A lane marked BRTS, reserved exclusively for buses in a Bus Rapid Transit System. These lanes are physically separated from regular traffic by curbs or barriers, creating a smooth, uninterrupted path for buses. This segregation is key – it eliminates the stop-and-go frustration caused by cars and other vehicles, allowing buses to zip through the city at much faster speeds.

BRTS lanes are a common sight in many cities worldwide, offering a significant upgrade from regular buses. They not only cut down travel times but also boost the reliability of public transport. Passengers can expect buses to arrive and depart on schedule, making commutes more predictable. BRTS corridors often go hand-in-hand with other improvements like dedicated bus stops with easier boarding and advanced traffic management systems. (Rizvi & Sclar, 2014)

There are many cities in India as well as worldwide that are currently practicing the lane marking practice to dedicate the bus movement, Delhi has a very huge network of dedicated busway lanes, these lanes are marked on the kerb side of the carriageway, and can also be used by other traffic in emergency cases or at the time when city buses are not in the motion.

There is a drawback about these lanes, at the left turns the buses conflict with the left turn vehicles, which results in a decrease in the overall efficiency of the bus movement. (Kaladji et al., 1997)

Figure 7 Image of a Lane marked BRT

2.2 Metro Neo Specifications

2.2.1 Civil Structure: At-grade Metro neo System:

This passage outlines key considerations for building a cost-effective and efficient Metro Neo system. Here's a breakdown of the key points:

Route Planning

- Careful study is required to determine the best route for the Metro Neo system. Factors like available space (Right of Way or ROW), speed, traffic flow, safety, and cost will all be weighed.

Segregated Lanes

- Dedicated lanes will be separated from regular traffic using a continuous physical barrier like a curb or fence. This ensures smooth and uninterrupted travel for Metro Neo vehicles.
- The total ROW required for both directions (Up and Down lanes) will be 8 meters. The specific design of the lane will consider the guidance system used and the operational demands of the Metro Neo.

Adapting to Road Width

- In narrow roads, a single-lane Metro Neo system can be built on one side of the road, with the other lane on a parallel road if space allows. This single lane will occupy 4 meters of width.

Platform Design

- The minimum platform width will be 1.12 meters for side platforms and 4 meters for island platforms.
- To minimize road space usage, platforms for Up and Down lanes can be staggered on opposite sides of the road.

Station Facilities

- Stations will be basic, focusing solely on the platform area. No separate rooms will be built for equipment.
- Essential amenities like lighting, passenger information systems, CCTV cameras, ticketing machines (both vending and reloading), and signage will be provided. However, features like automatic fare gates, platform screen doors, security scanners, and metal detectors will not be included.

Platform Shelters

- To save costs, platform shelters will only cover one-third of the platform length instead of the entire area.

Accessibility

- A crucial aspect will be ensuring easy, convenient, and safe access to Metro Neo stations. This will involve creating a well-designed pedestrian crossing system with traffic calming measures, improved footpaths and surrounding areas, and plans for last-mile connectivity. Importantly, these accessibility features should not significantly increase station size. (MoHUA, 2019)

2.2.2 Civil Structure: Elevated Metro Neo System

This section outlines the key considerations for constructing a cost-effective and functional elevated Metro Neo system. Here's a breakdown of the key points:

Finding the Optimal Path

Just like ground-level routes, careful planning is needed to determine the best-elevated route. This involves analyzing factors like available space, desired speed, impact on traffic flow, safety considerations, and overall cost.

Minimizing Footprint

To limit the impact on existing roads, the support structures (piers) for the elevated track will occupy a maximum of 2.2 meters at the median, including safety barriers. The entire elevated track (viaduct) itself will be no wider than 8 meters. It must also be designed to provide a minimum clearance of 5.5 meters above roads to ensure safe passage for vehicles below. In case of emergencies, the viaduct itself should be a safe zone.

Platform Design

Platform widths on elevated stations will be the same as those on ground-level stations: a minimum of 1.12 meters for side platforms and 4 meters for island platforms. To save costs, platform shelters will cover only one-third of the platform length.

Focusing on Functionality

Elevated Metro Neo stations will prioritize functionality over frills. Their design will ensure a smooth flow of passengers between platforms and vehicles. Basic amenities like lighting, CCTV cameras, and public information systems will be available on the platforms. However, features like automated fare gates, platform screen doors, security scanners, and metal detectors are not included. Ticketing machines for buying and topping up fares will be located near or under the staircases leading to the platforms, not on the platforms themselves.

Station Access

Passengers will access platforms directly via staircases from ground level. There will be no concourse areas for transferring between lines. While elevators will be provided for accessibility, escalators will be used sparingly and only in stations with a critical need. Similarly, footbridges or underpasses to cross roads will be avoided in most cases. Instead, well-designed pedestrian crossings with traffic calming measures and clear signage will be mandatory.

Accessibility for All

As with ground-level stations, ensuring easy, convenient, and safe access is crucial. This will involve improvements to surrounding areas, proper pedestrian crossings, better footpaths, and planning for last-mile connectivity. Importantly, these accessibility features should not significantly increase station size. The space beneath or near the staircases can be used for passenger amenities like ATMs, vending machines, or staff facilities.

Security Measures

Measures will be taken to restrict access to platforms during non-operational hours. (MoHUA, 2019).

2.2.3 Comparative table of different MRTS systems

Table 3 Comparative table of various MRTS systems

PARAMETER	Metro Rail system	LRT/Metrolite	Metro Neo	Electric Bus
PHPDT range	More than 45000	Upto 15000	8000 - 10000	Upto 8000
Number of coaches	6 coaches or more	2 to 3 coaches	Single Coach- 1 to 3 or single articulated or bi-articulated coaches	Single or articulated bus
Coach Dimensions	2.9 m/3.2 m wide 22 m long	2.9m wide 22 m long	2.55 m wide 12 M , 18 m and 24-25m Long	2.5m wide 12-24 m long
Coach Capacity	300 persons per coach	200 persons per coach	90, 140, and 225 respectively	90-225
Length of platform required	185m to 210m	90m	30 m & Terminal Stations 60 m	50m
CAPEX/km	Rs. 250 Crore/Km	175 crore/km	70- 80 crore/km (for elevated)	70-75 crore per Km (for elevated)
Deck width of viaduct	9 m to 10 m	7.0 to 8.5 m	8.0 m	7.0 to 8.5 m
Speed (Max)	80 KMPH	80 KMPH	70 KMPH	50 KMPH
Turning Radius(minimum)	120 M	60M	25 M	60 M

(MoHUA, 2019)

2.2.4 Rail Guidance

Kerb Rail Guidance/Centre Rail Guidance shall be used for the Metro Neo system. (KAUSHIK PATOWARY, 2015)

Kerb Rail Guidance

Kerb Guided Bus (CGB) technology is a system that allows Bus Rapid Transit (BRT) to operate in very narrow lanes. Unlike other guided bus technologies that are still under development, Kerb Guided Bus is already operational.

Centre Rail Guidance

Central Rail Guidance technology could potentially be a system that uses a central rail to guide buses along a dedicated route. A physical rail embedded in the ground or on an elevated structure that the bus makes contact with to maintain its position.

2.2.5 Rolling Stock Specifications of Metro Neo

Electric vehicles with rubber tires will run on dedicated tracks, either elevated or at ground level. Cities can choose the ideal coach configuration based on passenger demand, with options for single (12 meters), double (18 meters), or even triple (24 meters) articulated coaches. All coaches will have a standard width of around 2.55 meters and a low floor (300-350 mm) for easy access. (MoHUA, 2019)

Durability is a priority, with the car structure built from stainless steel or aluminum and designed for a minimum lifespan of 30 years. The system's incline and turning radius will be determined based on local needs and available technology. Metro Neo also incorporates innovative features for efficiency and safety. The coaches will utilize a kerb rail or center rail guidance system for precise movement and will be equipped with batteries for up to 20 km of operation without overhead power. Additionally, regenerative braking captures energy during braking to further optimize efficiency. Passenger safety is paramount. Coaches will have couplers for connecting in case of breakdowns, certified obstruction detection systems, and side evacuation doors with ample space for movement on the median. The design even considers passenger safety in the unlikely event of a broken contact wire falling on the roof.

Table 4 Rolling Stock Specifications

Parameters	Single Coach	Articulated	Bi-Articulated
Dimensions (M)	12x2.5x3.5	18x2.5x3.5	24x2.5x3.5
Car Body	Stainless steel/Aluminum		
Tare weight(tonne)	12-13	18-19	25

Carrying Capacity (@ 6pax/ sqm.)	90	140	225
Capital Cost (crores)	2.25	3.75	5.38
Traction system	750 V DC overhead twin (positive and negative) contact wires placed in parallel.		

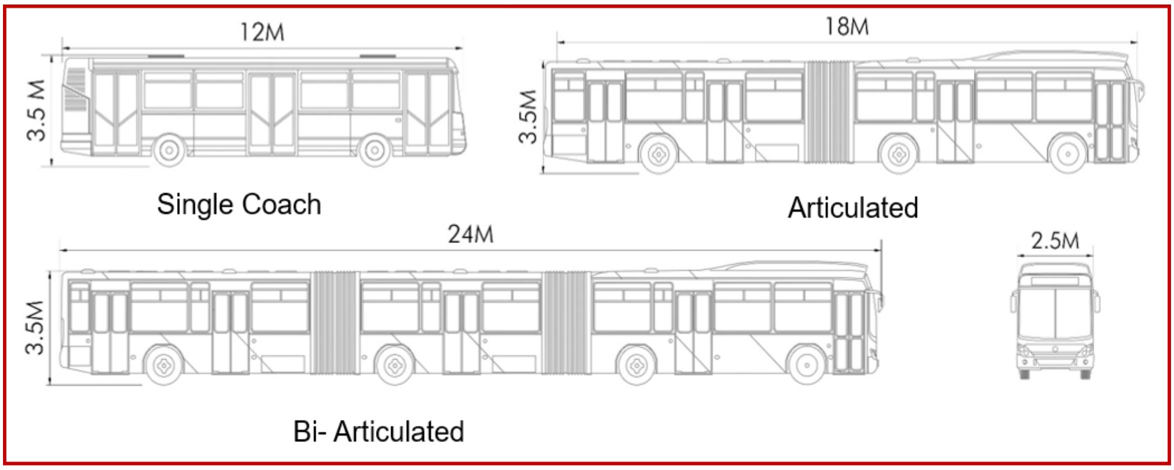

Figure 8 Size of rolling stock of Metroneo

2.2.6 Relevance in the international context

Metro-Neo is a hybrid of guided bus & trolley bus systems. Guidance technology recommended for Metro-Neo is followed in guided bus systems worldwide, while the OHE twin wires resemble that of the traction system in trolleybuses. (KAUSHIK PATOWARY, 2015)

A. Guided Busway

B. Trolley Busway

A. Guided Busway

There are currently four types of guided bus systems worldwide, which are being used widely or have been used in the past. (KAUSHIK PATOWARY, 2015)

Kerb Guided: The first Curb Guided Bus (CGB) route chugged into operation in 1980, marking a significant step forward in public transportation. However, unlike some technologies that exploded onto the scene, CGB adoption was a slow and steady climb. Despite the initial lag, the concept persevered. Since 1998, nine new routes have been implemented, and the future looks bright with even more on the horizon.

Notably, this growth has been concentrated in the U.K., where CGB technology has found fertile ground for development and refinement. (Phillips, 2006)

Technology

- Vehicles: Regular buses are modified with the addition of kerb wheels attached to the front axle.
- Guidance System: These kerb wheels physically guide the bus by running alongside vertical curbs constructed on a dedicated track.

Infrastructure

- Track: Made of concrete with vertical curbs typically around eight inches high.
- Right-of-Way: Can operate in very narrow lanes, ideal for situations where space is limited. Potential locations include Medians of arterial streets or freeways, abandoned railroad alignments, abandoned railroad alignments, alongside active railroads, Bridges or elevated structures, Tunnels, under buildings, etc.

Figure 9 Image showing kerb-guided technology and Infrastructure

Advantages

Kerb-guided bus systems offer several advantages for public transportation. They provide a smoother ride for passengers due to the reduced sway caused by the physical guidance from the curbs. Additionally, the dedicated lanes separate buses from traffic congestion, ensuring faster and more reliable travel times. This segregation also creates a safer environment for both bus passengers and other motorists. A key benefit is the space-efficiency. Kerb-guided buses can operate in narrow right-of-way (ROW) areas, making them ideal for situations where traditional bus lanes are impractical. This allows for the creation of dedicated transit lanes in areas where space might be limited. (Bain, 2002)

Worldwide practices

Table 5 Worldwide cities of Kerb Guided Busway system

SN	Starting Year	City	Network Length	Extended length
1	1980	Essen, Germany	6	
2	1986	O-Bahn Busway, Adelaide	12	3 (1989)
3	1995	Ipswich, UK	0.2	
4	1998	Leeds, UK	3.5	
5	2001	Nagoya, Japan	6.5	
6	2001	Bradford, UK	23	
7	2003	Crawley, UK	15	
8	2004	Edinburgh, UK	15	
9	2011	Cambridgeshire, UK	25	
10	2013	Luton, UK	7.7	
11	2016	Leigh-Salford-Manchester BRT	22	
12	2018	Bristol, England	50	

The Kerb guided bus system has been used in 12 cities worldwide and all are functional to date, there is only one system that has extended its network by 3 km which is O-Bahn Busway, Adelaide.

Outcome

While currently not widely expanded, kerb guided buses hold the title of the most adopted guided bus system. Bristol, England, boasts the most extensive network, spanning 50 kilometers across 5 routes. However, expansion seems cautious, with only one city adding a modest 3 kilometers to its system. This suggests a measured approach to implementation, possibly due to factors like infrastructure integration or cost considerations. Despite this, kerb guided buses remain a significant player in guided bus technology. (Wilson, 1999)

Rail Guided

Unlike curb-guided systems, rail-guided buses rely on a dedicated track with a central or side rail to steer the vehicles. This offers precise control and a smooth ride. These buses may also be equipped with overhead wires for electric operation, similar to trams. While potentially offering some advantages, the infrastructure requirements for a central or side rail might be more complex and expensive compared to curb-guided systems. The limited use of the term suggests this technology might be less widespread or have a different name depending on the specific implementation. (Wilson, 1999)

Technology and infrastructure

Central guided bus systems, utilize vehicles with rubber tires for independent movement, offering more flexibility than trams with their flanged wheels. These buses even have steering wheels for operation on sections without a guidance rail, like over a third of Nancy's route. They share some tram characteristics though, with a unidirectional design and bus-like mirrors. Passenger comfort is prioritized with a lower floor for easier boarding. The vehicles themselves are articulated, reaching a length of 24.5 meters (respectable, but shorter than most modern trams), and can accommodate 40 seated passengers with additional standing room for 105.

The key infrastructure component for this system is a central guidance rail embedded in dedicated lanes, which the vehicles physically follow for precise movement. Unlike trams, this rail doesn't support the weight of the bus. Overhead wires for electric operation can be integrated depending on the specific system design. Overall, compared to tram systems with their flanged wheels requiring grooved rails, Central guided infrastructure is less complex to install and maintain.

Figure 10 Images showing Rail Guided technology and Infrastructure

Advantages

Central guided bus systems offer a smooth and comfortable ride for passengers. Rubber tires reduce noise and vibration compared to traditional buses, while the central guidance rail ensures precise movement, minimizing sway. This translates to a more pleasant travel experience, especially for those prone to motion sickness.

Limitations

Central-guided bus systems face some limitations. The constant friction of rubber tires on the central guidance rail can lead to wear and tear on the road surface, increasing maintenance needs. Additionally, transitioning between guided and unguided sections can be complex, potentially introducing delays or requiring additional infrastructure. Finally, unlike completely segregated systems, vehicles may still merge with traffic in some sections, potentially impacting efficiency and passenger experience.

Worldwide practices

Table 6 Worldwide cities having Central Rail guided system

SN	Starting Year	City	Network length	Extended length
1	2000	Nancy, France	11	Closed in 2023, Replaced by Trolley bus
2	2002	Caen, France	15.7	Closed in 2023, Replaced by Trolley bus
3	2006	Clermont-Ferrand	15.8	2
4	2007	TEDA Modern Rail guided Tram, China	7.8	Closed in 2023

5	2007	Padua Tramway, Italy	6.7	3.6
6	2009	Zhanjiang Tram, Shanghai China	9.8	Closed in 2023
7	2013	Ile de France, line 5	6.6	
8	2014	Ile de France, line 6	14	2.6
9	2015	Ayacucho Tram, Columbia	4.3	Plans to expand
10	2015	Venice Tramway	20	

There are 10 cities worldwide that have or currently using the Rail Guided bus system, most of them are in Europe, four cities have closed their operation and 4 are planning to expand their network, Two Chinese cities have closed their operations because of less to no ridership during non-peak hours, The two oldest systems Nancy, France and Caen, France have also closed its functioning, because they have replaced the network with Electric buses.

Outcome:

A closer look at Central Guided Bus Systems Central Rail Guided system, globally reveals a mixed picture. While initially promising, 4 out of 10 known systems have been shut down. Notably, larger, bustling Chinese cities haven't seen success with the Central Rail Guided system, suggesting limitations in handling high passenger volumes and dense traffic. Interestingly, European implementations in cities with lower population density and well-organized traffic seem to have fared better. Another trend observed is that some Central Rail Guided systems were upgraded from conventional tram networks. This might indicate a search for improvement over existing systems but with some drawbacks. These observations suggest that GLT might be better suited for specific contexts and might not be a universally successful solution for all urban environments. (Wilson, 1999)

Optical Guided

An optical guided bus system is a type of guided bus that uses cameras mounted on the bus to track reflective strips or lines painted on the road surface. This allows the bus to be steered automatically along the designated route, improving efficiency and safety. (Operations & Operations, 2019)

Technology and Infrastructure

Optical guided bus systems use cameras mounted on buses to scan special markings on a dedicated lane. Onboard software interprets the markings and steers the bus if needed, eliminating the need for physical barriers. This allows for a lighter and potentially cheaper infrastructure compared to traditional guided systems.

However, smoother ride quality in these systems is more due to automation than just the optical guidance. While traditional buses can be jerky due to increased power and acceleration, optically guided buses can potentially implement limiters to control these factors and create a smoother ride. Additionally, improved ride quality can come from better infrastructure design, like smoother pavements and routes with less steep inclines, rather than solely relying on optical guidance technology.

Figure 11 Images showing Optical Guided bus technology and infrastructure

Advantages

Beyond precise docking and low maintenance, optical-guided bus systems offer several advantages. Compared to traditional buses, they boast increased travel speeds due to smoother, automated steering and dedicated lanes. This also translates to better reliability and punctuality. The lack of physical barriers makes the infrastructure lighter and potentially cheaper to construct. Additionally, these systems can improve passenger experience with features like optimized door-to-platform alignment and the potential for smoother rides through automation and infrastructure improvements. Overall, optical-guided buses provide a cost-effective and efficient way to enhance public transportation.

Limitations

Beyond challenges with weather conditions like snow, rain, and intense sunlight, optical-guided bus systems face limitations. The technology relies on clear visibility of road markings, which can be obscured by debris or worn paint. Merging with regular traffic can also disrupt the system. Additionally, these systems often require dedicated lanes, limiting their flexibility in existing road networks. Finally, the initial cost of outfitting buses and infrastructure with cameras, sensors, and software can be high. (*Optical Guided*, 2019)

Worldwide practices

Table 7 Worldwide cities having an optical guided bus system

SN	Starting year	City	Network Length	Extended length
1	2008	Castellon, Spain	12	
2	2001	Rouen, France	32	
3	2004	Las Vegas, America	24	Discontinued in 2016
4	2018	CRRS Autonomous RRT (China)	10	

Despite initial promise, optical-guided bus systems haven't seen widespread adoption. Since 2001, only four applications exist globally. Even in Las Vegas, the system served a limited purpose, assisting solely with station docking, not general lane guidance. Ultimately, harsh weather conditions like desert sun, dirt, and grease proved problematic, causing the system's discontinuation. This limited track record and susceptibility to environmental factors raise concerns about the technology's overall reliability and scalability.

Electromagnetic Guided

Electromagnetic-guided buses ditch the cameras and markings for a more embedded approach. Sensors installed directly on the designated lane track the bus's position. These sensors can take various forms, but one common method utilizes magnetic pulses. Small magnets placed at regular intervals, typically around 5 meters apart, emit pulses that the bus detects. Onboard software interprets these signals and controls the steering mechanism, keeping the bus precisely aligned within the lane.

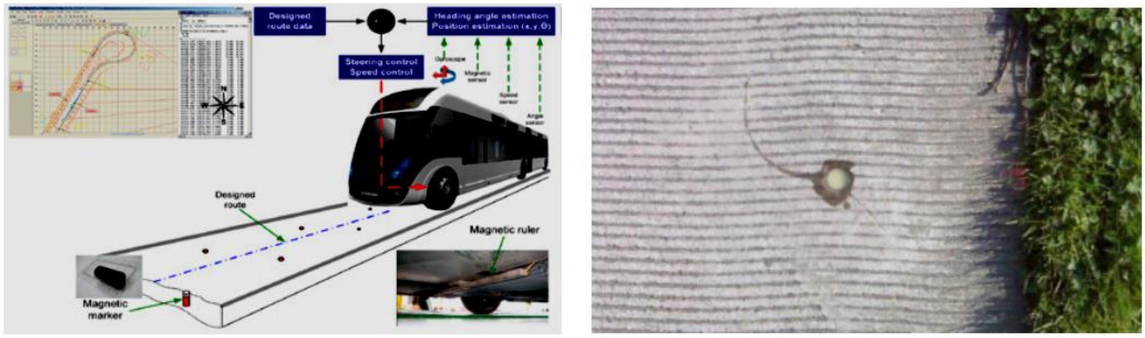

Figure 12 Image showing Electromagnetic Bus guided Infrastructure and technology

Advantages

Electromagnetic guided buses boast several advantages beyond smooth transition to unguided operation. Their embedded sensors, unlike optical systems, are unaffected by weather or worn markings, ensuring reliable operation. This precise guidance also translates to improved fuel efficiency due to smoother travel and potentially allows for tighter following distances between buses, increasing passenger capacity.

Limitations

While electromagnetic guidance offers a weather-proof alternative, it faces its limitations. Since the technology is still under development, its long-term reliability and performance remain unproven. Additionally, embedding sensors in the road necessitates extensive infrastructure modifications, potentially making it costly and disruptive to implement in existing cities. Research is ongoing in this area.

Worldwide practices

Table 8 Worldwide cities having an electromagnetic guided bus system

SN	Starting Year	City	Network length	Extended length
1	2006	Douai, France	34	0
2	1995	Eindhoven, Netherlands	9	0

- Only 2 applications worldwide from 1995 to 2006
- Has not achieved market due to proprietary and expensive capital and operational costs. (Wilson, 1999)

Overall inferences from all four guided bus systems.

There are a total of 28 guided bus systems currently in practice worldwide out of which some have extended their lengths or some have scrapped the system, it has been observed that kerb guided bus system is the most widely used system worldwide with a total of 11 cities implementing the same, all of 11 cities are currently operational, Rail guided system is also widely used technology with a total of 10 cities using it or has used it, It is also observed that 2 major Chinese urban centers have scraped this system due to less ridership in non-peak hours and 2 European cities have also scraped it, this is due to its emergence with traffic. Optical guided systems have been implemented in 4 cities, 2 in Europe, 1 system in China, and 1 system in America. The optical guided system in Las Vegas in America has been scraped as it was only used for the movement of rolling stocks in depots. The electromagnetic guided bus system has only been implemented in 2 cities worldwide, both are in European cities, these systems due to their highly expensive operation and maintenance, this system still needs recognition.

Therefore Metro Neo has adapted Kerb guided and Rail guided technology for its operational functionality because of their highly proven performance worldwide.

B. Trolley Busway

Trolleybuses are electric buses that ditch the bulky battery packs for a simpler power source.

Technology and Infrastructure

Two overhead wires deliver electricity to the bus through spring-loaded poles on its roof. These poles constantly slide against the wires, maintaining contact and powering the bus's electric motor. This eliminates the need for onboard battery charging and extends the bus's operational range significantly. However, trolleybuses are restricted to designated routes with overhead wires, limiting their flexibility compared to regular buses.

The infrastructure for a trolleybus system revolves around a network of overhead wires strung along designated routes. These wires come in pairs, typically suspended from poles on either side of the road. One wire acts as the positive pole, delivering electricity to the bus. The other wire serves as the negative return path, completing the electrical circuit. This dual-wire setup is essential for powering the bus's electric motor as it travels. The system also includes substations that convert AC power from the grid to the DC voltage required by the trolleybuses. Additionally, strategically placed feeder lines connect the substations to the overhead wires, ensuring a consistent flow of electricity throughout the network.

Figure 13 Image showing trolley bus technology and Infrastructure

Advantages

Trolleybus systems boast several advantages beyond the well-known benefits. They offer regenerative braking, where the bus's kinetic energy during braking is converted back into electricity and fed back into the overhead wires. This improves energy efficiency and reduces wear on brakes. Additionally, trolleybuses are highly manoeuvrable due to their rubber tires, allowing them to navigate tight corners and curves more effectively than trams. Furthermore, the overhead wires are relatively simple to install and maintain compared to the complex infrastructure required for subways or light rail systems. This translates to lower construction costs and easier integration into existing road networks.

Limitations

Trolleybuses, despite their merits, come with some drawbacks. Unlike trams with their fixed tracks, trolleybuses require more driver control to stay aligned with the overhead wires, potentially impacting manoeuvrability. Additionally, the overhead wires themselves can be space-consuming, reducing the effective width of a lane compared to a bus lane without wires. This can lead to less efficient use of road space, especially in narrow streets. Furthermore, overtaking other trolleybuses within the system can be difficult or even impossible without additional infrastructure like duplicate overhead wires and switching mechanisms. This can limit operational flexibility and potentially hinder service frequency during peak hours. Finally, the transition to trolleybuses requires additional driver training compared to regular buses due to the specific handling characteristics and potential for disruptions caused by losing contact with the overhead wires.

Worldwide scenarios

Trolleybuses have a complex history of rise and fall. While once a common sight, their usage declined significantly in the 1960s and 1970s due to the popularity of diesel-powered buses. These diesel buses offered greater flexibility and range compared to trolleybuses which are restricted to routes with overhead wires.

The data seems to confirm this trend, with over 110 trolleybus systems scrapped after 2000, while only 14 new ones were introduced during the same period. However, there are signs of a recent revival. Despite the continued scrapping of older systems, there has also been a renewed interest in trolleybuses. This could be due to several factors.

Firstly, concerns about air pollution and noise may be prompting cities to reconsider electric trolleybuses as an alternative. Additionally, advancements in battery technology could see hybrid trolleybuses emerge, combining the overhead wires' range advantage with some of the flexibility of diesel buses. Overall, the trolleybus story is not over yet, and it remains to be seen if these recent trends will mark a true comeback for this electric public transportation system. (KAUSHIK PATOWARY, 2015)

Case study of Moscow Trolley Busway

The Moscow trolleybus system, once the world's largest, introduced in the year 1933 with a fleet size of 50 trolley buses was dismantled in its entirety by 2020. This decision came despite public opposition and a lack of convincing arguments from the city authorities.

The official reasons for the demolition included the trolleybuses' age, unreliability, and high maintenance costs. Additionally, officials claimed that modern trolleybus manufacturers could not meet the city's requirements and that electric buses were a more environmentally friendly alternative.

Opponents of the demolition argued that the trolleybuses were not outdated and that electric buses were both more expensive and less efficient. They also pointed out that the demolition destroyed a significant amount of infrastructure, including the Moscow trolleybus plant and the Moscow experimental electrical plant.

The true reasons behind the demolition remain unclear. Some believe that the authorities were interested in selling off trolleybus depots and substations, while others believe that the decision was made to benefit private bus companies. It is also possible that the demolition was simply the result of poor planning and a preference for a new, untested technology.

The Moscow trolleybus case study highlights the importance of considering social and political factors in addition to technical and economic factors when making transportation decisions. It also raises questions about the role of public participation in the decision-making process.[1,2]

Overall Inference from Guided Busway and Trolley Busway

Metroneo technology is adapted from kerb guided/Central rail guided systems for its guidance on surface and overhead power traction is influenced by trolley busway.

2.3 Ridership performance of BRTS, Light Rail System, and Metro Rail

To analyse the performance of various MRTS systems, the performance of BRTS, Light Rail Transit, and Metro Rail systems has been taken into consideration in the Indian context as well as systems worldwide. The performances have been evaluated based on population, daily ridership, and route length of the system. The cities that have been taken for the evaluation have less than 30 lakhs of population as of the base year of the operation of these MRTS in the particular city.

2.3.1 BRTS

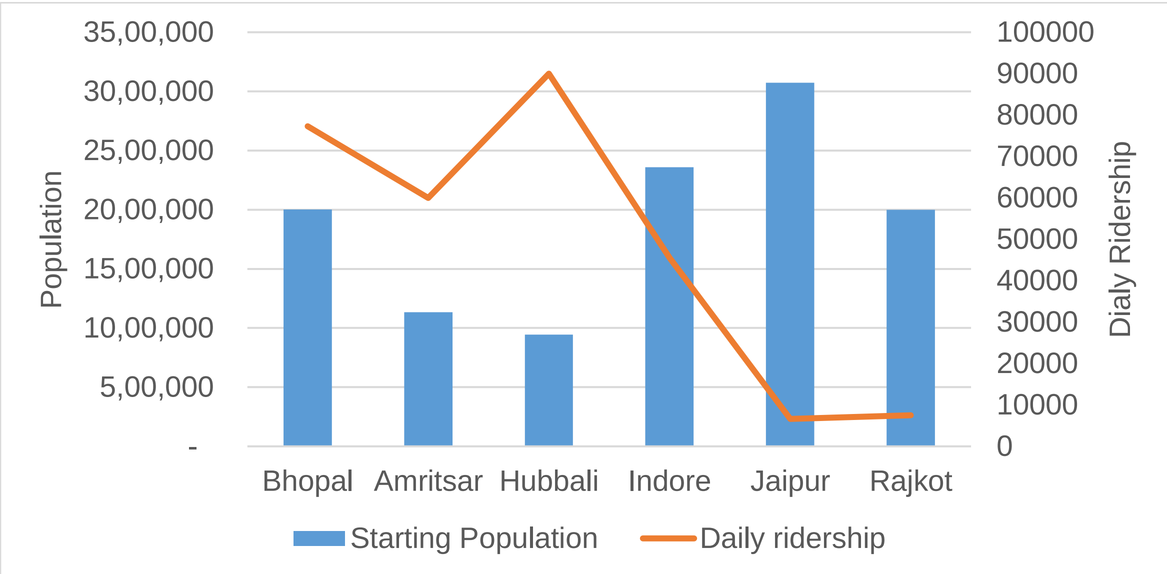

Figure 14 Daily ridership of BRTS of various cities of India, concerning their population

Table 9 BRTS data of Indian cities

City	Bhopal	Amritsar	Hubbali	Indore	Jaipur	Rajkot
Starting Population	20,03,000	11,32,761	9,43,857	23,60,000	30,73,350	20,00,000

Service Opened	2013	2016	2018	2013	2010	2012
Daily ridership	77289	60000	90000	45500	6622	7500
System Length	24	31	22	12	7	11
Ridership/km	**3220.4**	**1935.5**	**4090.9**	**3791.7**	**946.0**	**681.8**

Tier-2 cities with a population of fewer than 30 lakhs or around 30 lakhs are taken into consideration for the performance evaluation of BRTS in India, It can be observed that the system lengths are not too long in all cities, even with smaller system lengths the average daily per km ridership is 2450. [3]

2.3.2 Light Rail Transit

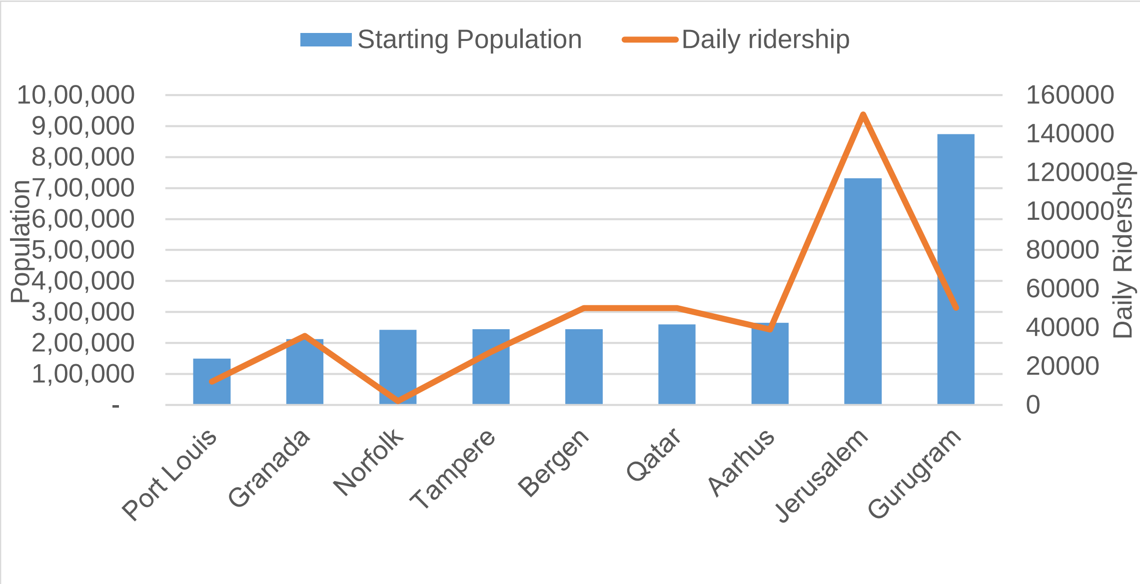

Figure 15 Daily ridership of Light rail transit system of various cities worldwide, concerning their population

Table 10 Light Rail Transit system data of worldwide cities

City	Starting Population	Service Opened	Daily ridership	System Length	Ridership/km
Port Louis	1,50,000	2019	12000	26	**461.5**
Granada	2,12,429	2017	35634	17.5	**2036.2**
Norfolk	2,42,800	2011	2000	12	**166.7**
Tampere	2,44,315	2021	27379	16	**1711.2**
Bergen	2,45,000	2010	50000	9.8	**5102**
Qatar	2,60,000	2017	50000	21	**2381**
Aarhus	2,65,273	2017	39000	12	**3250**

Jerusalem	7,32,000	2011	150000	13.9	**17985**
Gurugram	8,73,965	2013	50137	11.7	**4285**

Cities having a population of less than 30 lakhs or around 30 lakhs are taken into consideration for the performance evaluation of Light Rail Transit systems worldwide. Most of the cities don't have very long network lengths, after observing the data from all of the cities the daily per km ridership is coming out to be 4153. [4]

2.3.3 Metro Rail

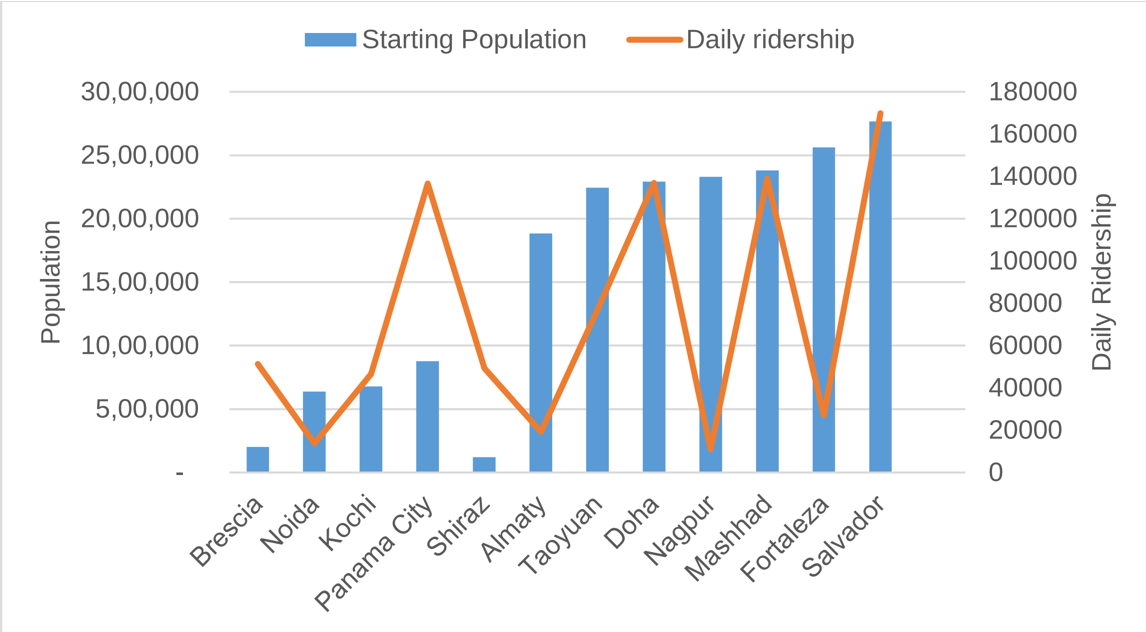

Figure 16 Daily ridership data of the Metro Rail system of various cities worldwide, concerning their population

Table 11 Metro Rail data of worldwide cities

City	Starting Population	Service Opened	Daily ridership	System Length	Ridership/km
Brescia	2,00,423	2013	51233	13.7	**3740**
Noida	6,37,272	2019	13699	29.7	**461**
Kochi	6,77,381	2017	46575	27.4	**1700**
Panama City	8,76,824	2014	136712	36.8	**3715**
Shiraz	1,20,854	2014	49315	24.5	**2013**

Almaty	18,83,425	2011	19178	13.4	**1431**
Taoyuan	22,44,000	2017	76712	53.1	**1445**
Doha	22,93,100	2019	136986	76	**1802**
Nagpur	23,31,078	2019	10959	26.1	**420**
Mashhad	23,82,000	2011	138904	37.5	**3704**
Fortaleza	25,62,963	2012	27123	24.1	**1125**
Salvador	27,67,031	2014	169863	32.5	**5227**

After analysing the ridership data of worldwide cities, with a population of less than 30 lakhs, it is observed that daily per km ridership is coming out to be 2232. (Tiwari & Jain, n.d.)

Overall Inference (BRTS, LRTS, and Metro Rail)

From the above data, it has been inferred that, for cities having a lesser population than 30 lakhs, the ridership of BRTS and LRTS is more than the ridership of Metro Rail. This suggests that high-capacity transit systems like Metro Rail are suitable for very large urban agglomerations, it is suitable for the cities where population is huge, have extended road networks, population density is huge and people cannot rely on their vehicles for long distances traveling within the city. Cities having a population of less than 40 lakhs may plan to have a Light Rail Transit system or dedicated busways for the travel demand of the city.

2.3.4 Case Studies of Delhi and Bhopal BRTS

Delhi: Delhi's Bus Rapid Transit System (BRT) was planned in 1997 to address air pollution concerns. After several years of discussion and planning, a 5.8 km pilot route with a dedicated bus lane was built. This "Open BRT" system allowed other vehicles to use the lane alongside DTC buses. (Rizvi & Sclar, 2014)

Figure 17 Central median BRTS corridor

Initially, the BRT lane was placed in the center median, but this design was not well-received. It was later shifted to a kerb-side lane in some areas. However, this design also had limitations as it increased the number of unavoidable left turns, impacting traffic flow and bus speed.

Figure 18 Kerb side lane BRTS corridor

Despite initial challenges, the BRT lane did provide faster travel times for buses using the corridor. However, after eight years of operation (2008-2016), the pilot route was dismantled due to public criticism. Opponents argued that the dedicated lane reduced overall road capacity and worsened traffic congestion for private vehicles. (Kaladji et al., 1997)

Bhopal: Launched in 2006, Bhopal's BRTS (Bus Rapid Transit System) aimed to be a solution for the city's growing traffic woes. It boasted a dedicated bus lane stretching 24 kilometers and a fleet of over 225 buses. However, the system faced several hurdles from the start. In 2023 the corridor had a total of 82 stops and it was observing an average ridership of 77289 per day. (MYBUS & BCLL, 2017)

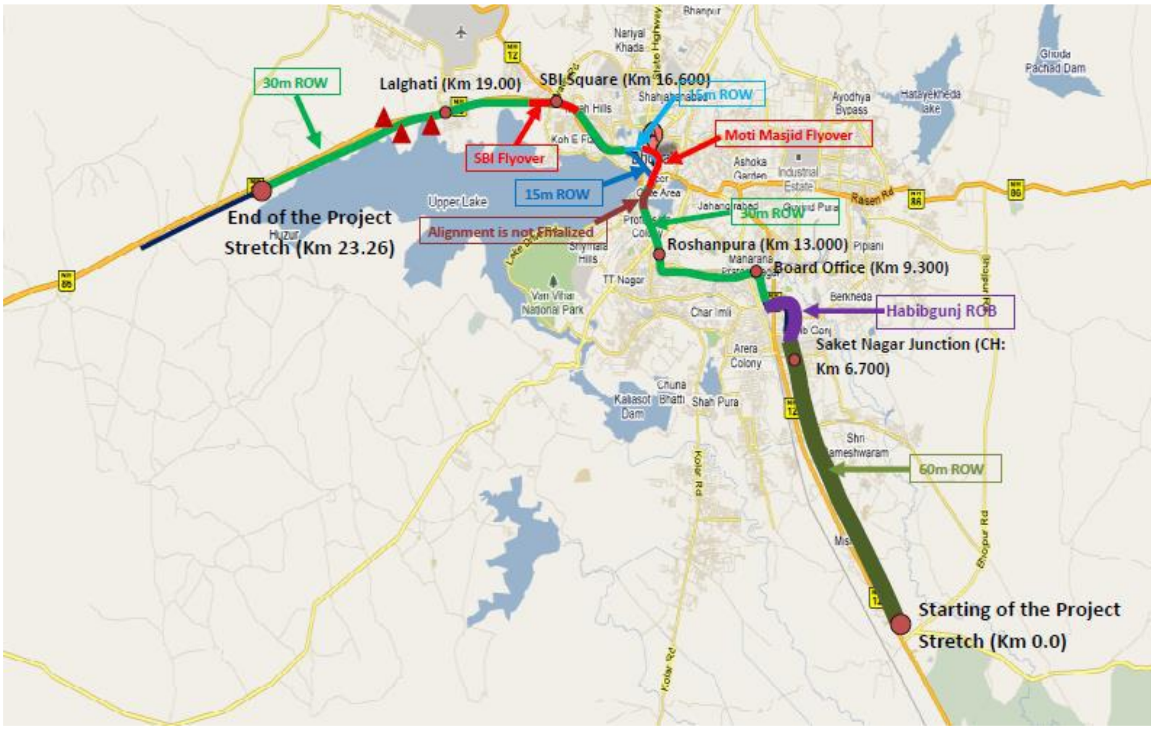

Figure 19 Route map of Bhopal BRTS

Firstly, Bhopal lacked a strong public transport network before the BRTS, leading to a heavy dependence on private vehicles. People were hesitant to switch to buses due to a lack of familiarity and ingrained habits.

Secondly, two-wheeler dominance added to the problem. Traffic rules were often flouted, with triple riding and lack of helmets being common. This indiscipline created chaos on the roads.

Fourthly, the overall traffic management was poor. Missing lane markings and inadequate pedestrian infrastructure made navigating the roads a challenge for everyone.

Finally, on-street parking added to the chaos. Cars parked haphazardly further reduced road space, hindering BRTS efficiency.

Despite these challenges, there are various other reasons also for the scraping of Bhopal BRTS, The most widely talked about reason is to increase the carriageway width on the existing ROW. The other one is that the authorities are planning to construct two flyovers on these corridors, the first one in Misrod and the second one in Bairagarh.

These challenges, coupled with public resistance to change, ultimately led to the scrapping of the Bhopal BRTS in December 2023. The authorities argued that the dedicated lanes caused more traffic congestion for private vehicles. (Kaladji et al., 1997).

2.3.5 Metro system projected to actual daily ridership (%) (Indian Cities)

Table 12 Metro rail ridership data of Indian cities having operational metro network

SN	City	Average Trip Length	Population (in Lakhs)	Operational System Length (KM)	Ridership DPR Forecast (Lakhs)	Actual Rider-ship (Lakhs)	Actual Ridership / Completion Year	Percentage of Forecast Ridership (%)
1	Jaipur	9.1	39.09	11.98	2.1	0204	2019-20	9.71
2	Ahmedabad Metro	5	80 59	37.902	6.75	0.3	2022-23	4.44
3	Bengaluru Metro	10	123.26	38.6	20	5.5	2022-23	27.5
4	Kolkata Metro	5	148.5	47.85	15	5.84	2019-20	38.93
5	Mumbai Metro	9	204.11	66.04	10.06	3.334	2017-18	33.14
6	Hyderabad Metro	13	100.04	67.47	19	1.5	2021-22	7.9
7	Chennai Metro	12	109.71	54.14	7.57	0.92	2019-20	12.15
8	Kochi Metro	12	30.82	26.8	3.8	0.49	2019-20	12.89
9	Lucknow Metro	7	36.76	22.87	0.943	0.258	2020-21	27.36
10	Delhi Metro	11	302.9	349.27	53.47	25.37	2017-18	47.45
11	Nagpur Metro	7.6	28.93	3822	1.9	0.133	2021-22	7
12	Pune Metro	10.4	66 29	12	6	0.35	2017-18	5.83
13	Kanpur City	6.4	31.23	8.621	6.61	0.1	2022-23	1.51

Thirteen Indian cities are taken for the performance evaluation of metro rail, despite their size and population, all of these cities have operational as well as under construction metro corridors, Kolkata is the oldest city in India to have a metro, starting in the year 1984. Delhi has continuously experienced the growth of metro rail since its inception in 1996 and the first line started in the year 2002. Mumbai, which has been relying on regional rail (Mumbai local) for a very long time, having vast connectivity within the city and its suburban areas, is also constructing a metro in the city. From the above data, it is observed that the actual ridership and the expected ridership of the metro rail have a huge difference in every city in India. Most of the cities have actual ridership in operational metro networks lesser than

30% except for Delhi, Mumbai, and Kolkata having ridership of 47.45%, 33.14%, and 38.93% respectively. It is also seen that the Average trip length of the city is not dependent on the population of the city but can be a function of density and urban form, For example: Kolkata is a large city with a population of 14.8 million and has a lesser ATL then many tier-2 cities, due to its high density. Kochi being an island town with having significantly smaller population than Mumbai has more ATL than Mumbai.

The reasons behind this gap between Tier-1 and Tier-2 cities can be many:

Bigger cities, with populations exceeding 10 million, tend to see higher metro ridership compared to smaller ones. This can be attributed to several factors.

Larger cities are more likely to have extensive metro networks. With numerous stations spread across the city, metro systems offer greater accessibility and convenience for commuters, making them a compelling alternative to private vehicles. Extensive road networks in big cities often come with congestion issues. Gridlock and slow-moving traffic make personal vehicles a less attractive option, pushing residents towards faster and more reliable metro systems. Smaller cities may still rely heavily on shared public transport options like buses. While these can be functional, they might not offer the same level of comfort, speed, or punctuality as metro systems. Large cities often have a significant migrant population. These newcomers, unfamiliar with the city's layout, might find metro systems, with their clear maps and designated stations, to be a user-friendly way to navigate their new surroundings.

Metro ridership struggles in smaller Indian cities due to several factors.

Trips tend to be shorter in these cities, making alternatives like walking, cycling, or public buses more practical for daily commutes. Smaller cities often have a more reliable network of shared public transport like buses. These options, while perhaps slower than a metro, can be sufficient for shorter distances and offer greater flexibility, especially for last-mile connectivity to final destinations. Cost plays a role, Metros can be more expensive than buses or rickshaws, a deterrent for budget-conscious residents in smaller cities. The other major factor is that the passengers do not want to experience the procedure of climbing up to the metro station, taking a ticket, passing the security, then moving to the platforms and waiting for the metro rail to arrive instead in smaller cities, passenger prefers to easily board a sharing auto and travel without performing boarding procedure of a metro. (Tiwari & Jain, n.d.)

2.3.6 Analysis of Metro Rail in tier-2 Indian Cities

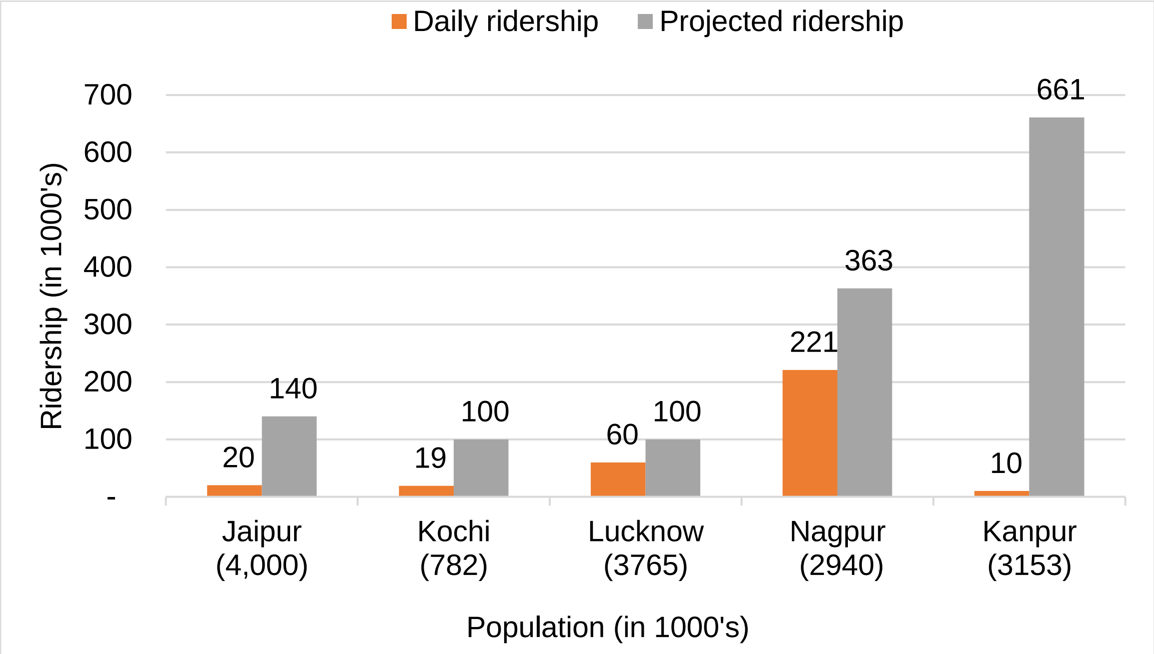

Figure 20 Predicted vs. actual ridership of metro in tier-2 Indian cities

Table 13 Ridership data of Metro Rail in tier-2 Indian cities

City	Jaipur	Kochi	Lucknow	Nagpur	Kanpur
Population (2021)	40,00,000	7,82,000	37,65,000	29,40,000	31,53,000
Service Opened	2015	2017	2017	2019	2021
Ridership data (year)	2019 -20	2020 - 21	2021 -22	2022 - 23	2022 - 23
Daily ridership	20,000	19,000	60,000	2,21,000	10,000
Projected ridership	1,40,000	1,00,000	1,00,000	3,63,000	6,61,000
System Length	12	24.5	22.8	38.22	8.98

The graph depicts the actual ridership vs. the ridership that has been predicted in the Metro Rail DPR, all the five cities taken for this analysis are tier-2 Indian cities and are growing at a very rapid rate in terms of population as well as spatially, It is observed that there is significant difference in the actual ridership to the ridership which was predicted for the same year.

The average percentage of daily ridership in all these cities is coming out to be **24%** of the predicted ridership. (Tiwari & Jain, n.d.).

3. SITE STUDY

To support the research, one tier-2 city has been selected to further proceed with the research, the city is Agra, there is a proposal for Metro Rail, there are 2 metro corridors proposed in Agra, and both the corridors are in phase-1 of Agra metro. The city will be helpful to do the alternate analysis of Metro Rail with Metroneo.

In the quest for efficient and sustainable urban mobility solutions, India is exploring various mass transit technologies. Metroneo, a relatively new concept, presents itself as a potential contender, particularly for tier-2 cities. This study investigates the feasibility of Metroneo as an alternative to existing or proposed rail systems in the city of Agra.

The city of Agra is selected as the site to support the research, Agra being the third largest city in terms of population in the state of Uttar Pradesh, India, has a very good potential to be the priority to take it as a live example of site selection, Agra has a very strong historical background, Once the capital of Mughal empire, the city still owns its historical charm having many world-famous architectural monuments like Taj Mahal, Red fort, etc. The city attracts a lot of Foreign as well as Indian tourists. Being the pathway of Uttar Pradesh from the eastern region of the country, it offers employment to a very large amount of the population. The city is currently observing rapid population growth due to migration as well as its native population. The second reason to select Agra as the site is the availability of Metro DPR, which is the very first source of data collection for the analysis.

3.1 General background of Agra:

Agra, a major tourist hub famous for the Taj Mahal, has seen its city limits sprawl significantly in recent decades. The city's population has also boomed, placing a strain on infrastructure.

Development has been uneven, with densely populated areas like Lohamandi and Shahganj struggling to keep up with the growth. This density is partly due to their historical significance, as settlements thrived there during the Mughal period.

Unequal development has led to pockets with high concentrations of people and jobs, putting pressure on infrastructure like transportation. Traffic congestion, accidents, and pollution are all serious problems. Most people rely on private vehicles due to the lack of convenient public transportation options.

To address these issues, a Comprehensive Mobility Plan (CMP) was created in 2017. The CMP outlines short-, medium-, and long-term solutions for improving Agra's transportation infrastructure. It proposes mass transit systems along key travel corridors to help alleviate traffic congestion and improve the overall quality of life for residents. (Authority, 2017)

Understanding Tier-2 Cities and their Transit Needs:

Tier-2 cities in India represent a unique demographic. They are experiencing rapid urbanization, leading to increased traffic congestion and a growing demand for public transportation. While not megacities with sprawling infrastructure, they still require robust and efficient transit systems to cater to their expanding populations. Traditional Metro Rail systems, often associated with tier-1 cities, can be expensive and disruptive to implement. This is where Metroneo, with its purported advantages of lower costs and less intrusive construction, emerges as a potential solution.

The Case of Agra: Metro Rail vs. Metroneo

The city of Agra, famed for the Taj Mahal, is currently considering a Metro Rail project. This system, if implemented, would involve a fixed rail network, elevated or underground, with high passenger capacities. However, Metro Rail projects are known to be capital-intensive and require significant land acquisition. Construction can be disruptive, leading to temporary traffic chaos and impacting existing businesses.

Metroneo, on the other hand, presents itself as a potentially less disruptive option. Depending on the specific technology employed (rubber-tired or steel-wheeled), Metroneo could require a more flexible and adaptable infrastructure. This could lead to faster construction times and potentially lower costs compared to a traditional Metro Rail system.

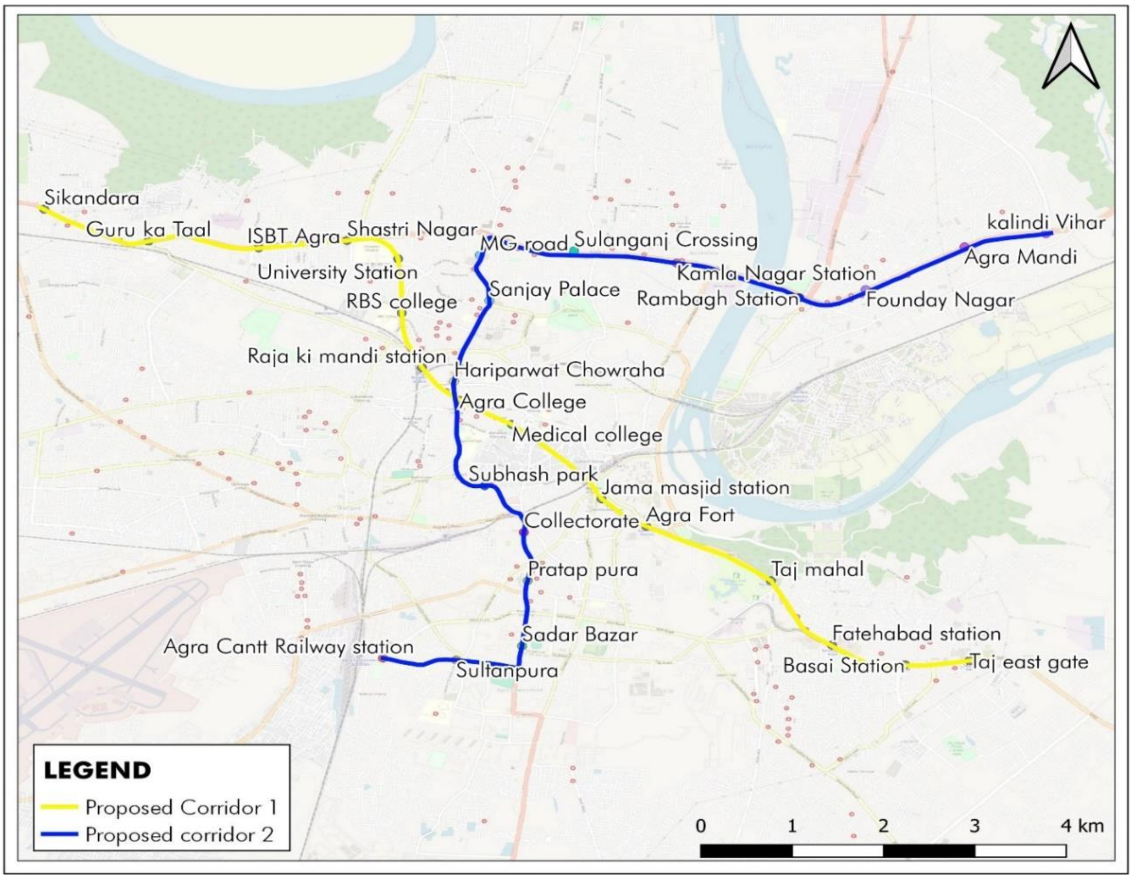

Figure 21 Proposed metro corridors in Agra

There are two metro corridors proposed in Agra, namely corridor-1 and Corridor -2, Corridor-1 starts from Sikandara and ends at Taj East gate with a total length of 14 km and 15 stations having underground and elevated corridor alignment, Corridor -2 starts from Agra cant railway station and ends at Kalindi Vihar with a total length of 16 km and total length of 16 km, with completely elevated alignment. Corridor - 1 is taken as the selected corridor for further analysis.

3.2 Criteria to select Agra as site

Agra is a tourist town, that has been observing a huge influx of tourists all over the year, it lies in the category of tier-2 cities of India, The city has a proposed metro network, which is necessary to do the comparative analysis of Metro Rail and Metroneo, moreover, my research is based on secondary data, which is referred from Metro DPR of Agra.

3.3 Existing situation scenario of Agra

Agra, the city of Taj Mahal is the 3rd most populous city in Uttar Pradesh and is the administrative headquarters of the Agra district. According to Agra master plan 2021, the population of Agra in 2021 is 25.5 lakh, with a planning area of 520 sq. km. The study will be done based on the population of the horizon year 2051. (Authority, 2017)

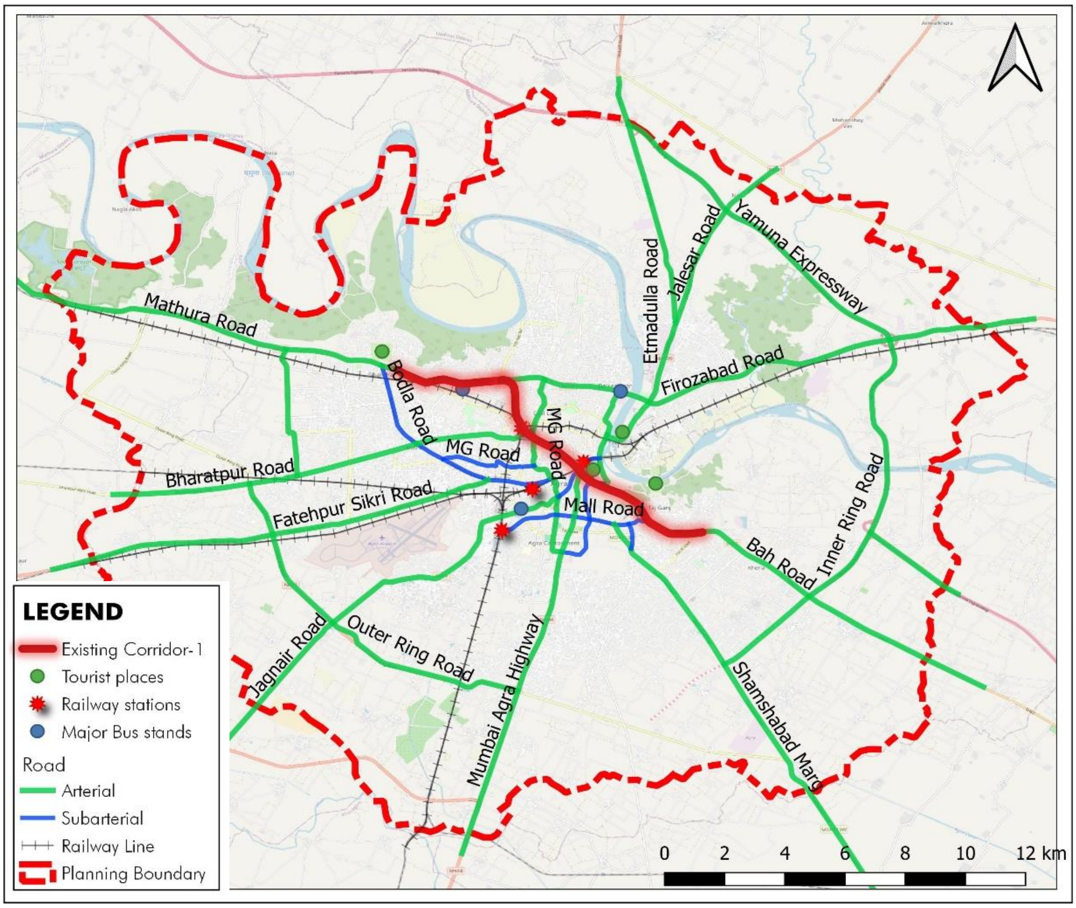

Figure 22 Map of Agra showing planning boundary, major passenger attraction points, and, Road network and the selected corridor-1 for analysis.

Daily alighting and boarding figures of major transport nodes

Agra has a well-developed transportation network connecting it to other parts of India. Here's a breakdown of the city's major transit hubs:

- **Buses:** Passengers can access various bus terminals, including ISBT near Transport Nagar, Idgah Bus Terminal, Bijlighar, and Water Works. The busiest terminal is Idgah, handling over 20,000 daily passengers boarding and alighting.
- **Trains:** Agra has four major railway stations: Agra Fort, Raja Ki Mandi, Agra Cantt, and Idgah. Agra Cantt sees the most passenger traffic, with nearly 29,000 daily boarding and alighting.
- **Air:** Kheria Airport serves domestic flights but currently has a low passenger volume. The city's Master Plan proposes to retain Kheria for future airport operations.

All the major transport nodes have been covered on the proposed metro corridor routes. (Authority, 2017)

Table 14 Daily boarding and alighting figures of major transport nodes in Agra

Railway Station	Daily boarding and alighting	Bus Stand	Daily boarding and alighting
Agra Fort railway station	19626	ISBT	9064
Raja ki Mandi	14418	Idgah bus stand	20446
Agra Cantt.	29045	Bijlighar	10765
Waterworks	9952	Waterworks	7161

Population

Agra boasts a large number of small-scale industries (around 7,000) and is the second-most self-employed city in India (as of 2007). This combination of industry and tourism has attracted migrant workers over the years, leading to a population boom. The annual population growth rate jumped from 2.4% (1981-1991) to 3% (1991-2001).

Considering historical census data and growth trends, a study area was defined as encompassing core, middle, outer, and special zones. Based on these factors, the estimated population of this area in 2017 was 2.37 million. The population in the study area for the horizon years, 2021, 2031, 2041, and 2051 is presented in the table below.

Table 15 Population for the Horizon year and Decadal population growth of Agra Planning Area

Year	Population (lakh) Planning area	Decadal growth (%)
2021	25.5	
2031	31.3	22.7
2041	36.2	15.6
2051	41.9	16

Issues and Challenges on Roads

On street parking and encroachment on both sides of the road at Jama masjid

Uncontrolled movement of animals near University area

Damaged road Infrastructure

Congested road section

3.4 Travel Characteristics

3.4.1 Road network

Agra has a total road network length of 414 km with an average trip length of 5.2 km, Agra faces congestion on its roads, because of less ROW majorly in the major arterial roads, because of haphazard driving, parking, hawking-vending, and passenger movement.

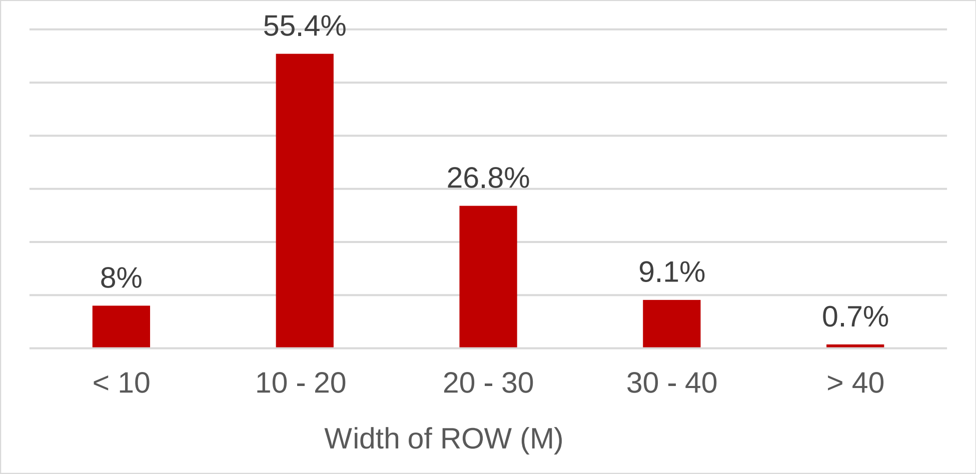

Figure 23 Distribution of road network in Agra as per ROW

3.4.2 Modal Share

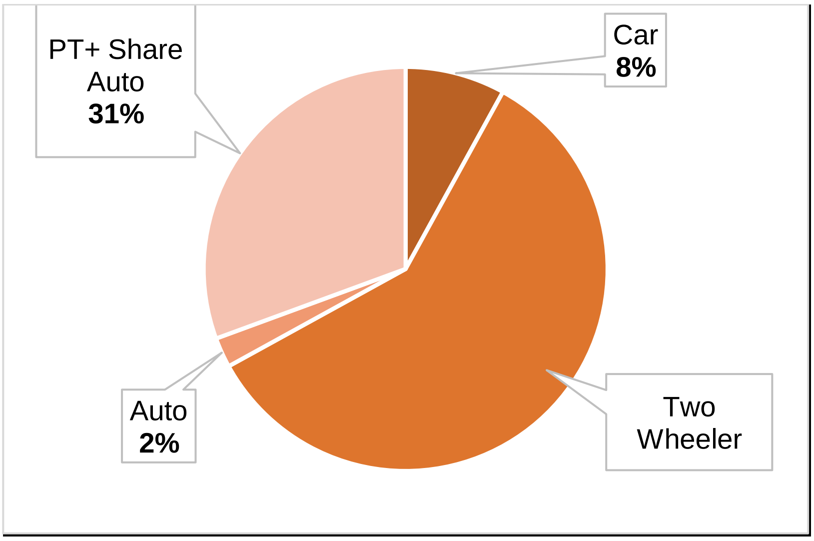

Figure 24 Modal share of Agra

Agra has a large number of dependency on two-wheelers and IPT services, although there are city buses available for commute, those are not as reliable as IPT.

Public transportation is essential for any city, offering cost-effective ways to move large numbers of people and reducing traffic congestion. It allows residents to access education, jobs, and social activities more easily.

Unfortunately, Agra's public transport system is limited. Buses are the only mass transit option, operated by Agra Mathura City Transport Services Limited (AMCTSL). The fleet consists mainly of regular buses with a few low-floor and minibusses, totaling only around 170 vehicles. This translates to nine buses per 100,000 residents, far below the recommended standard of 60-70 buses for a city of Agra's size. To fill the gap, private autos, shared autos, cycle rickshaws, and e-rickshaws are also available. (Authority, 2017)

3.4.3 Trip length distribution

The graph depicts the distribution of trip lengths in Agra, likely for a specific mode of transportation or a group of travelers. The x-axis represents the trip length in kilometers, divided into ranges. The y-axis represents the percentage of trips that fall within each range.

Based on the graph, we can infer that a significant portion of trips in Agra are relatively short, with most trips being less than 9 kilometers. There is a cluster around the 2-6 kilometer range, indicating that a substantial number of trips could commute within the city or short day trips in the surrounding areas. (Authority, 2017)

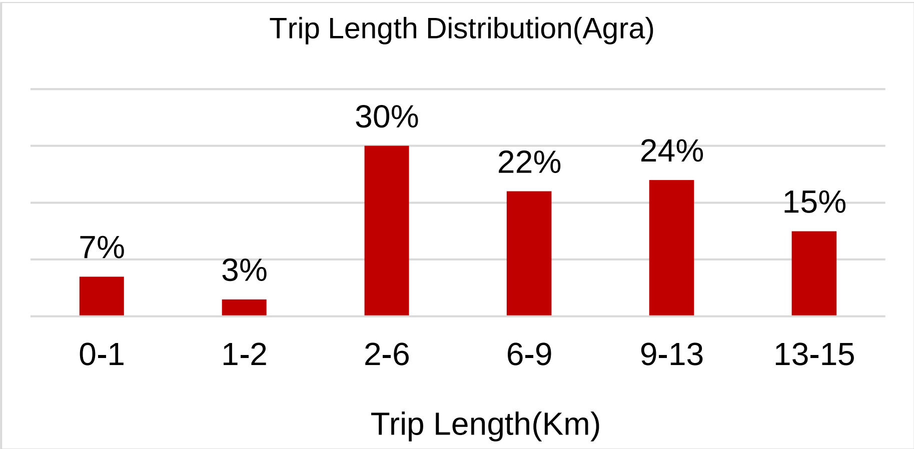

Figure 25 Trip length distribution of Agra

3.4 Comparative Analysis: A Framework for Evaluation

To effectively compare Metroneo with the existing proposals in Agra, a robust evaluation framework needs to be established. Key factors to consider include:

A. Passenger Demand: Understanding ridership projections for both cities is crucial. Metroneo's capacity should be sufficient to handle the expected passenger volume without compromising efficiency.

B. Project Cost: A detailed cost-benefit analysis comparing Metroneo with the proposed Metro Rail and LRT systems is necessary. Factors like construction costs, land acquisition needs, and operational expenses should be considered.

C. Urban Integration: Metroneo's infrastructure requirements need to be assessed in the context of each city's existing urban landscape. The system should be seamlessly integrated with existing roads and minimize disruption to the built environment.

4. ANALYSIS

Data collection for the research is majorly based on secondary sources, the sources involve various websites, Google Earth, etc. Data analysis will majorly focus on achieving all three of my objectives, the first objective of my research has already been achieved from the Case study part of the literature study in the second chapter.

4.1 Research Parameters

The research will be based on 4 parameters

1. Demand
2. Route alignment
3. Space requirement
4. Overall Cost

Now the focus will be on the other two objectives, the second objective which revolves around the novelty of Metroneo will be achieved by “Route alignment and Space requirement” parameters, and the third objective which revolves around the budgetary considerations will be achieved through the “Overall Cost” parameter.

These parameters will be used to compare the Metro Neo system with other MRTS with the support of the selected city of Agra. Corridor -1 (Sikandara to Taj East gate is chosen for the analysis)

As Indian tier-2 cities like Agra grapple with growing populations and increasing traffic congestion, the need for efficient and sustainable urban mobility solutions becomes paramount. This study aims to compare the Metro Neo system with other established Mass Rapid Transit Systems (MRTS) using four crucial parameters:

4.1.1 Demand

Agra: Existing traffic studies and ridership projections for the proposed Agra Metro Rail project will be analyzed. These projections will be compared with the passenger capacity of the proposed Metro Neo system to ensure it can efficiently handle the anticipated passenger volume. This analysis will involve considering factors like population growth projections, origin-destination patterns, and travel habits within the city.

As per Agra metro DPR 2017, the ridership data for the proposed metro corridor (corridor – 1) has been provided, according to the provided data they have also calculated the PHPDT of the route for the base year till the horizon year 2051. The ridership projection has been done considering the most optimistic scenarios and considering the most possible mode shift from every transport mode towards Metroneo.

Existing Metro Demand (Provided in DPR)

The Existing provided ridership data for the Existing corridor is given in the table below, including the PHPDT. (Authority, 2017)

Table 16 Provided ridership data of Metro (Corridor-1) in Agra Metro DPR

Corridor Name	Daily Ridership(lakh)			
Sikandara to Taj East Gate	2024	2031	2041	2051
	270000	342000	420000	503000
	Maximum PHPDT			
	10200	15300	24000	31500

It has been analyzed in the previous chapter-1 (Literature study) in the performance case studies of Metro Rail in tier-2 cities in India, that an average of only **24%** of ridership is achieved in tier-2 Indian cities, therefore we are considering 2 scenarios (least optimistic- **25%** and most optimistic-**35%**)

In both of these scenarios, the demand is reduced to 25% and 35% of the demand that has been projected in the DPR. The Alternative analysis for Metroneo will be based on these scenarios.

Scenario-1 (Least Optimistic)

Table 17 Ridership and PHPDT data for scenario-1 of projected data

Scenario – 1(Least optimistic) (assuming demand 25% of predicted)				
Corridor Name	Daily Ridership			
Sikandara to Taj East Gate	2024	2031	2041	2051
	67500	85500	105000	125750
	Maximum PHPDT			
	2550	3825	6000	7875

Scenario-2 (Most Optimistic)

Scenario – 2 (Most Optimistic) (assuming demand 35% of predicted)					
Corridor Name	Daily Ridership				
Sikandara to Taj East Gate	2024	2031	2041	2047	2051
	94500	119700	147000	172000	176050
	Maximum PHPDT				
	3570	5355	8400	10000	11025

Scenario 2 has been considered as the maximum demand that metro rail and Metroneo can achieve for the base as well as for the horizon year of 2051. The threshold PHPDT of Metroneo is 10000, which will be achieved in the year 2047. We will move forward with scenario 2 for further analysis which will focus on an alternative analysis between Metro and Metroneo on the selected Corridor.

4.1.2 Route Alignment

An efficient and well-defined route alignment is crucial for any MRTS to effectively connect key areas within a city and encourage ridership. This study will evaluate potential alignments for both Metro Neo and other considered systems in Agra:

- Connectivity: The ability of each system's proposed route to connect major residential areas, commercial centers, employment hubs, and tourist destinations will be assessed. The chosen system should offer convenient access to various points of interest within the city.
- Integration with Existing Transportation Network: The potential for each system to seamlessly integrate with existing bus networks, rickshaw stands, and other

modes of transportation will be evaluated. This integration will encourage multi-modal travel and provide commuters with last-mile connectivity to their final destinations.

This parameter will focus on the alignment of the existing to analyze the novelty of Metroneo, a Metroneo corridor will be superimposed on the existing corridor and check how can the corridor be made more efficient in terms of reducing the length, finding possibilities of converting sections from Elevated/Underground to At-grade, or reducing the underground section, possibility to use existing infrastructure like flyovers, underpasses, existing carriageway, etc. It will also be checked if the Metroneo corridor can be passed through those streets where the Metro corridor couldn't pass due to the turning radius, the width of the viaduct, etc.

Since the minimum turning radius required for a metro corridor is 130 meters and that for a Metroneo corridor is 32 meters, it is suggested to keep the turning radius to 60 meters for the future scope of converting the Metroneo system into a light rail system. Similarly, the width of the viaduct required for metro rail is 10 meters whereas the viaduct of Metroneo is 8 meters.

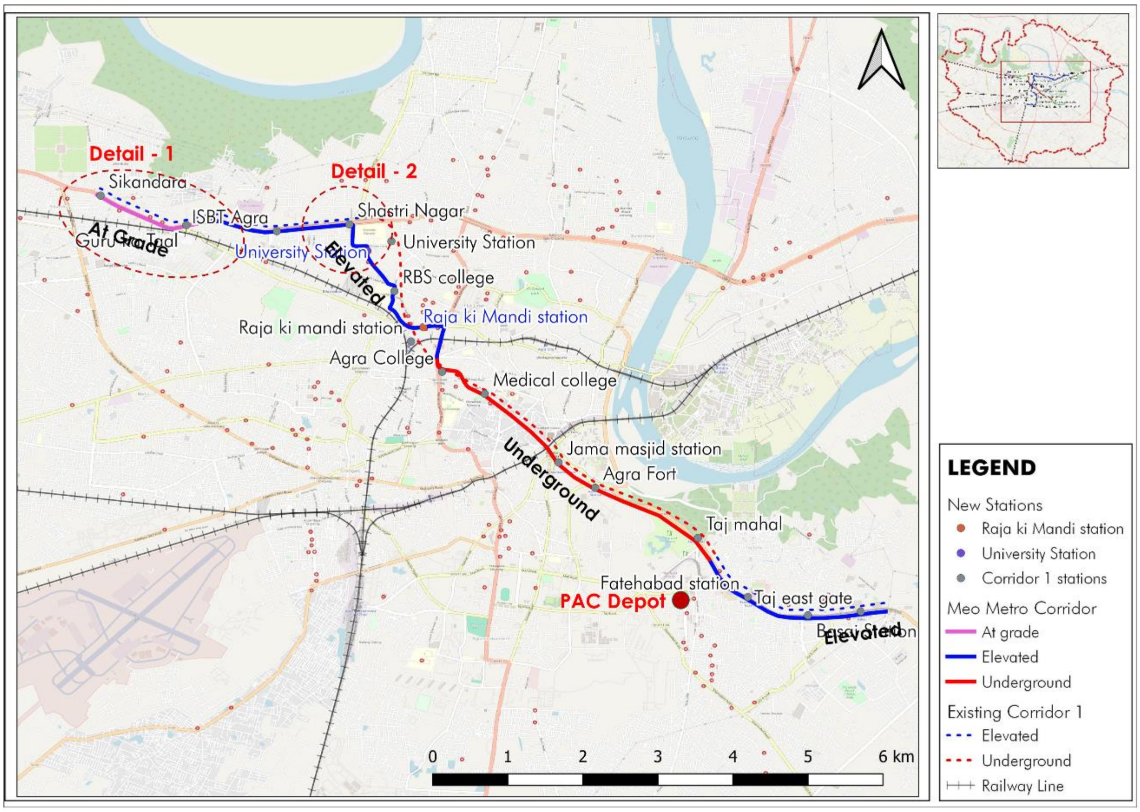

Figure 26 Map showing metro and Metroneo route alignment

In Figure 26, the map shows the existing metro route alignment, the location of stations, and the section details whether the alignment is elevated or underground. The new route of Metroneo is also shown on the map to show how many changes can be possible to the existing route to analyze the novelty of Metro Neo.

Existing Metro Rail corridor

The length of the corridor is 14 km having 15 stations, starting from Sikandara to Taj East Gate with both underground and Elevation sections. The corridor starts at the Agra – Delhi highway, making its way through congested areas of the city, and ends at Fatehabad road. From Sikandara to Shastri Nagar, the corridor is elevated and has 4 elevated stations. From the University station to the Taj Mahal station, there is an underground section having 8 underground stations, From the Fatehabad road station to the Taj East gate station the corridor is again elevated having 3 stations. There is a depot named PAC Depot located near Fatehabad Road station.

New Metro Neo corridor

Starting the corridor from Sikandara, for metro has an elevated viaduct and it is running on one side of the highway, now the alignment has been changed from elevated to At-grade for Metro Neo. Similarly to eliminate the underground portion of the alignment, the route has been diverted for Metroneo and it has been converted to an Elevated corridor from Shastri Nagar station to Agra College station. Rest of the underground section from Agra College station to Taj Mahal station. The length of the new Metroneo corridor is also coming out to be 14 km.

Detail-1

This at-grade section is running in the middle of the carriageway and the viaduct width is 8 meters, there are two stations in this section, namely Sikandara and Agra ISBT. The length of this at-grade corridor is 1522 meters, The detailed description of this section is shown in detail 1.

Figure 27 Map showing details of at grade section

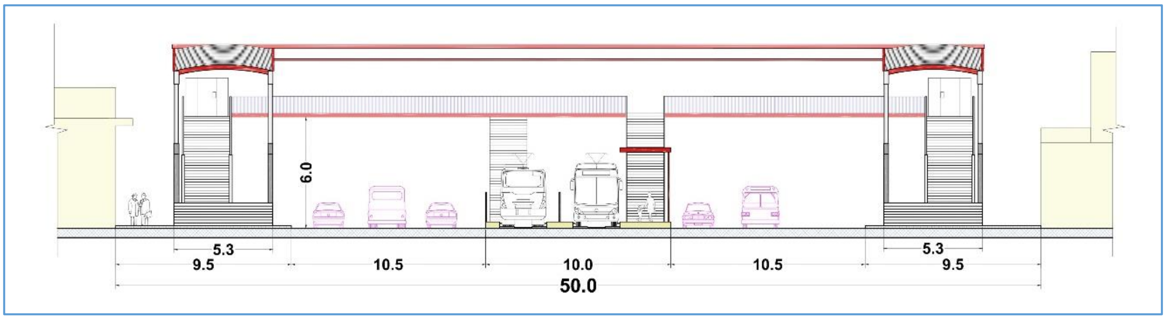

Figure 28 Section of Sikandara at grade Metroneo station

The ROW width of the highway is 50m, which is not being completely utilized, it is being encroached on the sides, It is a six-lane highway and acts as a bypass as well as an arterial road for the city, the carriageway acquires around 25 meters of the ROW, and rest of the ROW is not utilized efficiently, therefore it is possible to use 8 meters of ROW width and use it as at grade viaduct for Metro Neo.

The At-grade stations are designed in a segregated manner in the center of the ROW, to utilize to minimum width of the ROW, and provide sufficient space to the passengers at the platforms. The stations are not directly accessible from ground level instead the platforms are connected through a foot-over bridge which can also be used by the general public who wants to cross the road, The platforms will have check-in and check-out facilities, ticket kiosks, security guards, ITS technology-based information boards and security cameras. The width provided for the platform is 2.5 meters. The platforms will also be equipped with elevators connected from the foot over the bridge to the platform. There are 3-meter-wide staircases on both sides, along with the stairs there is also left for the escalators.

Detail-2

For the proposed Metroneo corridor the corridor after ISBT Agra station is elevated and this corridor is diverted from Shastri Nagar station to Agra college station, this proposal is done deliberately to reduce the unground section as well as to check if the corridor can be constructed on those roads where the ROW/Turning radius was not sufficient for a metro corridor to be constructed.

There are three stations on the diverted route namely University Station, RBS College, and Raja ki Mandi Station, among these stations the locations of RBS College Station and Raja ki Mandi Station are slightly changed. The width of the ROW of the diverted corridor is ranging between 15 meters to 18 meters.

The turning radius at each curve is kept 60 meters for the ease of turning of the rolling stocks. The drawback that can be faced due to the increased number of curves is a slight reduction in the speed of the rolling stocks. The new proposed route will help reduce the acquisition of land and property, reduce underground sections, etc.

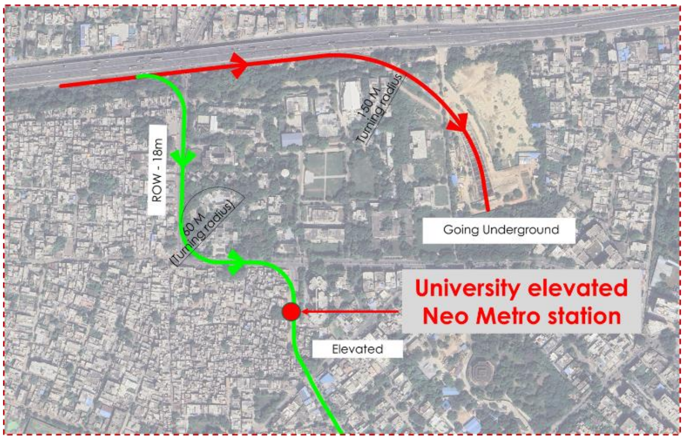

Figure 29 Map showing details of the Diverted section

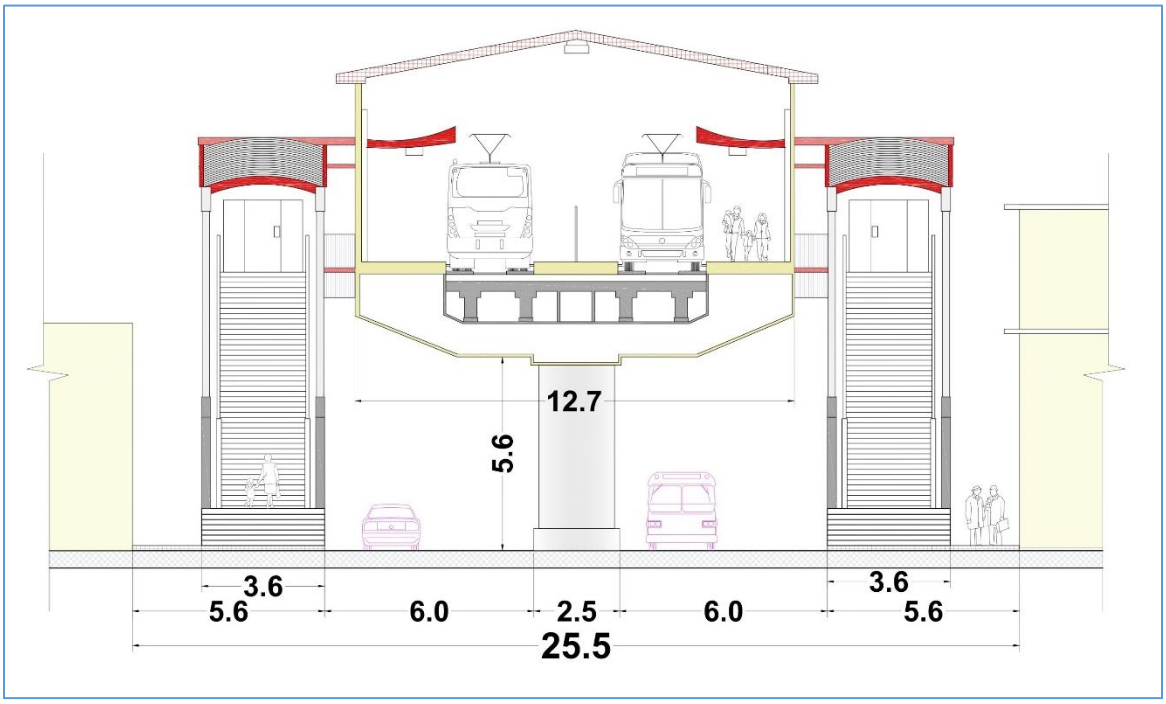

Figure 30 ROW section at University station Metroneo station

Although the ROW at the University station is 15 meters and the requirement of width is 25 meters, 5 meters of land will be acquired from both sides of the road to build the elevated station, for the viaduct there is no requirement of land acquisition.

The base of the pillar of Metroneo requires a width of 2.5 meters, stairs are built on both sides of the corridor having a width of 3.6 meters, platform width of 2.5 meters is provided in both directions. Passengers will be able to check in and out at the platforms, using ticket kiosks with security guards present for assistance. Digital information boards will display real-time updates, and security cameras will ensure safety. The platforms will be 2.5 meters wide and accessible by elevators connected to a footbridge.

The rest of the section from the medical college station is kept on the same alignment as it was for the metro proposal. There is a significant difference that has been observed after the implementation of the new corridor, the elevated section length is increased, the At-grade section is introduced and the underground section length is reduced.

Table 18 Length of Existing Metro and proposed Metroneo corridor sections

Length (M)		
	Existing Corridor (Metro)	**New Corridor (Metroneo)**
At grade	0	1522
Elevated	6410	7650
Underground	7590	4828
Total	14000	14000

From the above table, it can be inferred that the underground section has been reduced by 36%, and the Elevated section of the corridor has increased by 16%. Therefore in route alignment parameters we are making a difference in the requirement of resources like land acquisition, utilizing spaces efficiently, etc.

4.1.3 Space Requirement

Both Metro Neo and other MRTS options like Metro Rail and Metro Lite require dedicated infrastructure for their operation, but their spatial footprints can vary significantly. This study will assess the space requirements of each system in the context of Agra:

- Land Acquisition: The amount of land needed to construct stations and tracks for each system will be compared. This comparison will consider the impact on existing infrastructure, like roads and buildings, as well as potential disruptions to businesses and communities. Additionally, the feasibility of utilizing existing infrastructure, such as abandoned railway lines or canals, for certain sections of the chosen system will be explored.

- Space required for stations: For the demand that has been assessed for the most optimistic scenario, now there will be an analysis of the difference in the space required for the total number of stations for both the systems, Metro rail, and Metroneo.

- Space requirement for depots: The difference in the space for both the systems, Metro Rail and Metroneo will be analyzed according to the requirement of infrastructure requirement in both the systems for depot.

- Right of Way (ROW) Requirements: The width of land required for each system's right-of-way will be compared. A system with a smaller ROW requirement will be preferable, as it minimizes the need for land acquisition and reduces disruption to the existing urban fabric.

Area requirement for stations

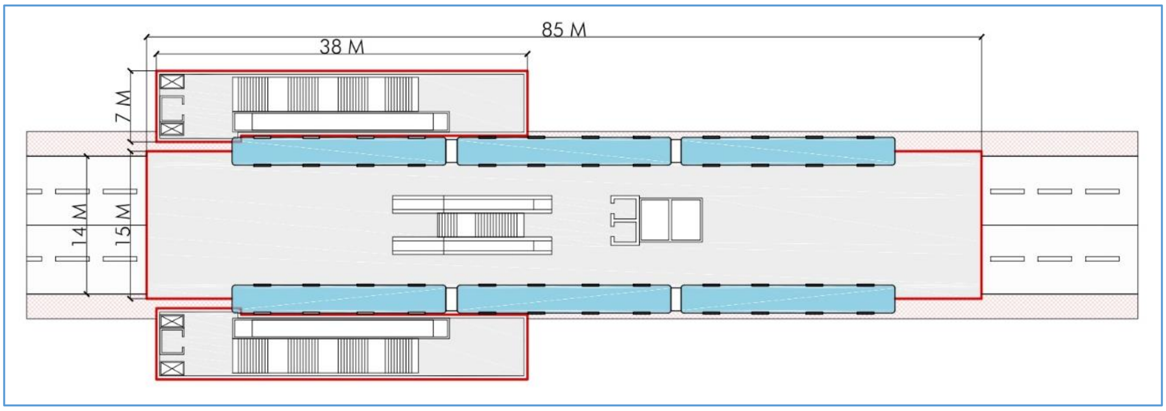

Figure 31 Typical Layout plan of an elevated metro station

The total area required for a typical elevated metro station is around 1800 sqm. The length of the station is around 85 meters and the width of the station is around 30 meters.

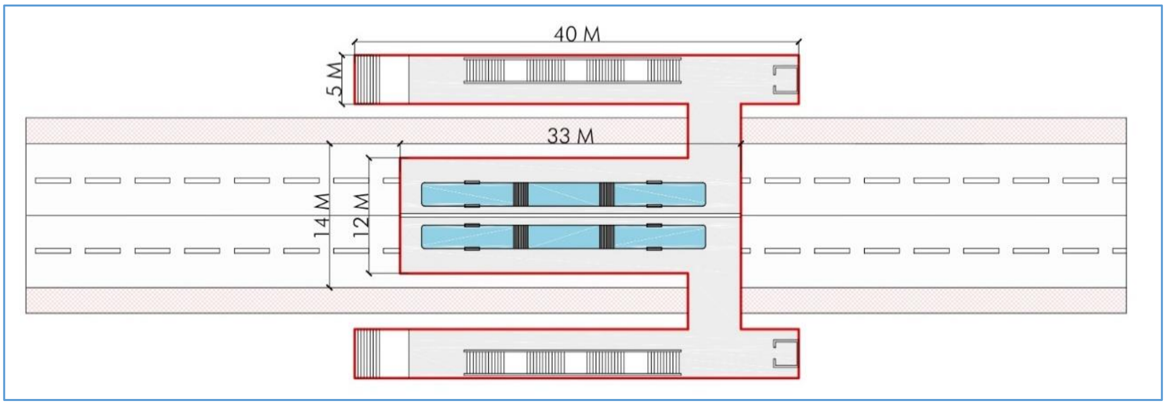

Figure 32 Typical Layout plan of an elevated Metroneo station

The total area required for a typical elevated Metroneo station is around 800 sqm. The length of the station is around 40 meters and the width of the station is around 12 meters, excluding the stairs and elevators and foot over bridge. The average area required for an underground Metroneo station is around 2000 sqm.

Table 19 Area requirement for Metro stations for corridor-1

Corridor 1 (Metro)				
Station type	U/G or Elevated	No. of stations	Area of 1 station	Total area (Sqm.)
A	Elevated	3	1934	5802
B	Elevated	2	2338	4676
C	Elevated	1	1769	1769
D	Elevated	1	1627	1627
F	Underground	3	4461	13383
G	Underground	2	2039	4078
H	Underground	1	4457	4457
I	Underground	2	4425	8850
Total Area				**44642**

Table 20 Area requirement for Metroneo stations for corridor-1

Area requirement for all stations of Metroneo corridor-1 (sq.m.)		
	Metroneo	
	Unit	Area
Elevated	8	6400
Underground	5	10000
At grade	2	1600
Total	**15**	**18000**

Area requirement for Depots

Table 21 Area requirement for maintenance depots for both systems

Area Requirement for Maintenance Depots		
	Metro	Metroneo
No. of Rolling Stocks (Horizon year)	15	35
Average area required on one rake (sqm.)	4054	1052
Total Area Required (sqm.)	**60810**	**36820**

The area required for maintenance depot for both the systems has been calculated according to the area given in the Metro DPR of Agra and Metroneo DPR of Dehradun, To do the calculations, the total area of the depot is divided by the number of rolling stocks of both the systems, then the dividend factor is multiplied with the number of rolling stocks which we need as per our demand. (Uttrakhand Metro Rail Corporation, 2021)

Area Requirement for Land Acquisition

Table 22 Difference in area of Land Acquisition

The difference in land acquisition of corridor-1 (sq.m.)		
	Metro	**Metroneo**
Permanent Land for station building	21852	8701
Permanent Land for the running corridor	26161	20434
Temporary Land Requirement (for cut and cover)	46500	32700
Temporary Land Requirement (For construction depot)	125000	9000
Total	**219513**	**70835**

Building a Metro system requires land for permanent structures like stations, tracks, and depots. Substations, radio towers, and access points also need space. Temporary land will be occupied by construction materials and worker facilities.

Compared to this, a Metroneo system, utilizing existing roads for dedicated bus lanes, requires significantly less permanent land acquisition.

The land area requirement for the Metro Rail corridor is already been provided in the Agra Metro DPR, with the help of the DPR of Dehradun Metroneo, the relatable areas have been calculated, for example – The at-grade station section of Metroneo does not require any land acquisition but the elevated section of Metro required land for station building on one side of the road, therefore the whole corridor has been analyzed for the area calculation. (Uttrakhand Metro Rail Corporation, 2021)

There are various purposes for which land is to be acquired, these purposes include:

1. Land for Elevated stretches: Elevated sections of the Metro/Metroneo won't need permanent land acquisition for the tracks themselves. Stations will require small pockets of land for entry/exits, traffic integration, and maintenance near the roadside, typically using existing footpaths or marginal setbacks. Only stations built away from the road will need permanent land for the entire station building.

2. Land for Underground stretches: Even underground sections won't need permanent land for most of the tracks. Similar to elevated sections, only small areas near the road will be permanently acquired for station entry/exits, traffic flow management, and ventilation shafts (for underground stations). These areas will utilize existing footpaths or marginal setbacks alongside buildings.

3. Land for Switch-over Ramps: To smoothly switch between elevated and underground sections, the Metro uses switchover ramps. These ramps take up a significant amount of space on the ground, stretching the entire width of the tracks. The length of the exposed ramp depends on the existing slope of the land and the incline of the Metro tracks (usually 3-4%). Because of this, ramps are built either where there's enough existing road width or in open areas.

Table 23 Area requirement difference for Metro and Metroneo

Area difference for all stations, acquired land, and depot of corridor-1 (sq.m.)				
	Metro		Metroneo	
	Unit	Area	Unit	Area
Elevated	7	13874	8	6400
Underground	8	30768	5	10000
At grade			2	1600
Maintenance Depot		60810		36820
Land Acquisition		219513		9000
Total		**324965**		**63820**

With the overall calculation, 20% of the area is required for Metroneo land acquisition as compared to Metro.

4.1.4 Overall Cost

Implementing any MRTS project involves significant financial investment. This study will conduct a comprehensive cost-benefit analysis comparing Metro Neo and other options in Agra.

- Capital Costs: Construction costs associated with each system, including station and track construction, and rolling stock requirement will be compared. An analysis of potential cost-saving measures specific to each technology, such as prefabricated station construction for Metro Neo, will be conducted.

- Operational and maintenance cost: Operational cost for each system till the horizon, the cost will include majorly the staff cost, which is associated with the salaries of working staff, maintenance expanses of the overall infrastructure till the horizon year, energy charges which include the expenses to be incurred for the cost associated with the battery expenses, traction power supply, power to operate depot, stations, offices, street lights etc.

- Revenue generation: fare box revenue and non-fare box revenue generation for each system will be calculated based on fare collection from passengers, Advertisement panels, Rent of kiosks, Parking charges at stations, film shooting charges, telecom cable, and tower license fees.

- Life cycle cost analysis: based on the overall cost associated with each system which is capital cost, operation and maintenance cost, land acquisition cost, current and future cash flow will be calculated for each year for each system and then it will be analyzed that how many years will it take for both the systems to recover the cost, and which system is more financially viable to be implemented in tier-2 cities. (Authority et al., 2019)(Authority, 2017)(Mass Rapid Transit Corporation, 2020)(Uttrakhand Metro Rail Corporation, 2021)

Rolling stock requirement:

Table 24 Requirement of Rolling Stock

Requirement of Rolling Stocks					
Year	PHPDT (Corridor-1)	For Metro		For Metro Neo (Bi articulated)	
		Rolling Stocks	Headway(peak hour)(mins)	Rolling Stocks	Headway (peak hour) (mins)
2024	3570	**7**	12'	**17**	4' 20"
2031	5355	**10**	7' 30"	**24**	2' 40"
2041	8400	**14**	5'	**30**	2' 8"
2051	10000	**16**	4' 18"	**35**	1' 50"

Rolling stock requirement is calculated following the peak hour trips of the corridor. It is also dependent on the capacity of the coach, as the maximum number of passengers that can be accommodated in a three-car coach of metro is 700 (most optimum capacity) and the maximum number of passengers which can be accommodated in a Bi-articulated coach is 240 (most optimum capacity), The number of headway required is calculated by dividing 3570(PHPDT) with optimum capacity, then number of coaches are distributed in one hour to get the headway of each coach.

Capital cost:

Table 25 Route alignment and formation cost

Alignment and Formation (cost in crores)				
	Metro (Length)	Metro (Cost)	Metroneo (Length)	Metroneo (Cost)
Underground Section	4.6	575	2	250.00
Underground Section (Cut and Cover)	2.08	253.76	2.08	253.76
Elevated section (Excluding station)	5.86	216.82	7.6	281.20
At grade section	0	0	1.52	22.80
Underground entry to the depot	0.25	30.5	0.25	30.50
Total		**1076.08**		**838.26**

The route alignment cost is calculated by comparing the cost/km of Metro and Metroneo with the reference provided in Metro DPR Agra and Metroneo DPR of Dehradun. The corridor sections for measuring the length of the section are the Underground Section, Underground Section (Cut and Cover), Elevated section (Excluding station), At grade section, and Underground entry to depot. The overall difference in the Route alignment and formation cost for Metroneo is 22% of Metro cost.

Table 26 Cost of station building

Station Buildings (Cost in crores)				
	Units	Metro (Cost)	Units	Metroneo (Cost)
Underground	7	994	5	350.00
Elevated	6	138	8	48.00
At grade			2	2.00
Lifts		21..62		11.00
Escalators		33.58		15.00
Total Cost		**1165.58**		**426.00**

The difference in cost of construction of Metro stations and Metroneo stations is calculated with the area required for each station, the cost includes additional cost of lifts and escalators also. The overall difference in the station building cost for Metroneo is 36.5% of the Metro cost.

Table 27 Land acquisition cost

Land Acquisition Cost (in crores)				
	Metro (Area)	**Metro (Cost)**	**Metroneo (Area)**	**Metroneo (Cost)**
Area Requirement for Maintenance Depots	60810	150	36820	90.82
Permanent Land for station building	21852	243.92	8701	78.71
Permanent Land for the running corridor	26161		20434	
Temporary Land Requirement (for cut and cover)	46500		32700	
Temporary Land Requirement (For construction depot)	125000		9000	
	219513	**393.92**	**70835**	**169.53**

The land acquisition cost for each system is calculated according to the land acquired along the routes of both alternative routes of Metro and Metroneo as well as the land required for ancillary buildings. The cost of land is calculated according to the land value of the property of the particular area. These lands are owned by private owners as well as government authorities like Defense, Railways, Colleges and institutes, etc.

Table 28 Total capital cost of both the systems

Total Capital Cost (Crores)		
	Metro	**Metroneo**
Land Acquisition Cost	**393.9**	**298.4**
Alignment and Formation	1076.1	838.3

Station Buildings	1165.6	426.0
Pway	115.8	90.0
Traction, power supply, Signaling, and Telecom.	409.9	82.1
Environment and R & R incl. Hutments etc.	8.8	4.0
Misc. Work	84.0	35.0
Capital expenditure on security and Staff Quarters	27.5	7.3
Capital Expenditure on Intermodal integration including Footpaths for pedestrians	39.0	23.5
Rolling Stocks	80.0	112.4
Total of all items except land	3006.6	1618.4
General charges @ 5% on all items except land	150.3	80.9
Total of all items including G. Charges	3156.9	1699.3
Contingencies @ 3 % on all items except land	94.7	51.0
Gross Total including Contingencies (excluding Land Cost)	**3251.6**	**1750.3**
Gross Total including Contingencies (including Land Cost)	3645.5	2048.7
Completion cost	**4010.1**	**2253.6**

Table 28 shows a comparison of the total capital costs for building a Metro corridor and a Metroneo corridor along the same route in Agra.

The table breaks down the total cost into various categories, including land acquisition, station construction, electrical systems, and rolling stock (trains or buses). Here's a summary of the key findings from the table:

- The total capital cost for the Metro corridor is nearly double that of the Metroneo corridor (₹4010 crore vs. ₹2253 crore).
- Land acquisition costs are significantly higher for the Metro corridor due to the need for wider rights-of-way to accommodate the larger trains and stations.

- Station construction costs are also higher for the Metro corridor because Metro stations are typically larger and more elaborate than Metroneo stations.
- The cost of electrical systems, including traction power and signaling, is higher for the Metro corridor due to the more complex technology involved.
- The cost of rolling stock is higher for the Metroneo corridor because Metroneo systems typically require more buses than Metro systems to achieve the same capacity.

Capital cost:

Table 29 Operation and maintenance cost of both the systems

Operation and Maintenance Cost (Crores)		
	Metro	**Metroneo**
(Staff Cost + Maintenance expenses + Energy charges) till 2047	574.5	117.5
Additional Cost (Major)	803.16	228.47
Total	**1377.6**	**346.0**

There are four major breakdowns associated with the operation and maintenance cost of each Metro and Metroneo system. These expenses include staff costs, Maintenance costs, Energy charges, and Additional major costs which are spent at particular stages of the lifecycle of the system.

The staff cost is 35 persons/km with an avg. annual salary of 7.12 lakh, escalation of 9% pa for metro and 15 persons/km with an average. Annual salary of 7.12 lakh, escalation of 9% pa for Metroneo.

The regular maintenance cost is 1.37 crores/km in 2024 with an escalation of 5% pa for Metro and 0.95 crores/km in 2024 with an escalation of 5% pa for Metroneo.

The energy charges are 2.8 crores/km with an annual escalation of 5% and 0.23 crores/km with an annual escalation of 5% for Metroneo.

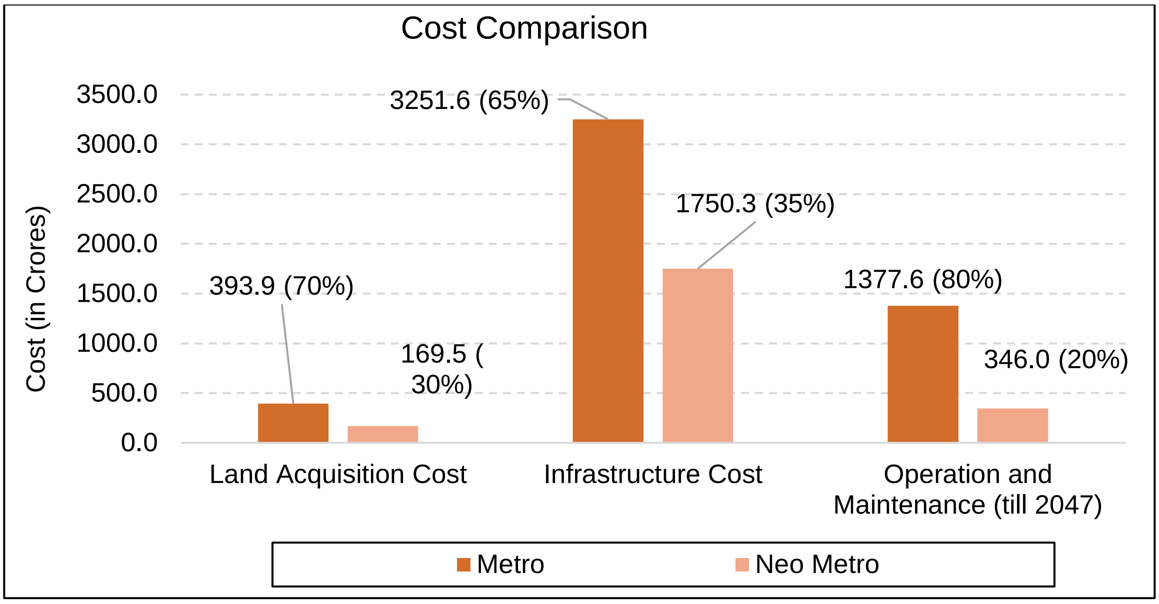

Figure 33 Capital and operational cost comparison of Metro and Metroneo

The graph shows a cost comparison between a metro and a neo-metro system. The metro is more expensive than a neo-metro in all categories. For instance, the cost of land acquisition for the metro is ₹3500.0 crore, whereas the cost of land acquisition for the neo-metro is ₹1750.3 crore (which is about 50% of the metro cost). Similarly, the cost of infrastructure for the metro is ₹3251.6 crore, whereas the cost of infrastructure for the neo-metro is ₹1377.6 crore (which is about 42% of the metro cost). The trend continues for operation and maintenance costs as well. Overall, building a neo-metro system is significantly cheaper than building a metro system.

Revenue Generation:

Revenue generation is calculated based on fare box revenue and no-fare box revenue for each system.

Table 30 Proposed fare structure of Metro and Metroneo

Fare Structure for Metro and Metroneo				
Trip length (km)	Fare2024	Fare2031	Fare2041	Fare2051
0-1	10	14	18	22
1 - 2	15	21	27	33
2 - 6	20	28	36	44
6 - 9	30	42	54	65

9 - 13	40	56	72	87
13 - 15	50	70	90	109

Table 30 gives the fare structure adopted for Metro and Metroneo in Agra. The same fare structure is currently being adopted by AC city buses in Agra. Assuming fare revision of 5 % every 2nd year same as adopted by Lucknow Metro, the fare structure for Agra Metro/Metroneo for horizon years has been worked out.

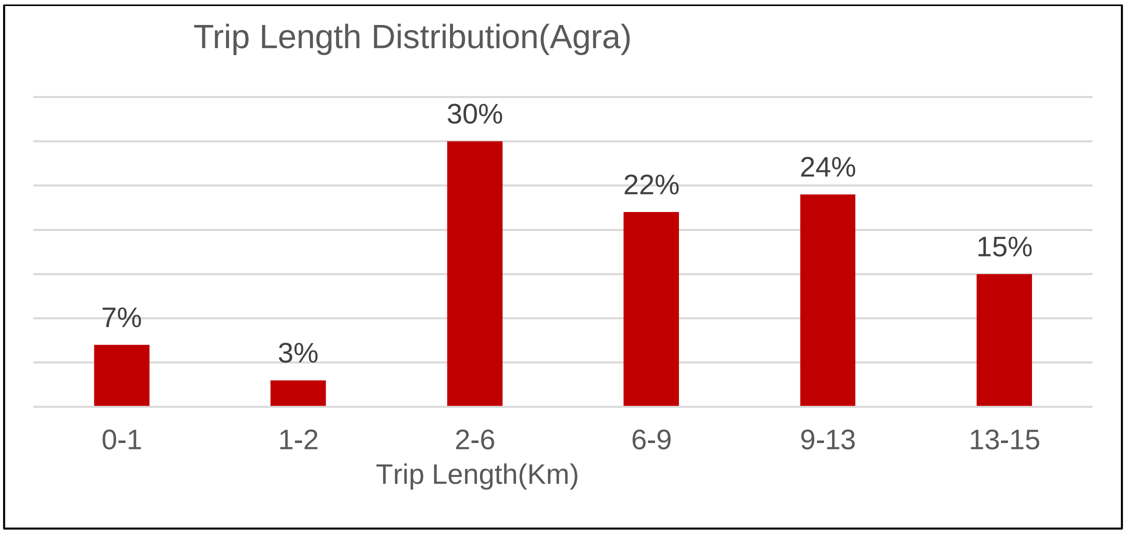

Figure 34 Trip length distribution of Agra

Farebox Revenue generation (Metro and Metroneo)

Year-wise fare box revenue generation is calculated with the help of the number of trips in the years 2024, 2031, 2041, and 2051. The number of trips has been calculated based on trip length. These trips are then multiplied by the fare (according to distance). Per-day fare collection is obtained, for the years 2024, 2032, 2041, and 2051, which is then multiplied by 365 to get a collection of one year.

Linear regression process is used to get the collection of each year from 2041 till 2051.

Table 31 Fare box revenue collection

Year	Trips/day	Annual Revenue (Crores)
2024	90540	99.36
2031	119700	182.65

2041	147000	301.63
2051	176050	420.61
Total revenue (2024-2051)		**7279.63**

Farebox revenue collection for both the systems Metro and Metroneo is 7298.63 crores. The revenue generation is calculated considering 100% ridership till the horizon year.

Non Farebox Revenue generation (Metro and Metroneo)

Table 32 Non fare box revenue

Types of Revenues	2024-2051	
	Metro	Metroneo
Advertising panels inside stations and train coach	1715.3	857.6
Kiosk rentals	57.1	34.3
Parking charges at stations	663.4	663.4
Film shooting charges	19.5	19.5
Telecom cable and tower license fee	84.8	84.8
Total	**2540.0**	**1659.5**

Non-fare box revenue for the existing metro corridor has been in the DPR, the non-fare box revenue provided in the DPR is in accordance with the projected demand of the corridor, therefore there is a need to recalculate the non-fare box revenue for the demand which is analyzed afterward for both the systems.

For the metro corridor, the Advertising panels inside stations and train coach revenue are considered as 60% of the provided revenue, The kiosk rentals and parking revenues are considered as 50% of the provided revenue, The film shooting charges, telecom cable, and tower license fee are considered as same of provided revenue.

For the Metroneo corridor, the Advertising panels inside stations and train coach revenue and kiosk rentals are considered as 30% of the provided revenue, The parking revenue is considered 50% of the provided revenue, The film shooting charges, telecom cable, and tower license fee are considered as same of provided revenue.

These percentage considerations are taken with consultation of Gaurav Gupta, manager (Design) DMRC, and Kaushalesh Dangi (MMRC).

Life cycle cost analysis

Table 33 Future cash flow (Metro)

Future Cash Flow (Metro)					
Year	**Infrastructure Capital Cost (Including Taxes)**	**Operation and Maintenance cost**	**Infrastructue Cost (Additional)**	**Gross Revenue**	**Net Cash Flow**
2024	4010.1				-4010.1
2024-2031		941.3		1545.7	604.4
2031-2041		2138.4	56	3349.5	1155.1
2041-2043		631.1	747.2	858.9	-519.4
2043-2051		3630.1		4065.6	435.5
					-2334.4

Table 34 Future cash flow (metroneo)

Future Cash Flow (Metroneo)					
Year	**Infrastructure Capital Cost (Including Taxes)**	**Operation and Maintenance cost**	**Infrastructue Cost (Additional)**	**Gross Revenue**	**Net Cash Flow**
2024	2253.6				-2253.6
2024-2031		300.5		1392.4	1091.9
2031-2041		584.8	105.5	3047.3	2357.1
2041-2043		155.3	123.0	783.7	505.5
2043-2051		797.3		3715.7	2918.4
					4619.1

Life cycle cost analysis is carried out for each system Gross revenue is calculated with fare box and non-fare box revenue, The net cash flow is calculated by subtracting gross revenue from all the involved costs (Capital cost, Operation and maintenance cost, and Additional cost).

The final cash flow in the horizon year (2051) is turning out to be (-2334.4 crores for Metro and 4619.1 crores for Metroneo).

Cost Recovery

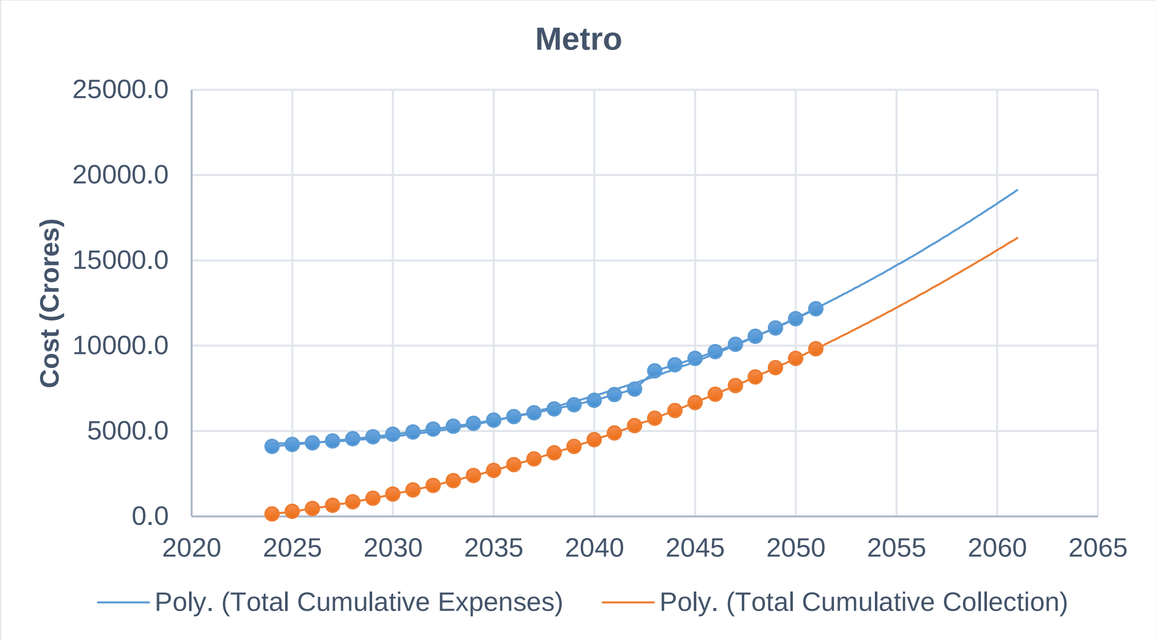

Figure 35 Graph showing the trend line of Total expenses and Total collection for metro

Metro is not getting its breakeven point even after the horizon year (2051).

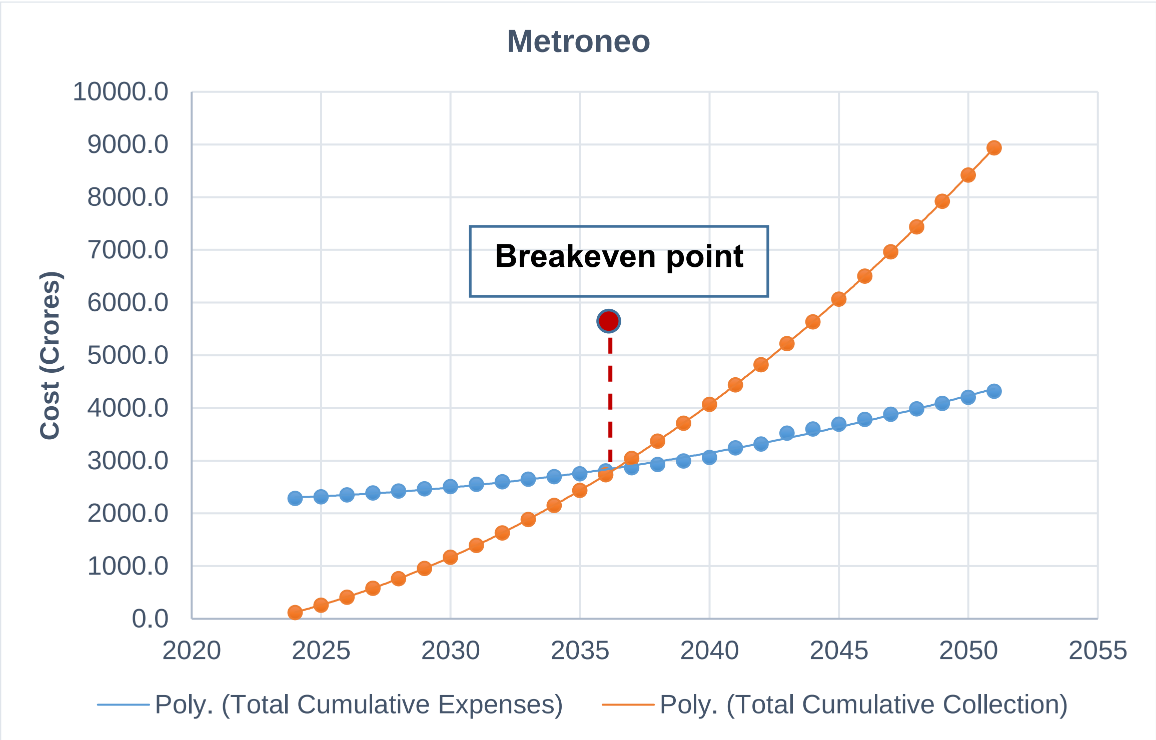

Figure 36 Graph showing the trend line of Total expenses and Total collection for Metroneo

Metro Neo is achieving a breakeven point in 2036, after this year the system will be profitable till the ridership threshold year (2047).

5. CONCLUSION

Cities with a population ranging (from 10-40 lakhs) with most of the trips (5-10 km) are suitable for at-grade bus systems.

High-capacity systems like the metro are very attractive for long trips in large cities with a population (> 8 – 10 million)

Metroneo system can cater to Peak Hour Peak Direction Passenger demand up to the year 2047 in Agra and has less capital and maintenance cost as compared with metro rail, with similar service quality.

Based on the quantitative analysis, Metro Neo comes out to be a profitable PT system in terms of cost, the profit earned can be used to upgrade Metroneo to light rail in the future if required.

Recommendations

1. The dominance of motorized two-wheelers (MTWs) in Indian cities can be addressed through a robust public transport (PT) system. The affordability of MTWs necessitates a PT option that is equally, if not more, cost-effective to operate and own.

To effectively compete with MTWs, the PT system must prioritize:

- Accessibility: Stations located within a 500-meter walking distance for most residents.
- Efficiency: Travel times that are faster or equal to those of MTWs for similar trips.
- Safety and Reliability: A system that is dependable and ensures passenger safety.

By implementing these measures, Indian cities can encourage a shift towards public transportation, reducing reliance on private vehicles and creating a more sustainable urban environment.

2. Public transportation systems risk losing riders to motorized two-wheelers (MTWs) unless they can offer competitive fares and travel times. This means pricing fares based on the marginal cost of using an MTW and implementing measures to improve bus speeds compared to cars and MTWs.

3. The key to attracting commuters from MTWs and cars to public transport (PT) lies in addressing the factors that make PT a less attractive option. Simply providing comfortable buses is not enough if they get stuck in traffic. Effective PT needs to be reliable, faster than driving while congested, and offer solutions for parking limitations at destinations.

For long-distance commuters, a shift towards PT becomes even more crucial, especially for low-income individuals who may currently rely on bicycles or walking due to affordability or lack of PT options. PT that is faster than these alternatives can significantly improve their access to job opportunities.

4. This analysis shows that a well-designed public transport (PT) system can achieve high accessibility by combining different modes. Here's how:

- Local coverage: A network of buses with extensive routes ensures most residents (within 500 meters) have easy access to PT.
- Long-distance trips: High-capacity systems like metro or LRT handle longer trips efficiently, even with a smaller network compared to buses.
- Combined approach: By integrating buses, BRT/Trolleybus, and metro/LRT, the PT system can serve nearly 90% of the population.
- Integration is key: Effective PT requires integration at various levels: policy, planning, design, and operation. This ensures a seamless and efficient user experience across all modes.

In short, a strategic mix of bus networks for local coverage and high-capacity systems for long distances, combined with strong integration, offers the optimal solution for maximizing public transport accessibility.

5. A well-designed public transport system is crucial for a healthy city, just like essential services such as water and electricity. To ensure everyone has access,

governments should take responsibility for planning, funding, and maintaining quality PT. The level of financial support will vary depending on factors like ridership and the chosen system (e.g., cost-effective at-grade buses vs. high-capacity metros). Careful financial planning is key, considering both ridership uncertainties and long-term operational costs. By factoring in various scenarios, governments can ensure a sustainable and accessible public transport system for all.

6. Prioritizing walking, cycling, and IPTs is crucial as nearly half of all trips are under 5 kilometers. Upgrading all roads to be pedestrian and bicycle-friendly, along with potentially city-wide IPT availability, would effectively address these short journeys. These modes can also function as feeder systems for high-capacity public transport like buses and metros.

For trips between 5 and 10 kilometers, implementing a formal bus network on arterial roads is recommended. In larger cities, a comprehensive network with high frequency (10 buses per hour) can entice riders. Open BRT systems with dedicated lanes for public transport during peak hours would further enhance attractiveness, especially for motorcycle, scooter, and occasional car users facing congestion. Since two-wheeled vehicles are more prevalent, public transport must compete with their inherent convenience and affordability.

Therefore, tier-2 cities should introduce full-sized buses on arterial roads alongside fixed-route and personalized IPT options. Shared lanes with safe crossings can accommodate buses, with a few high-demand corridors receiving exclusive lanes to boost capacity. Long-term planning should incorporate high-capacity systems like Light Rail Transit requiring dedicated right-of-way

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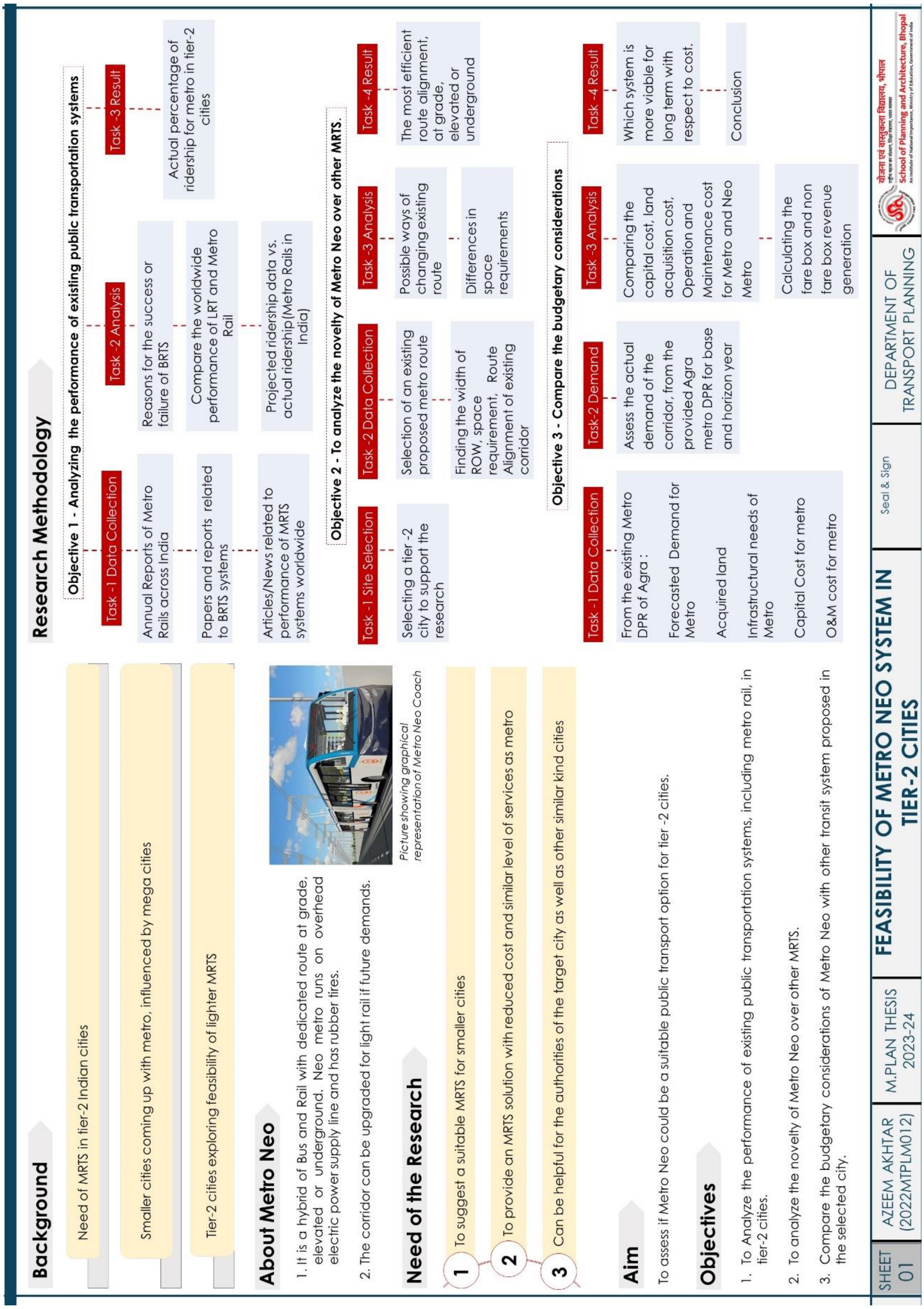
7. ANNEXURES

Sheet 1



Sheet 2

Literature Review

SN	Name of the Document	Author & year	Findings	Learning Outcomes
1	Standard Specifications of Metro Neo	MoHUA, 2020	Civil structure of Metro Neo, At grade and Elevated structure, Technology used for running the system	Differenciate between structural specifications of Metro Neo with other MRTS
2	A framework for selecting an appropriate urban public transport system in Indian cities	Geetam Tiwari, Deepti Jain (2022)	Transportation needs of Indian cities based on their population and size, Performance of Metro systems in Indian cities	The suitable transporation options for a city with respect to its size and population, Ridership Analysis
3	A Case Study on Indore BRTS with Reference to Other Indian Cities	Jayati Singh, Harivansh Kumar Chaudhary, Akash Malik (2022)	The current situation of BRTS in Indian cities, BRTS running status in Delhi, Pune and Indore	Barriers faced by BRTS system, Types of BRTS corridors and their advantages and Disadvantages.
4	An Update on Curb Guided Bus Technology and Deployment Trends	David Phillips, 2006	History and Technology of Kerb Guided bus systems worldwide	Specifications of Kerb guided bus system, Worldwide usage over time
5	Debunking the myths around optically-guided bus (Trackless trams)	Wong, Y. Z., 2018	Technology and worldwide practices of Optical guided bus system	Differences between various guided bus systems with respect to their advantages and disadvantages
6	Alternatives analysis report for Jammu MRTS	RITES, 2020	Alternative Analysis for the feasibility of MRTS in the city of Jammu between Metro Rail and Light Rail.	Method of finding the cost difference between two transporation systems, Performonce evaluation parameters
7	Detailed project report for metro neo project in Dehradun	UKMRC, 2021	Actual site specifications of Neo metro	Differences in various actual site parameters of Metro and Neo Metro

Literature Study

Definition of Mass Rapid Transit System

Mass rapid transit system (MRTS) is a high capacity public transport system which maybe a rail/bus that carries large number of passengers across the urban area faster & comfortably. However, there is a new hybrid system established in India which has features of both rail & bus.

Rail-based MRT

Bus-based MRT

Metro Neo specifications

Right of Way (for 2-way) 8.0m (At-grade) /2.2m (Elevated)

Grade Separation Exclusive/At-Grade

PHPDT Up to 10,000

Rolling Stock Standard Bus (12m) Articulated (18m) Bi-Articulated (24m)

Guidance System Kerb Guided/Central Rail Guided

Operational Speed 25 - 30 kmph

Axle Load 10 Ton

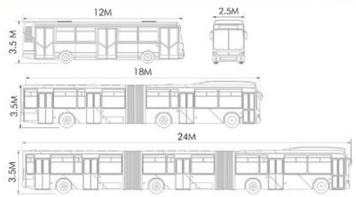
Platform Width 1.12m (Side platform) 4.0m (Island platform)

Cost per km (INR) 76 crores

Source :Standard specifications of metro neo (MoHUA)

Rolling stock specifications

Parameters	Single Coach	Articulated	Bi-Articulated
Dimensions (M)	12x2.5x3.5	18x2.5x3.5	24x2.5x3.5
Car Body	Stainless steal/Aluminium		
Tare weight(tonne)	12-13	18-19	25
Carrying Capacity (@ 6pax/ sqm.)	90	140	225
Capital Cost (crores)	2.25	3.75	5.38
Traction system	750 V DC overhead twin (positive and negative) contact wires placed in parallel.		



SHEET 02	AZEEM AKHTAR (2022MTPLM012)	M.PLAN THESIS 2023-24	FEASIBILITY OF METRO NEO SYSTEM IN TIER-2 CITIES	Seal & Sign	DEPARTMENT OF TRANSPORT PLANNING	योजना एवं वास्तुकला विद्यालय, भोपाल School of Planning and Architecture, Bhopal

Sheet 3

Comparative table of different Public Transport systems

PARAMETER	Metro Rail system	LRT/Metrolite	Metro Neo	Electric Bus
PHPDT range	More than 45000	Upto 15000	Upto 8000	Upto 8000
Number of coaches	6 coaches or more	2 to 3 coaches	Single Coach- 1 to 3 or single articulated or bi-articulated coaches	Single or articulated bus
Coach Dimensions	2.9 m/3.2 m wide 22 m long	2.9m wide 22 m long	2.55 m wide 12 M , 18 m and 24-25m Long	2.5m wide 12-24 m long
Coach Capacity	300 persons per coach	200 persons per coach	90, 140 and 225 respectively	90-225
Length of platform required	185m to 210m	90m	30 m & Terminal Stations 60 m	50m
CAPEX/km	Rs. 250 Crore/Km	175 crore/km	70- 80 crore/km (for elevated)	70-75 crore per Km (for elevated)
Deck width of viaduct	9 m to 10 m	7.0 to 8.5 m	8.0 m	7.0 to 8.5 m
Speed (Max)	80 KMPH	80 KMPH	70 KMPH	50 KMPH
Turning Radius(minimum)	120 M	60M	25 M	60 M

Relevance of Neo Metro in international context

1. Guided Busway
2. Trolley Busway

Metro-Neo is a hybrid of guided bus & trolley bus systems. Guidance technology recommended for Metro-Neo is followed in guided bus systems worldwide, while the OHE twin wires resemble that of the traction system in trolley buses.

1. Guided Busway

Rapid transit system exclusively for bus fitted with appropriate guidance equipment to use the system

+

2. Trolley Busway

Trolley bus is an electric bus that draws power from dual overhead wires using spring loaded trolley poles

1. Guided Busway

1.1 Kerb Guided

Technology

Lateral wheel fitted on bus guided through kerb guides. Buses are fitted with kerb wheels as a mechanical attachment

Concrete running surfaces with vertical curbs about eight inches high.

Advantages of Kerb Guided bus system

- Reduced sway
- More permeable area
- Need less ROW
- Segregated with traffic

12 Systems worldwide

12 Functional till date

1 Extended its network

2 Outside Europe

- Only 1 city has extended its system by 3 kms only
- Most adopted bus guided system
- Longest network is in Bristol, England with 50kms and 5 routes

Sources : An Update on Curb Guided Bus Technology and Deployment Trends, https://www.amusingplanet.com/2015/08/guided-busways.html, Kerb guided bus: is this affordable LRT?

1.2 Rail Guided

Technology

Metal wheels of train coach guided by the central rail

Rails embedded in the road as a guidance for the metal wheels

Advantages

- Reduced noise and vibration
- Reduced sway
- Precise docking

Limitations

- Bad road surface due to continue friction of rubber tires.
- Transition from guided to unguided is complex
- Merged with traffic

- 4 out of 10 systems closed
- Not successful in bigger cities of China
- Successful in Europe have less population, density and organized traffic
- Mostly upgraded from conventional trams

10 Systems worldwide

4 Closed

4 Length Expanded

3 Outside Europe

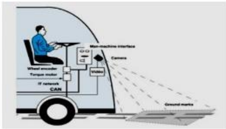
Sources : Nancy and Caen, France , https://www.amusingplanet.com/2015/08/guided-busways.html

SHEET 03	AZEEM AKHTAR (2022MTPLM012)	M.PLAN THESIS 2023-24	FEASIBILITY OF METRO NEO SYSTEM IN TIER-2 CITIES	Seal & Sign	DEPARTMENT OF TRANSPORT PLANNING	योजना एवं वास्तुकला विद्यालय, भोपाल School of Planning and Architecture, Bhopal

Sheet 4

1.3 Optical Guided

Technology



Lane markings placed along road & is captured by onboard system.

Clear lane markings on the road for sensor to capture

Advantages

Precise docking

Low maintenance cost

Limitations

Unproven for snow, heavy rain and fog

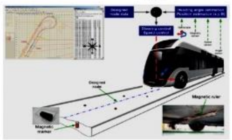
Merged with traffic

SN	Starting year	City	Network Length	Extended length
1	2008	Castellon, Spain	12	
2	2001	Rouen, France	32	
3	2004	Las Vegas, America	24	Discontinued in 2016
4	2018	CRRS Autonomous RRT (China)	10	

- Only **4** applications worldwide from 2001 to 2018
- In Las Vegas, optical guidance was used for station docking only and not general lane assist.
- Discontinued in Las Vegas due to poor reliability of road markings due to desert sun, dirt, greace etc.

1.3 Electromagnetic Guided

Technology



Sensors embedded on the lane to guide the bus

Magnetic pulse placed along lane at 5m spacing & helps with guidance.

Advantage & limitation

Easy transition to unguided

Still under development

- Only **2** applications worldwide from 1995 to 2006
- Has not achieved market due to proprietary and is expensive

Inferences from all 4 Guided bus systems

- Out of 28 bus guided systems worldwide Kerb guided is the most widely used followed by Central rail guided system.
- Except for Kerb Guided all 3 are merged with traffic.
- All kerb guided systems are functional till date
- Both Optical and Electro magnetic guided still lacks recognition

2. Trolley Busway

Technology

Trolleybus is an electric bus that draws power from dual overhead wires using spring-loaded trolley poles.

Two wires, and two trolley poles, are required to complete the electrical circuit. (negative and positive)

300 Trolley bus systems In operation worldwide

43 Countries

800 Trolley bus systems Used to Exist worldwide

Decreasing trend of trolley buses was seen during 1960-1970, because of diesel powered buses.

110 Trolley bus systems Scraped after 2000

14 Trolley bus systems Introduced after 2000

Decreasing trend of trolley buses was seen due to increasing popularity of CNG and electric buses

Advantages of trolleybus system

Better hill climbing

Environment friendly

Quieter than Trams and motorbuses

Cheaper infrastructure than trams

Limitations of trolleybus system

More control required

Less efficient use of ROW

Unable to overtake

More driver training required

Moscow Trolleybus network (case study)

1933 50 trolleybuses introduced → **2011** 88 routes, 1700 rolling stock 1 million ridership daily World's largest network → **2020** Trolley bus system operation ended

For reasons for scraping of network :

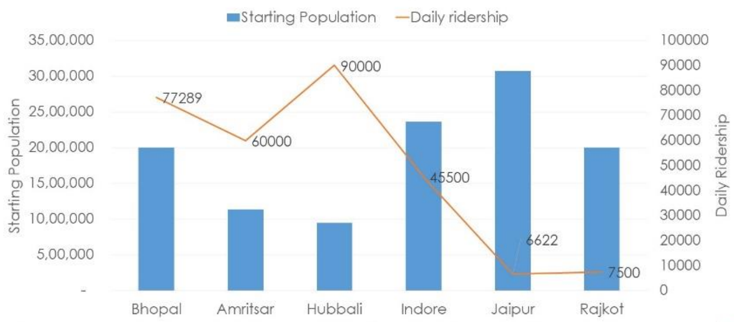
- Selling of Depots by Authorities
- to satisfy the needs of private transport companies
- To replace OHE system to Electric and Diesel base fleet

Source - https://www.urban-transport-magazine.com, https://blog.leibniz-ifl.de

SHEET 04	AZEEM AKHTAR (2022MTPLM012)	M.PLAN THESIS 2023-24	FEASIBILITY OF METRO NEO SYSTEM IN TIER-2 CITIES	Seal & Sign	DEPARTMENT OF TRANSPORT PLANNING	योजना एवं वास्तुकला विद्यालय, भोपाल School of Planning and Architecture, Bhopal

Sheet 5

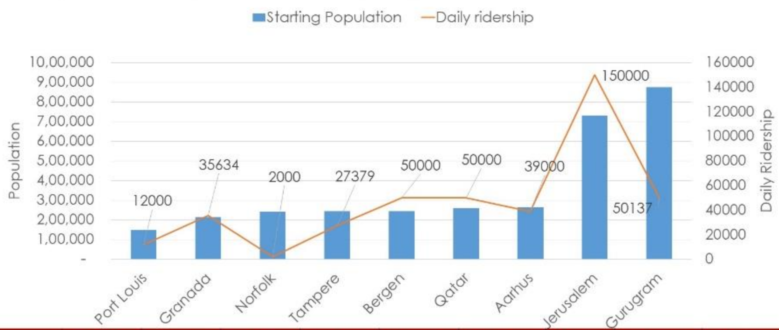
Case study (BRTS)



City	Bhopal	Amritsar	Hubbali	Indore	Jaipur	Rajkot
Daily ridership	77289	60000	90000	45500	6622	7500
System Length (km)	24	31	22	12	7	11
Ridership/km	**3220.4**	**1935.5**	**4090.9**	**3791.7**	**946.0**	**681.8**

- Even with smaller system lengths, Average daily per km ridership is 2450.

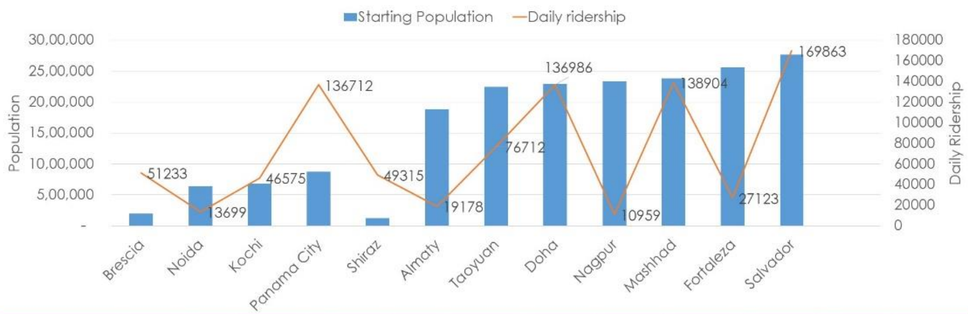
Case study (Light Rail Transit)



City	Port Louis	Granada	Norfolk	Tampere	Bergen	Qatar	Aarhus	Jerusalem	Gurugram
Daily ridership	12000	35634	2000	27379	50000	50000	39000	150000	50137
System Length (km)	26	17.5	12	16	9.8	21	12	13.9	11.7
Ridership/km	461.5	2036.2	166.7	1711.2	5102	2381	3250	17985	4285

- Average daily per km ridership is 4153.

Case study (Metro Rail worldwide)



City	Brescia	Noida	Kochi	Panama City	Shiraz	Almaty	Taoyuan	Doha	Nagpur	Mashhad	Fortaleza	Salvador
Daily ridership	51233	13699	46575	136712	49315	19178	76712	136986	10959	138904	27123	169863
System Length	13.7	29.7	27.4	36.8	24.5	13.4	53.1	76	26.1	37.5	24.1	32.5
Ridership/km	**3740**	**461**	**1700**	**3715**	**2013**	**1431**	**1445**	**1802**	**420**	**3704**	**1125**	**5227**

- The average ridership/km is 2232

OVERALL INFERENCE :

For the cities below 30 lakh population the case studies show more ridership of BRT and LRT than metro rail

Tier-2 cities (population < 30 lakhs)are taken into consideration for the analysis BRT, Metro Rail and LRT

Source : Global BRT Data, Online Secondary Data Sources

SHEET 05	AZEEM AKHTAR (2022MTPLM012)	M.PLAN THESIS 2023-24	**FEASIBILITY OF METRO NEO SYSTEM IN TIER-2 CITIES**	Seal & Sign	DEPARTMENT OF TRANSPORT PLANNING	योजना एवं वास्तुकला विद्यालय, भोपाल School of Planning and Architecture, Bhopal

Sheet 6

Metro system projected to actual daily ridership (%) (Indian Cities)

SNO	City	Average Trip Length	Population (in Lakhs)	Operational System Length (KM)	Actual Ridership/ Completion Year	Percentage of Forecast Ridership (%)
1	Jaipur (Phase-1)	9.1	39.09	11.98	2019-20	9.71
2	Ahmodabad Metro	5	80 59	37.902	2022-23	4.44
3	Bengaluru Metro	10	123.26	38.6	2022-23	31.32
4	Kolkata Metro	5	1485	47.85	2019-20	38.93
5	Mumbai Metro	9	204.11	66.04	2017-18	33.14
6	Hyderabad Metro	13	100.04	67.47	2021-22	7.9
7	Chennai Metro	12	10971	54.14	2019-20	12.15
8	Kochi Metro	12	30.82	26.8	2019-20	12.89
9	Lucknow Metro	7	36.76	22.87	2020-21	27.36
10	Delhi Metro	11	3029	349.27	2017-18	47.45
11	Nagpur Metro	7.6	28.93	3822	2021-22	7
12	Pune Metro	10.4	66 29	12	2017-18	5.83
13	Kanpur City	6.4	3123	8.621	2022-23	1.51

Actual ridership in operational Metro systems is less than 20% in most cities other than Delhi where it is 47%, Kolkata 38%, and Mumbai 33.14%.

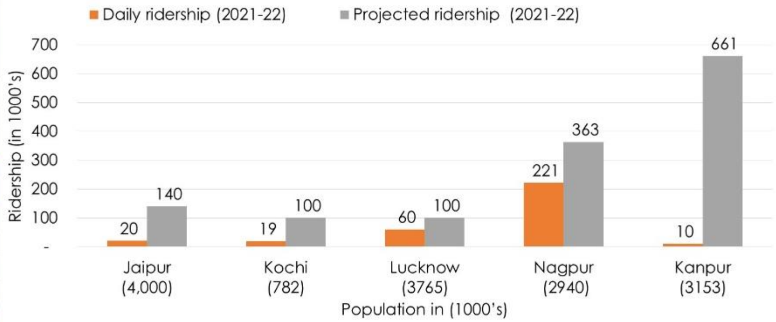
Reasons (Delhi, Mumbai and Kolkata):

- Population > 10 million
- Extended metro network
- Extended Road network
- Non reliability on shared PT
- Huge migratory population

Reasons (Tier-2 cities)

- Shorter trips
- More reliability on Shared PT for last mile connectivity
- Lesser fare of IPT

Analysis of Metro Rail (Indian cities – tier -2)



City	Jaipur	Kochi	Lucknow	Nagpur	Kanpur
Population (2021)	40,00,000	7,82,000	37,65,000	29,40,000	31,53,000
Service Opened	2015	2017	2017	2019	2021
Daily ridership (2021-22)	20,000	19,000	60,000	2,21,000	10,000
Projected ridership (2020-21)	1,40,000	1,00,000	1,00,000	3,63,000	6,61,000
System Length (km)	12	24.5	22.8	38.22	8.98

Tier -2 Indian cities are taken into consideration

Inference :
The average daily ridership is just **24%** of actually predicted ridership in tier-2 Indian cities.

Case study of Delhi and Bhopal BRTS

1. Delhi

100 km
Initial Plan

5.6 km
Pilot route was built in 2008

Two types of corridors were introduced :

1. 

Central median

2. 

Kerb side lane

Issues faced :
Bus only lane is used by general traffic.
Long bus queues in bus priority corridors.

- After 8 years of operation in 2016 the corridor got disassembled.

2. Bhopal

82
Bus stops

24 km
Started in 2013

77,289
Daily Ridership

273 crores
Cost of Construction

Map showing Bhopal BRTS route

- The BRTS route is supported by Trunk, Standard, Complimentary and Intermediate Para Transit (IPT) routes.

Issues faced by BRTS corridor :

- Merging with general traffic
- Non continuity of dedicated lane
- Two wheelers hindrance
- Movement of general traffic inside the corridor

Reasons for scraping of BRTS corridor :

- To increase ROW width for general traffic
- To construct flyovers in Misrod and Bairagarh

Source : A framework for selecting an appropriate urban public transport system in Indian cities, IIT Delhi

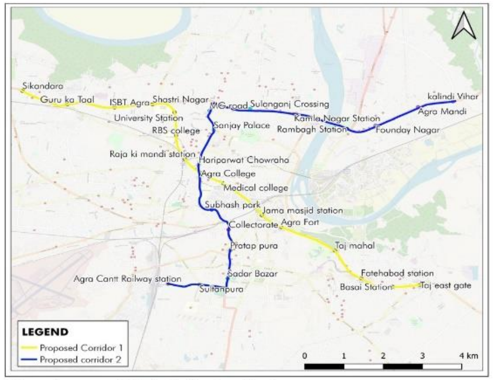
SHEET 06	AZEEM AKHTAR (2022MTPLM012)	M.PLAN THESIS 2023-24	FEASIBILITY OF METRO NEO SYSTEM IN TIER-2 CITIES	Seal & Sign	DEPARTMENT OF TRANSPORT PLANNING	योजना एवं वास्तुकला विद्यालय, भोपाल School of Planning and Architecture, Bhopal

Sheet 7

ANALYSIS

Site Selection

Considering Agra as the site to support the study



Map of proposed Metro Rail network in Agra

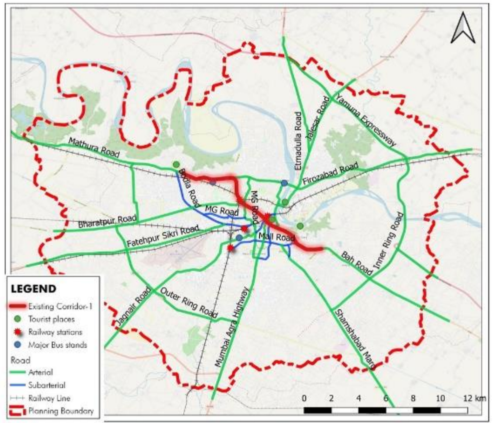
AGRA
Population – 25.5 lakhs (2021)
Planning area – 520 sq.km.
(source – Agra master plan 2021)

Criteria to select Agra as site

- Under Construction metro as well as functional
- Availability of secondary data

Length (km)
Corridor 1 – 14,
No. of stations - 15
Corridor 2 – 16,
No. of stations - 16

Existing Situation Scenario



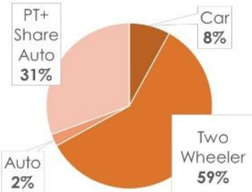
Map showing road network and major transport nodes in Agra

Agra, the city of Taj Mahal is the 3rd most populous city in Uttar Pradesh and is administrative headquarters of the Agra district.

414 KM Road length

5.2 KM ATL

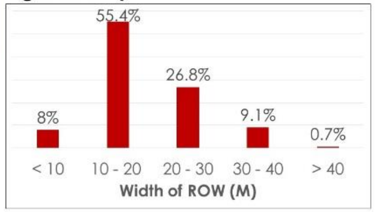
Modal Share



Population

Year	Population (lakh) Planning area	Decadal growth (%)
2021	25.5	
2031	31.3	22.7
2041	36.2	15.6
2051	41.9	16.0

Distribution of road network as per right of way



Research Parameters

The research is based on 4 parameters

1. Demand
2. Route alignment
3. Space Requirement
4. Overall Cost

1. Demand

Corridor Name	Daily Ridership (lakh)			
	2024	2031	2041	2051
Sikandara to Taj East Gate	270000	342000	420000	503000
	Maximum PHPDT			
	10200	15300	24000	31500

Source – Agra Metro DPR

It is observed that an average of only **24%** of ridership is achieved in tier-2 Indian cities, therefore we are considering 2 scenarios (least optimistic- **25%** and most optimistic-**35%**)

Scenario – 1 (Least optimistic) (assuming demand 25% of predicted)

Corridor Name	Daily Ridership			
	2024	**2031**	**2041**	**2051**
Sikandara to Taj East Gate	67500	85500	105000	125750
	Maximum PHPDT			
	2550	3825	6000	7875

Scenario – 2 (Most Optimistic) (assuming demand 35% of predicted)

Corridor Name	Daily Ridership				
	2024	**2031**	**2041**	**2047**	**2051**
Sikandara to Taj East Gate	94500	119700	147000	172000	176050
	Maximum PHPDT				
	3570	5355	8400	10000	11025

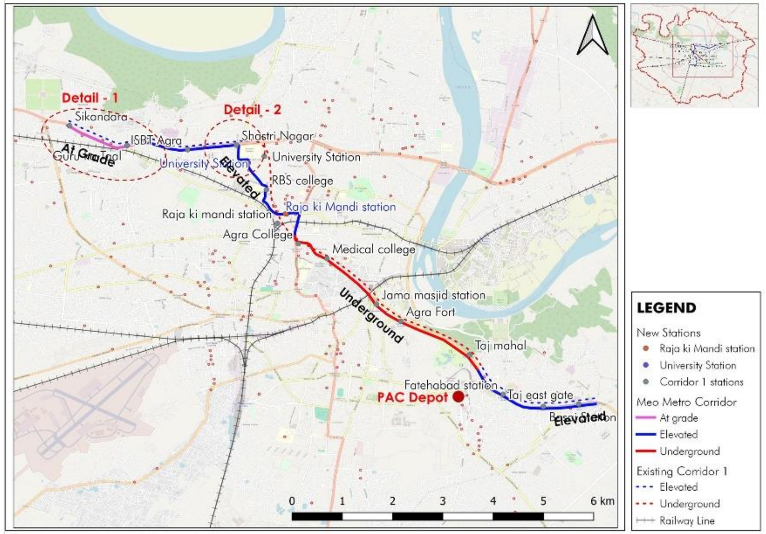
In 2047, the maximum PHPDT (for Neo Metro) is achieved
We will move forward with (scenario-2) for further analysis

SHEET 07	AZEEM AKHTAR (2022MTPLM012)	M.PLAN THESIS 2023-24	**FEASIBILITY OF METRO NEO SYSTEM IN TIER-2 CITIES**	Seal & Sign	DEPARTMENT OF TRANSPORT PLANNING	योजना एवं वास्तुकला विद्यालय, भोपाल School of Planning and Architecture, Bhopal

Sheet 8

2. Route Alignment

Imposing Metro Neo Corridor on existing Corridor -1, with changes in alignment



Map showing Metro and Neo metro corridor

Length (M)	Existing Corridor	New Corridor
At grade	0	1522
Elevated	6410	7650
Underground	7590	4828
Total	14000	14000

- Reduced Underground section by **2762 m (36%)**
- Introduced at grade section by **1522 m**

At grade alignment

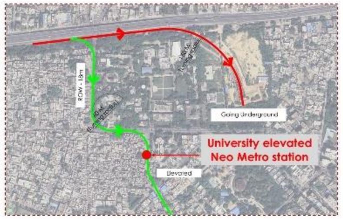
1522 m Length

2 No. of stations

Detail - 1

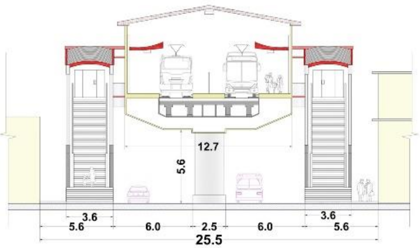
Section of Sikandara at grade Neo Metro station

Detail - 2



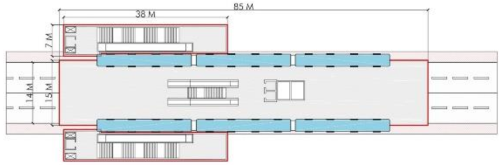
Inference : By proposing different route, we can reduce the land acquisition area.

Drawback : Speed will be reduced due to more curves on the route

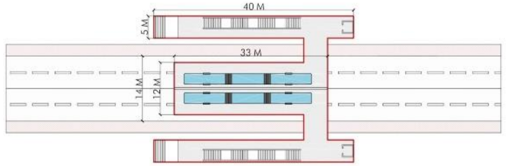


Section of elevated University Neo Metro station

3. Space Requirement



Typical Layout plan of an elevated metro station



Typical Layout plan of an elevated Neo Metro station

800 sqm
Required for elevated and at grade Neo Metro station

1800 sqm
Required for elevated metro station

2000 sqm
Required for underground Neo metro station

Area difference for all stations and depot of corridor-1 (sq.m.)	Metro		Neo Metro	
	Unit	Area	Unit	Area
Elevated	7	13874	8	6400
Underground	8	30768	5	10000
At grade			2	1600
Maintenance Depot		60810		36820
Total		105452	15	54820

Difference in land acquisition of corridor-1 (sq.m.)	Metro	Neo Metro
Permanent Land for station building	21852	8701
Permanent Land for running corridor	26161	20434
Temporary Land Requirement (for cut and cover)	46500	32700
Temporary Land Requirement (For construction depot)	125000	9000
Total	219513	70835

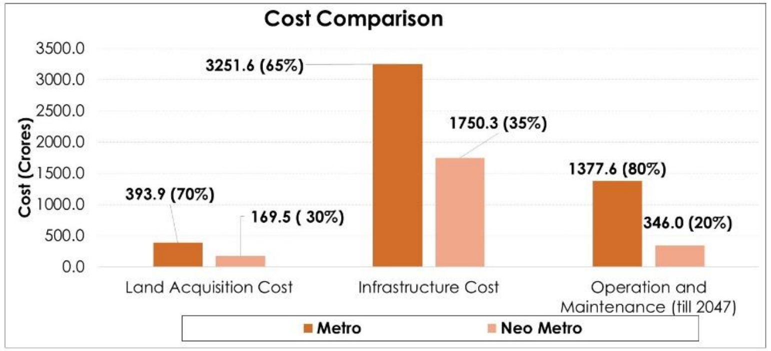
SHEET 08	AZEEM AKHTAR 2022MTPLM012	M.PLAN THESIS 2023-24	FEASIBILITY OF METRO NEO SYSTEM IN TIER-2 CITIES	Seal & Sign	DEPARTMENT OF TRANSPORT PLANNING	योजना एवं वास्तुकला विद्यालय, भोपाल School of Planning and Architecture, Bhopal

Sheet 9

4. Overall Cost

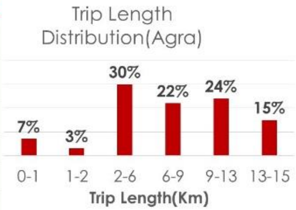
Total Capital Cost (Crores)	Metro	Neo Metro
Land Acquisition Cost	**393.9**	**298.4**
Alignment and Formation	1076.1	838.3
Station Buildings	1165.6	426.0
Pway	115.8	90.0
Traction, power supply, Signaling and Telecom.	409.9	82.1
Environment and R & R incl. Hutments etc.	8.8	4.0
Misc. Work	84.0	35.0
Capital expenditure on security and Staff Quarters	27.5	7.3
Capital Expenditure on Inter modal integration including Footpath for pedestrians	39.0	23.5
Rolling Stocks	80.0	112.4
Total of all items except land	3006.6	1618.4
General charges @ 5% on all items except land	150.3	80.9
Total of all items including G. Charges	3156.9	1699.3
Contingencies @ 3 % on all items except land	94.7	51.0
Gross Total including Contingencies (excluding Land Cost)	**3251.6**	**1750.3**
Gross Total including Contingencies (including Land Cost)	3645.5	2048.7
Completion cost	**4010.1**	**2253.6**

Operation and Maintenance Cost (Crores)	Metro	Neo Metro
(Staff Cost + Maintenance expences + Energy charges) till 2047	574.5	117.5
Additional Cost (Major)	803.16	228.47
Total	**1377.6**	**346.0**



5. Revenue Generation

Requirement of Rolling Stocks	For Metro		For Metro Neo (Bi articulated)	
Year	Rolling Stocks	Headway(peak hour)(mins)	Rolling Stocks	Headway(peak hour) (minutes)
2024	7	12'	17	4' 20"
2031	10	7' 30"	24	2' 40"
2041	14	5'	30	2' 8"
2051	**16**	4' 18"	**35**	1' 50"



Fare Structure for Metro and Neo Metro

Trip length (km)	Fare2024	Fare2031	Fare2041	Fare2051
0-1	10	14	18	22
1 - 2	15	21	27	33
2 - 6	20	28	36	44
6 - 9	30	42	54	65
9 - 13	40	56	72	87
13 - 15	50	70	90	109

- The fare is decided on the bases of existing AC buses fare of the city, with an increase of 5% increment in every 2 years.

Fare box Revenue generation (Metro and Neo Metro)

Year	Trips/day	Annual Revenue (Crores)
2024	90540	99.36
2031	119700	182.65
2041	147000	301.63
2051	176050	420.61
Total revenue (2024-2051)		**7279.63**

- Annual Fare box revenue is calculated according to 100% of projected ridership.

Non Fare box Revenue (Metro and Neo Metro)

Types of Revenues	2024-2051 Metro	2024-2051 Neo Metro
Advertising panels inside stations and train coach	1715.3	857.6
Kiosk rentals	57.1	34.3
Parking charges at stations	663.4	663.4
Film shooting charges	19.5	19.5
Telecom cable and tower license fee	84.8	84.8
Total	**2540.0**	**1659.5**

SHEET 09	AZEEM AKHTAR (2022MTPLM012)	M.PLAN THESIS 2023-24	FEASIBILITY OF METRO NEO SYSTEM IN TIER-2 CITIES	Seal & Sign	DEPARTMENT OF TRANSPORT PLANNING	योजना एवं वास्तुकला विद्यालय, भोपाल School of Planning and Architecture, Bhopal

Sheet 10

6. Cash Flow

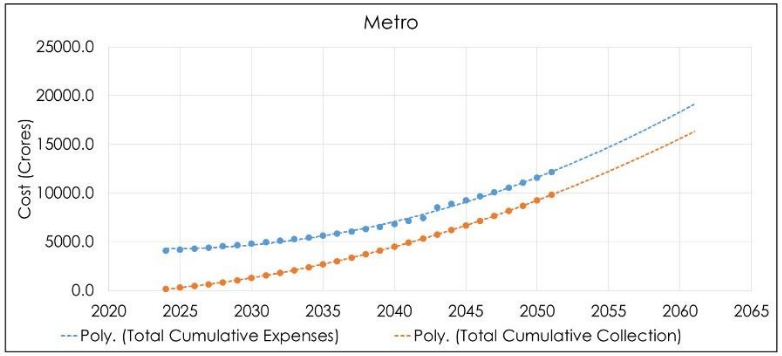
Future Cash Flow (Metro)					
Year	Infrastructure Capital Cost (Including Taxes)	Operation and Maintenance cost	Infrastructure Cost (Additional)	Gross Revenue	Net Cash Flow
2024	4010.1				-4010.1
2024-2031		941.3		1545.7	604.4
2031-2041		2138.4	56	3349.5	1155.1
2041-2043		631.1	747.2	858.9	-519.4
2043-2051		3630.1		4065.6	435.5
					-2334.4

Gross Revenue = Fare box revenue + Non fare box revenue

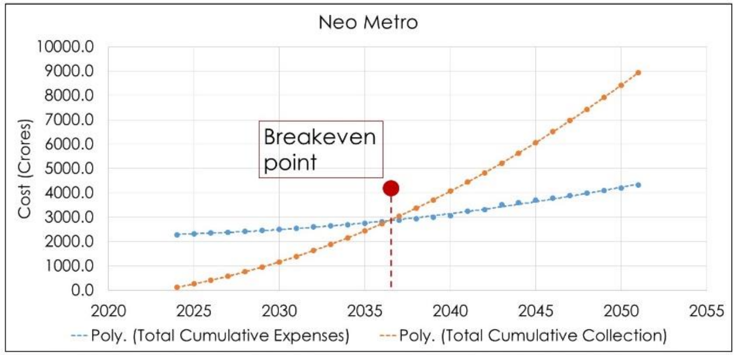
Future Cash Flow (Neo Metro)					
Year	Infrastructure Capital Cost (Including Taxes)	Operation and Maintenance cost	Infrastructue Cost (Additional)	Gross Revenue	Net Cash Flow
2024	2253.6				-2253.6
2024-2031		300.5		1392.4	1091.9
2031-2041		584.8	105.5	3047.3	2357.1
2041-2043		155.3	123.0	783.7	505.5
2043-2051		797.3		3715.7	2918.4
					4619.1

Metro is in loss of 2334 crores till the horizon year, while Neo Metro is getting positive cash flow 4619 crores till the horizon year.

7. Cost Recovery



Metro is not getting its breakeven point even at after the horizon year (2051).



Metro Neo is achieving breakeven point in 2036, after this year the system is profitable till the ridership threshold year (2047)

8. Conclusion

Cities with population ranging (10-40 lakhs) with most of the trips (5-10 km) are suitable for at grade bus systems.

High capacity systems like metro are very attractive for long trips in large cities with population (> 8 – 10 millions)

Neo Metro system can cater to Peak Hour Peak Direction Passenger demand up to the year 2047 in Agra and has less capital and maintenance cost as compared with metro rail, with similar service quality.

Based on the quantitative analysis, Metro Neo comes out to be a profitable PT system in terms of cost, the profit earned can be used to upgrade Neo metro to Light rail in future if required.

SHEET 10	AZEEM AKHTAR (2022MTPLM012)	M.PLAN THESIS 2023-24	**FEASIBILITY OF METRO NEO SYSTEM IN TIER-2 CITIES**	Seal & Sign	DEPARTMENT OF TRANSPORT PLANNING	योजना एवं वास्तुकला विद्यालय, भोपाल School of Planning and Architecture, Bhopal