



Convenience Of Monorail In Intra-city Transit System Of Mumbai

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Abstract: This study examines the monorail transit, as an intra-city transportation solution in Mumbai, India. The investigation starts by placing itself in the wider context of urban transport, with a particular focus on improving commuter convenience and solving urban transit problems. It starts with a broader survey of different vehicle & rail systems. It gradually zooms in to examine the infrastructure and efficiency of the existing transport systems in Mumbai—buses, local trains, and the metro. Mumbai's Monorail, a fledgling yet robust infrastructure that is poised for greater things, such focus is even more important in high-density, congested areas. The role of the monorail as a feeder transit system for metro and local trains in Mumbai has great potential to offer relief to urban transportation systems. The primary objectives of the research are to evaluate the feasibility of extending the monorail network citywide and its potential to address the immediate concerns experienced by Mumbai's daily commuters.

Index Terms - monorail, intra-city, transit, transportation, commuter, feeder, congestion.

I. INTRODUCTION

India's first Chembur-Wadala monorail section in Mumbai (The Economic Times, 2013) was on track for its August 2013 launch. Mumbai, a city of great significance, well known for its bustling dynamism and financial power, has a plethora of problems, with intra-city transport among them. Mumbai's transport systems are the backbone of this dynamic and financial centre of the country and are responsible for keeping this fast-growing city running smoothly. The main aim of this research is to determine the feasibility of the monorail to serve as an alternative and innovative solution to the existing transit issues of Mumbai. The explorations examine the possibility of extending monorail infrastructure to the entire city to address congestion and accessibility and provide insight into the monorail's ability to improve the everyday convenience of city dwellers.

The present research paper is designed to give an overview of the monorail's possibilities as a feeder transit system in Mumbai. We begin our survey by looking at the already existing highly structured transit in the city and breaking down the complex network of buses, local trains, the subway, and the monorail. The present critical analysis prepares the ground for a more extensive study of the monorail's operational principle and its interface with the city's infrastructure. The subsequent paragraph is devoted to the study of implementation of monorail infrastructure, presenting information on the main steps of project planning to operation and management.

To provide a complete view of the monorail's viability, the benefits of efficiency, less traffic, and cheaper operating costs balanced with drawbacks of high initial construction costs, restricted coverage, and possible public perception difficulties. The user-centred approach comes to an end with an examination of the crucial user perspective in which convenience, cost-effectiveness and stress reduction are motivators for the city's transit options.

II. METHODOLOGY

Research uses unified mixed-methods method to study intra-city transit system of Mumbai and monorail's potential as a viable option. Secondary data is obtained from reputable sources, providing a basis for rigorous qualitative and quantitative analyses. Card optimisation is applied to the delineation and interpretation of the existing transit networks, whereas the gathered secondary data enables a more systemic view of the field. The construction of monorail facility base on a waterfall structured model insists on a systematic and stepwise manner.

In order to confirm the monorail as a feasible and practical choice for city commuters, primary data is gathered via empathy mapping, which could facilitate a better understanding of user behaviour and expectations. SWOT analysis is used to compare the strengths and weaknesses of the monorail system to the alternatives available today. Moreover, a comparison has been also carried out so as to assess the performance of monorail against other well established transit systems.

This approach guarantees a systematic comprehension of monorail as, arguably, the best option for Mumbai commuters and its development future.

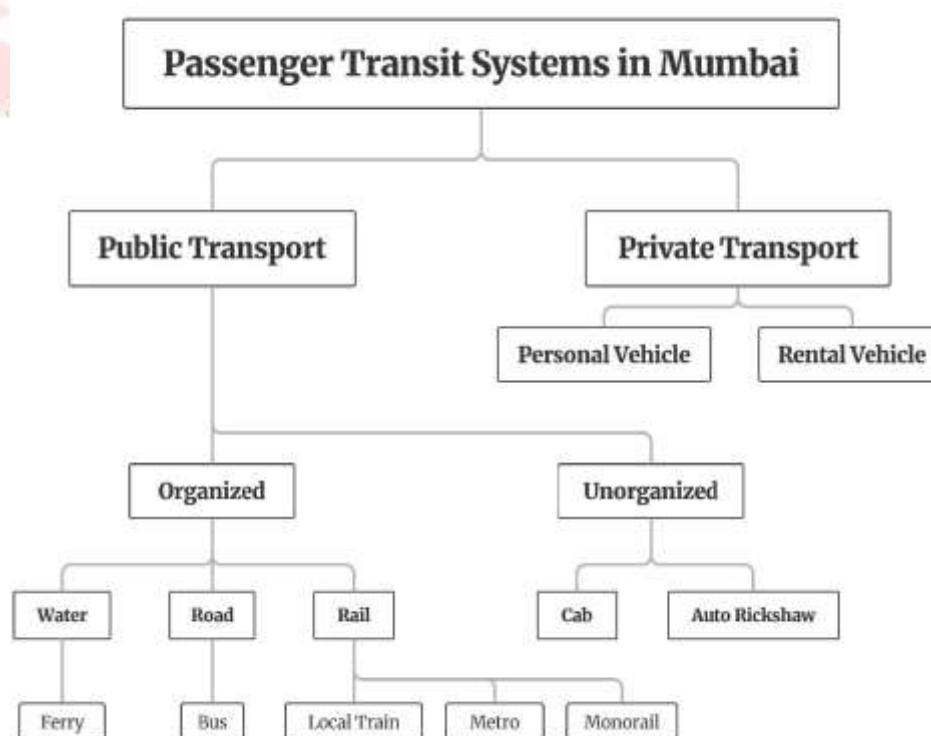
III. HYPOTHESIS

Monorail will take over the intra-city transit system of Mumbai as the infrastructure of Monorail is easier to set up in congested areas, can operate at cheaper rates than other metro transit systems, and has the potential to function as an effective feeder transit system.

IV. ORGANIZED TRANSIT SYSTEM - SECONDARY DATA, CARD SORTING, QUALITATIVE DATA, QUANTITATIVE DATA

When comparing monorails to other options of public transport, monorails have advantages including efficiency, decreased traffic, lower cost of operation and environmental considerations. Yet, there exist challenges such as high initial construction costs, low coverage, competing transport services, limited funding, public-perception concerns, and others, that all impact cost-effectiveness and adoption.

[Tree Diagram - 1] Passenger Transit Systems in Mumbai – Created by Author



4.1 Bus Transit System

Brihanmumbai Electric Supply and Transport (BEST) buses are fundamental to the public transport of Mumbai. They run a large-scale network of bus routes with different stations in the city. BEST buses serve as a lifeline for many Mumbaikars, connecting neighbourhoods, commercial areas, and suburban regions.

BEST Undertaking Ltd is the managing company that controls the busyness in the City of Mumbai. BEST buses afford an inexpensive and reasonably efficient way of transport. They are available to almost everybody who commutes which is very important for the reduction of traffic (Cook, 2021).

4.2 Local Train Transit System

The Mumbai Suburban Railway (commonly known as Mumbai local trains) is a big network of suburban rail services that links the city of Mumbai to its suburbs. It is one of the world's most travelled commuter rail networks.

The local trains in Mumbai are maintained by Indian Railways and are classified into Western, Central, Harbour, Trans-Harbour, and Uran lines. Mumbai local trains are the lifeline of intra-city transport, especially during peak hours. They are known for their affordability and accessibility.

4.3 Metro Transit System

The Mumbai Metro is an elevated and underground rapid transit system in the city. It is both a quicker and more economical means of transport, particularly for extended distances and densely populated routes.

The Mumbai Metro is the property of MMRDA [Mumbai Metropolitan Region Development Authority] and is operated by Mumbai Metro One Pvt. Ltd. [Line 1, Versova-Andheri-Ghatkopar] and the Mumbai Metro Rail Corporation Ltd. [Line 2A and 7, Gundavali-Dahisar-West Andheri] (Mumbai Metropolitan Region Development Authority, n.d.). Mumbai Metro offers a comfortable and time-saving transportation option, avoiding traffic jams. Handy for the passengers to easily transfer from one mode of transport, such as a bus or a light train.

4.4 Monorail Transit System

Mumbai Monorail is one of the kind mode of transport, which has single elevated track as an operation mode. It provides a further mode of public transportation, linking areas of the city which are unlikely to be well served by other 交通方式.

The Mumbai monorail is run by the Mumbai Metropolitan Region Development Authority [MMRDA] in Chembur-Wadala [Phase 1] and Wadala-Sant Gadge Maharaj Chowk [Phase 2]. The Monorail provides a scenic view of the city while offering a relatively faster mode of travel compared to road transport. In the sense that it contributes to reduce congestion on some paths and provides a pleasant experience.

The present trackway of Mumbai Monorail is from Chembur to Sant Gadge Maharaj Chowk. MMRDA claims it is divided into two phases as per the project implementation, Phase 1 is Chembur to Wadala [8.93 km, 22 minutes] and Phase 2 is Wadala to Sant Gadge Maharaj Chowk [11.20 km, 32 minutes] (Bhandekar More, 2017).

- Date of Commencement - 14th November 2008
- No. of stations - 17 Stations
- Train Composition - 4 cars
- Passengers Capacity - 562 Max Passengers
- Project cost excluding taxes - Rs. 2460 crore
- Design Speed - 80 kmph
- Scheduled Speed - 31 kmph
- Operation Hours - 05.00 Hrs to 24.00 Hrs (Mumbai Metropolitan Region Development Authority, n.d.)

The Operating Line:

1. **Chembur**
2. VNP Marg Junction
3. Fertilizer Township
4. Bharat Petroleum
5. Mysore Colony
6. Bhakti Park
7. **Wadala**
8. GTB Nagar
9. Antop Hill
10. Acharya Atre Marg
11. Wadala Bridge
12. Dadar East [Near Dadar Railway Station]
13. Naigaon
14. Ambedkar Nagar
15. Mint Colony
16. Lower Parel
17. **Sant Gadge Maharaj Chowk** (Bhandekar & More, 2017)

However, in September 2008 MMRDA presented the monorail project with a plan to build eight lines. The master plan was meant to bring the entire of Mumbai together. However, in September 2011, Mumbai Metropolitan Region's ambitious MMRDA plan of establishing around 200 km of monorail in the Mumbai Metropolitan Region received a setback. The Mumbai Metropolitan Region Development Authority (MMRDA) had decided not to proceed with any of the proposed future alignments of the monorail although for almost the entire master plan Detailed Project Reports (DPRs) were prepared. They clarified it did not imply that they were not interested in completing the project, it might not go according to the timeline that was originally anticipated (Siddhaye, 2011). Once again, as per MMRDA, on the basis of the above situation, there was no reason to look for any new route and if a new route was not commissioned and the outcome was reported, the commission was not planning any new route. As per a senior MMRDA officer, the requirement for the monorail will set in at the time all the proposed metro rail routes come out of operation and the monorail functions as an intermediate mode (Kulkarni, 2012).

V. WORKING MECHANISM OF MONORAIL - SECONDARY DATA, QUALITATIVE DATA

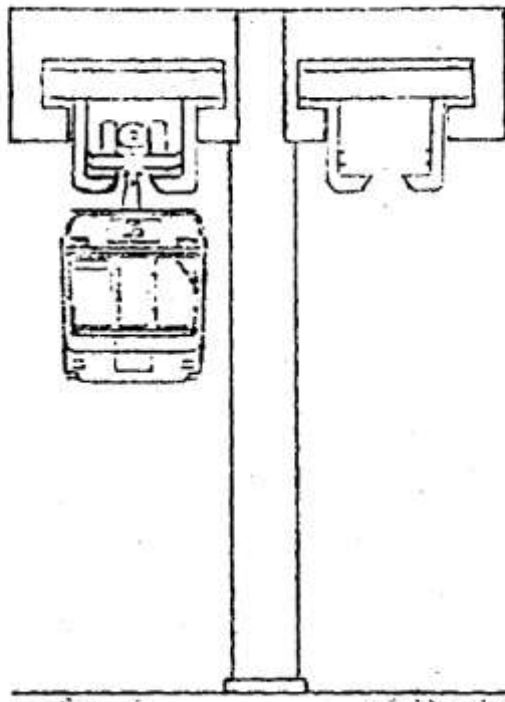
Monorail is a word that has been used for different kinds of vehicles, which bear on a slender rail/beam. Urban monorails are mobile objects that traverse one rail or beam and can be used for the transportation of the population of cities.

Monorail systems that meet the definition can be grouped on the basis of structure and propulsion method (Brackett, et al., 1982).

5.1 Suspended Systems

Suspended monorails are elevated railway systems where the track is raised high above the ground and the trains are suspended or hung underneath the rail. The suspended prototype mounts the vehicle directly under the rail beam (Brackett, et al., 1982).

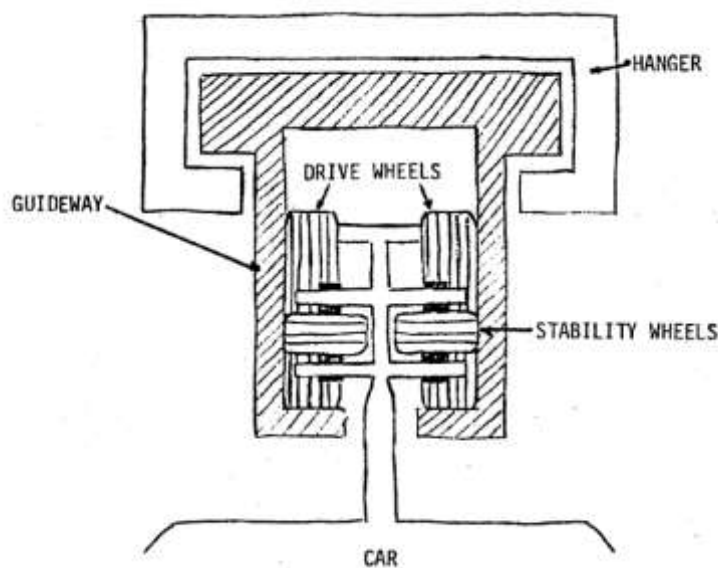
[Figure - 1] Suspended Monorail Systems (Brackett, et al., 1982)



Symmetrical Systems:

The rail beam is usually a box beam girder with a split bottom and a rectangular shape. The vehicle is suspended to the rail beam by dropping it directly below truck or bogie assemblies which are mounted into the rail beam. The drive wheels or traction tires are mounted on the bottom flanges of the girder (Brackett, et al., 1982).

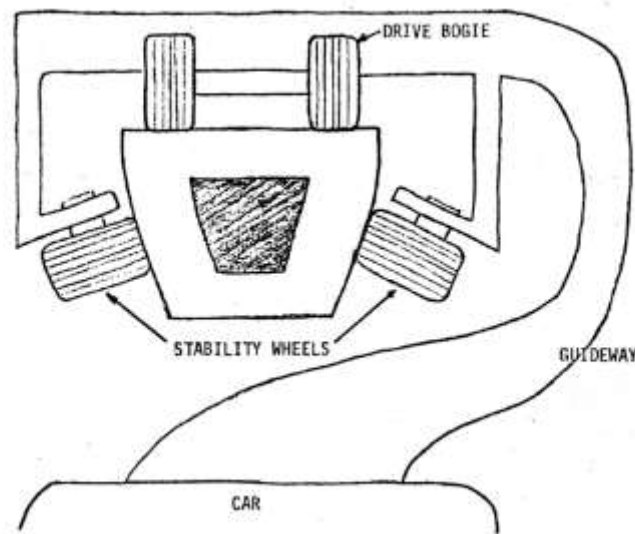
[Figure - 2] Guideway for Suspended Symmetrical Systems (Brackett, et al., 1982)



Asymmetrical Systems:

Vehicle load is fed to the driving wheels through a lateral arm, which is mounted to the top of the vehicle. The arm then snakes around the rail support and bonds to the bogie which supports the drive wheels (Brackett, et al., 1982).

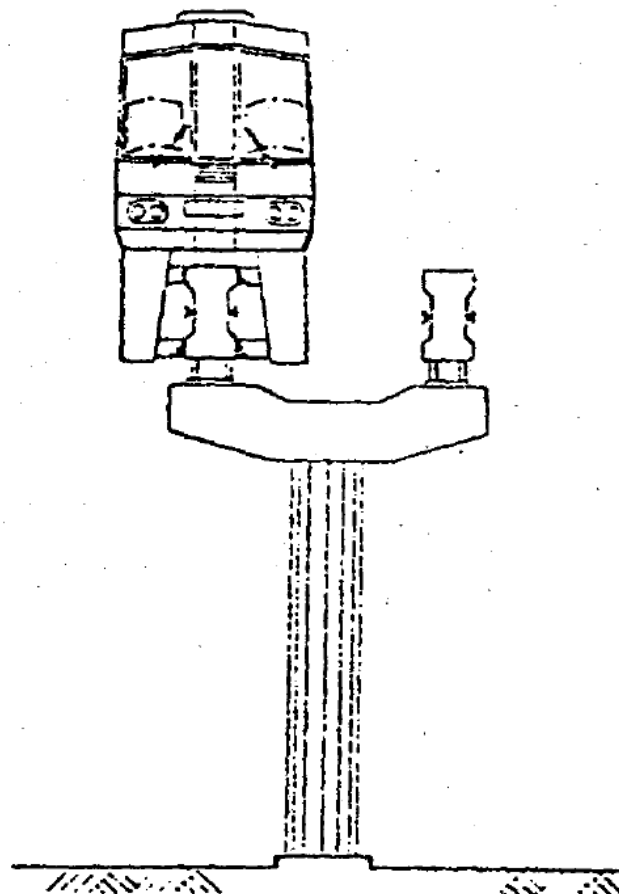
[Figure - 3] Guideway for Suspended Asymmetrical Systems (Brackett, et al., 1982)



5.2 Supported Systems

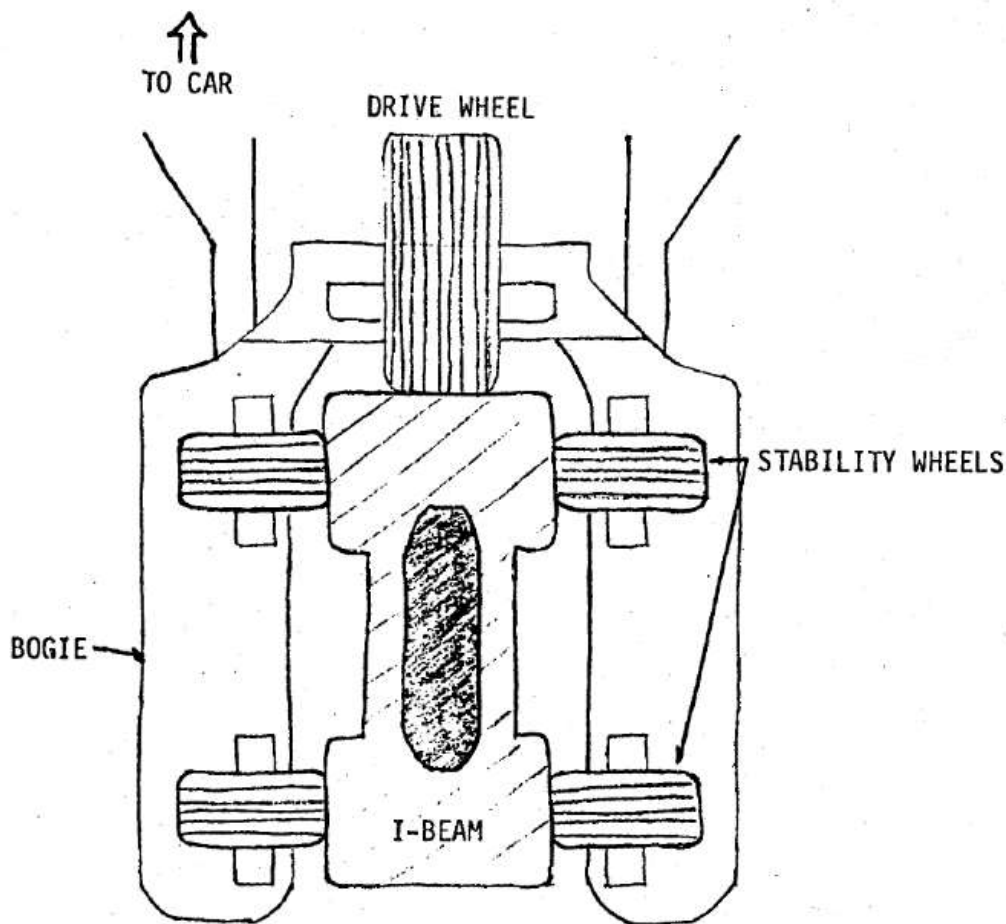
The vehicle straddled a concrete or steel running rail. The rail is of sufficient width to allow the drive wheels to ride on top and sufficiently deep to allow support wheels to be fitted on each side to provide lateral stability. This construction gives the effect that the vehicle is almost encircling the rail (Brackett, et al., 1982).

[Figure - 4] Supported Monorail Systems (Brackett, et al., 1982)



Supported systems are variations of the ALWEG Design. This design was created by a Swiss industrialist, Alex Wenner-Gren, in association with the Krupp Corporation of West Germany (Pyrgidis, 2016).

[Figure - 5] Guideway for Supported Systems (Brackett, et al., 1982)



Propulsion Systems:

These propulsion systems, however, include gasoline engines, electric motors, cable drive and magnetic levitation. Within these, by far the most prevalent has been the use of electric motors. Magnetic levitation is a relatively new technology in which magnetic forces are used to both lift the vehicle and propel it (Pyrgidis, 2016). The monorail systems used for urban transport are probably equipped with electric motors for driving. Such systems are current state-of-the-art technology that does not need further research and development before implementation (Brackett, et al., 1982).

Structural Components

Suspended monorails typically employ steel guideway (when supported asymmetrically), concrete and/or steel with steel or wood sliding surfaces (when supported symmetrically). Asymmetrical supported monorails are nowadays equipped with a triangular arrangement of steel rail on which the drive wheels can travel along the lower even surface of the rail and the stability wheels can travel along the lower even outer surface of the sloping side surface [Figure - 3]. The symmetric supported monorails have a split-bottom box girder made of prestressed concrete or steel plate with a wooden or steel plate running surface on the inside of the lower flanges [Figure - 2] (Brackett, et al., 1982).

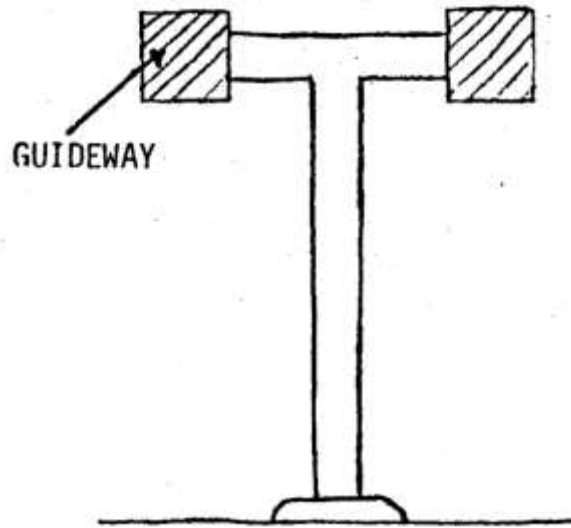
The most frequent setup in the case of the build supported monorail is a hollow-reinforced or prestressed concrete I-beam. This enables the drive wheels to travel along the top surface of the beam and the stability wheels to be in contact with the side of the beam [Figure - 5].

5.3 Pier Support Systems

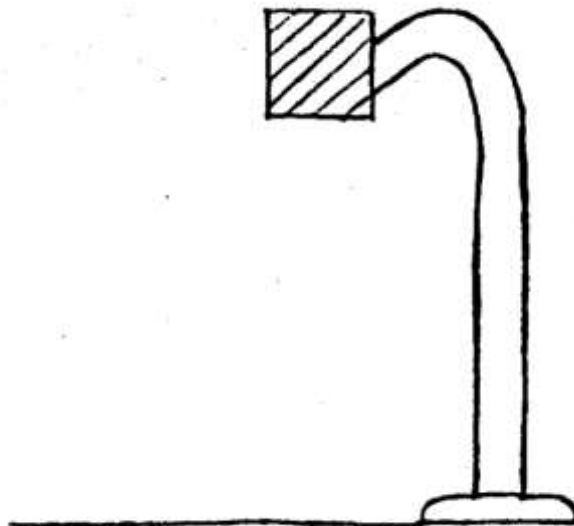
There are three basic types of pier supports:

1. **T-shaped support:** Used for two-way monorail traffic, one rail at each end of the cross member [Figure - 6].
2. **Inverted J-shaped support:** Used for one-way suspended monorail traffic [Figure - 7].
3. **Single column support:** Used for one-way supported monorail traffic [Figure - 8] (Brackett, et al., 1982).

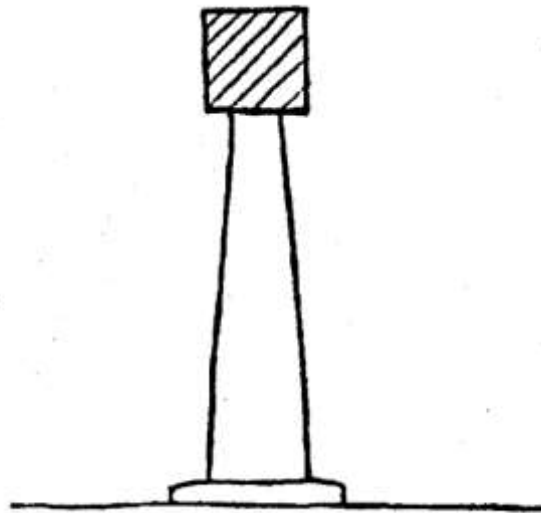
[Figure - 6] "T" Shaped Support (Brackett, et al., 1982)



[Figure - 7] Inverted "J" Shaped Support (Brackett, et al., 1982)



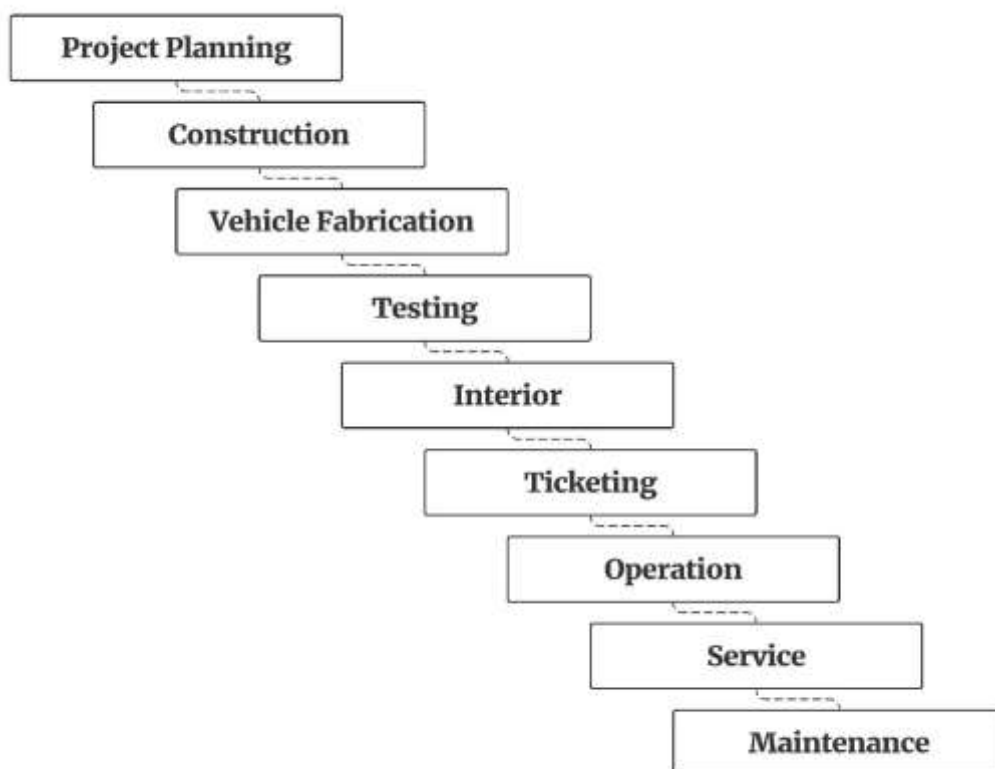
[Figure - 8] Single Column Support (Brackett, et al., 1982)



VI. IMPLEMENTATION OF MONORAIL INFRASTRUCTURE - WATERFALL

The construction and development of monorail infrastructure consists of a number of critical steps, from project planning to operation and administration.

[Flowchart - 1] Implementation of Monorail Infrastructure – Created by Author



6.1 Project Planning

This initial phase focuses on comprehensive assessments to gauge the feasibility of the monorail project, taking into account various factors. These include technical, economic, and environmental considerations. Decisions are reached concerning the suitability of monorail as a method of transportation. Route management, station siting, and incorporation into existing transport systems are carefully planned. Funding, which is received through government grants, private investors or a combination of both, is obtained. Environmental impact issues are screened with care, obtaining all necessary clearances. Public and stakeholder input as well as community involvement is stressed by including the public in the planning process, and by addressing and addressing concerns (Lea+Elliott, Inc., 2003s).

6.2 Construction

This phase describes the realization, i.e., the construction measure, of the monorail structures. Which consists in the elaboration of elevated rails seeing above and below support structures such as pillars and beams as well as installing of the rails. Monorail stations, platforms, and various passenger facilities are erected. Maintenance depots are created to house vehicles in storage and for servicing. The installation of electrical systems, track electrification and signaling equipment are implemented with the objective of safe and reliable operation (Japan International Cooperation Agency Oriental Consultants Global Co., Ltd., 2015).

6.3 Vehicle Fabrication

The initial production process for monorail vehicles is the detailed engineering of the vehicle specifications, taking into consideration dimension, load capacity and the technical specifications. Monorail car is very precisely manufactured in order to comply with the rigorous safety and operating requirements. Comprehensive testing ensures that vehicles meet strict safety and performance criteria.

6.4 Testing

In this stage monorail cars undergo demanding track testing to provide a smooth, stable operation. Comprehensive integration testing ensures the proper operation of all of the parts, from vehicles and signal infrastructure to stations. Safety testing procedures are carried out to assess the response to emergency drills including making drills to make sure they are adequately prepared.

6.5 Interior

Interior design and layout of monorail vehicle interiors are focused on passenger comfort and safety. This encompasses strategic planning of seating configuration, passenger movement, and provision of facilities such as air conditioning, lighting, and information systems. Attempts are made to make interior spaces accessible for passengers with disabilities.

6.6 Ticketing

Fare collection ticketing systems are in place providing passengers with a number of currencies to pay including paper tickets, smart cards or mobile applications. Pricing schemes are elaborated in order to satisfy passengers'. Ticket infrastructure including ticket vending machines, turnstiles, and ticket examination systems are on site at stations.

6.7 Operation

This stage involves the introduction of monorail services, following the development and maintenance of operating schedules, routes, and timetables. People (operators, station personnel and guarding personnel) are selected and trained to guarantee safe and effective operation. A strong focus is placed on delivering exemplary customer service, addressing passenger inquiries and concerns.

6.8 Service

Regular monorail operation ensues, adhering to established schedules. A dedication to safety is manifested by continued safety practices, i.e., regular inspections, security checks and sequential emergency response plans. Accurate prioritization of delays and disruptions is critical in order to deliver passenger satisfaction.

6.9 Maintenance

Preventive maintenance and early repair play an important role in ensuring the healthy operation condition of the monorail system. Routine safety inspection is performed in order to detect and rectify safety problems in the ultimate aim of improving the overall systemic safety.

VII. MONORAIL AS OPTIMAL CHOICE - SWOT ANALYSIS, COMPARATIVE ANALYSIS

When comparing monorails to other options of public transport, monorails have advantages including efficiency, decreased traffic, lower cost of operation and environmental considerations. Yet, there exist challenges such as high initial construction costs, low coverage, competing transport services, limited funding, public-perception concerns, and others, that all impact cost-effectiveness and adoption.

[Table - 1] SWOT Analysis on Monorail – Created by Author

Strengths • Efficiency • Environmental Friendliness • Reduced Congestion • Operational Cost	Weaknesses • Initial Cost • Limited Flexibility • Limited Coverage • Capacity Limitations
Opportunities • Urban Expansion • Integration • Tourism • Technological Advancements	Threats • Competition • Budget Constraints • Negative Public Perception • Regulatory Challenges

7.1 Feasible and Cost-Effective Transport

Monorail can be used as a means of transport in packed urban spaces that have little land area or in congested city centres. Their feasibility is due to the possibility of building some elevated rails, leaving fewer land demands than metro systems with deep networks of underground tunnels. Because of its low-cost nature, monorails are an effective solution for cities limited by a small amount of land and money.

7.2 Reduced Road Congestion

Monorails are also important in reducing road traffic congestion, a ubiquitous problem in cities where there is a high concentration of people. By providing an elevated and dedicated transportation route, monorails can effectively reduce traffic congestion and its associated problems, such as traffic jams and extended travel times. This not only serves the daily commuters but also improves urban mobility in general.

7.3 Rapid Implementation

The effective implementation of monorail lines is a plus, especially in urban areas that have an immediate need for transportation infrastructure. Elevated tracks and station construction are generally quicker and less intrusive than big tunnel and underground station construction. The rate of deployment facilitates cities to respond to their transport requirements in a faster manner, thereby easing urban transport congestion earlier.

7.4 Integration with Existing Infrastructure

Monorails allow a homogeneous fit within existing transport infrastructures including buses and other public transportation. By this integration the passengers have the possibility to smoothly transfer between modalities of the travelling process, which improves the convenience and the accessibility of the complete travelling system. Due to this, the way transportation in city areas goes from a user experience toward an experience using the digital internet, the urban transportation experience becomes increasingly user-friendly, thus, assuming a larger use of public transport and reducing the use of private cars, consequently relieving road congestion.

Other key factors for Monorail being an optimal choice:

- *Lower Environmental Impact:*
Monorails are usually electric-driven and therefore low-emission compared with conventional road-based transportation such as buses. This environmental sustainability means that they are a desirable option for municipalities seeking to decrease their carbon emissions.

- *Reduced Land Acquisition:*
Monorail systems typically need less land than metro systems, mainly because metro systems are used to have large underground stations and tunnels. This is also able to save costs and prevent residents and businesses from being displaced.
- *Capacity for Expansion:*
Monorail network extensions can be accomplished with a relatively small amount of additional lines and stations to meet the needs of increasingly urbanizing populations. This flexibility supports long-term transportation planning.
- *Reduced Operational Costs:*
Monorails can achieve low operation cost with respect to metro systems through a reduced complexity of track maintenance and lower energy use. This can contribute to long-term cost savings.
- *Improved Urban Accessibility:*
Monorail stations can help improve accessibility in urban cores which can provide easy access to commercial, residential and tourist destinations.
- *Tourism and Economic Benefits:*
Tourist prams in the city may have a positive impact on local economies by enhancing access to attractions & tourism, and ultimately providing jobs.

VIII. USER STUDY (COMMUTERS) - PRIMARY DATA, EMPATHY MAPPING

Monorail feeder services provide enhanced convenience to the users and it is highly appreciated by them. They also value the intuitive and direct link between the monorail and metro, avoiding the requirement for several modes of transport with uncomfortable transfers. With this streamlined travel experience, a corresponding decrease in waiting time leads to a positive perception of ease of use. Commuters particularly appreciate the ability to save time, as navigating through congested urban areas and coping with traffic are common challenges. As a feeder service, the monorail also alleviates these problems, which in turn improves the perception of ease.

Reduced stress is another major advantage. Additionally, users perceive monorail feeder services as cost-effective. The convenience of a single, affordable fare for both monorail and metro services lead to a positive perception of cost savings, making public transit a more financially attractive option.

Other complex transfers between monorail and metro will also impact on convenience. Transfer processes should be perceived as simple and easily handled by users in order to keep a good, easy-to-use perception of convenience. Stations should be designed for effortless transitions.

IX. ROLE OF GOVERNMENT

The governments overall multilayered function in Mumbai's transport infrastructure includes current operational management and future program opportunities. It includes capital financing securement of large-scaled ventures, managing and monitoring activities for safe and compliance and long-term transportation planning for effectively addressing future requirements of the city. Furthermore, the government has a crucial role in sustainability, accessibility, and inclusivity of public transit systems. Citizen engagement should be an integral part of transportation planning, communication should remain open, and projects that support economic growth and tourism should be actively encouraged. In addition, fare integration and inter-modal mobility are important features of government intervention to facilitate cost-effective and convenient transit systems. Planning ahead, investment by the government should also be maintained with regard to growth and modernizations of such transport systems in order to serve the changing Mumbaikar population and improve the connectivity and mobility of the urban fabric in the city of Mumbai.

X. CONCLUSION

As a feeder transits system in Mumbai, the monorail has significant potential to influence the urban transport mode landscape in the city. With this study, it is highlighted that its significant role in promoting ease, cost-effectiveness, and reducing traffic congestion plays a key role in a city where streets are very congested due to high-foot traffic density.

Beyond convenience, the monorail offers a cost-effective solution. Due to its low land demand and construction speed, it is a feasible option for a city lacking space and finances. The elevated tracks/stations diminish road traffic and improve urban mobility as a whole and thereby play a role in making a transit system more sustainable and efficient.

In the perspective of the future, research on monorail systems is still in an open-ended state, call for exploration in the key-fields. These include searching for traffic optimization for monorail extensions, planning integrated ticketing schemes to encourage smooth transfers from monorail to other modes of transport, exploring environmentally friendly solutions for carbon footprint reduction, and providing the best-in-class accessibility for all passengers. Also, economic gains, especially local economy and tourism growth.

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