Industrial Engineering Journal
ISSN: 0970-2555
Volume : 54, Issue 8, No.2, August : 2025

FEASIBILITY ANALYSIS OF METRO PROJECT: A CASE STUDY OF MUMBAI METRO PROJECT

Mr. Sachin Kothawale PG Student, Department of Civil Engineering, Pillai HOC College of Engineering and Technology, Rasayani University of Mumbai
Raju Narwade Associate Professor, Department of Civil Engineering, Pillai HOC College of Engineering and Technology, Rasayani University of Mumbai https://orcid.org/0000-0003-2349-0172 Email: rnarwade@mes.ac.in
Dr. Karthik Nagarajan Associate Professor, Department of Civil Engineering, Pillai HOC College of Engineering and Technology, Rasayani University of Mumbai https://orcid.org/0000-0002-2306-0327 Email: knagarajan@mes.ac.in

Abstract
This research paper presents a comprehensive feasibility analysis of the Mumbai Metro Project, focusing on its financial viability, environmental sustainability, and socio-economic impact. As Mumbai continues to grapple with rising congestion and inadequate public transport infrastructure, the Metro project emerges as a transformative solution to enhance urban mobility. The study examines various phases of the Mumbai Metro network expansion, spanning 337.1 kilometers, and evaluates ongoing and planned developments through data collected from government sources, stakeholder interviews, and case studies. Public-Private Partnerships (PPPs) are analyzed for their pivotal role in financing and operational sustainability, particularly through commercial exploitation strategies such as advertising and naming rights. The study also highlights the environmental and social benefits of the Metro, including pollution reduction, improved accessibility, and transit-oriented development. Challenges such as land acquisition, cost escalation, and integration with existing modes are critically assessed. Overall, the findings suggest strong public support and a positive outlook for the Metro's role in reshaping Mumbai's transportation landscape while promoting inclusive urban growth.

Keywords:
Mumbai Metro, Feasibility Analysis, Public-Private Partnership, Urban Transport, Sustainability, Infrastructure Development.

Introduction
The Mumbai Metropolitan Region Development Authority (MMRDA), established in 1975, plays a central role in the strategic planning, development, and governance of the Mumbai Metropolitan Region (MMR), covering approximately 4,355 square kilometers. As Mumbai continues to grow as India's financial capital, MMRDA is responsible for guiding its urban transformation and ensuring balanced regional development across its satellite towns and surrounding areas.
Mumbai's exponential population growth has led to immense pressure on its infrastructure, transportation, housing, and essential urban services. The rapid pace of urbanization has also heightened social inequality, environmental degradation, and the demand for basic amenities like water, waste management, and public transport. MMRDA is tasked with addressing these growing urban challenges through planned and inclusive development. In alignment with global smart city trends, MMRDA has integrated smart technologies and data-driven systems into its urban planning initiatives. Navi Mumbai, a planned township, is being developed as a smart city with investments in IoT, digital governance, smart mobility, and utility management systems. Other initiatives include sustainable infrastructure like smart street lighting, waste recycling, and real-time traffic monitoring. MMRDA encourages the adoption of energy-efficient technologies and eco-friendly practices in building design. This includes the promotion of green buildings with solar panels, rainwater harvesting systems, and waste-to-energy mechanisms. These initiatives are intended to support long-term sustainability and environmental protection in the face of dense urban growth.

MMRDA has been instrumental in managing real estate development to ensure economic expansion. A flagship achievement is the development of the Bandra-Kurla Complex (BKC), a prominent commercial hub that has attracted banks, multinational corporations, and government offices, significantly contributing to Mumbai's economic growth. Additionally, MMRDA supports the creation of Special Economic Zones (SEZs) to attract investment in sectors like finance, manufacturing, and IT, offering tax incentives and advanced infrastructure.
As part of an integrated planning strategy, MMRDA promotes mixed-use developments that combine residential, commercial, and recreational spaces within a single zone. These developments not only address land scarcity in Mumbai but also foster efficient land use, urban inclusiveness, and improved quality of life for city dwellers.

The Role and Functions of MMRDA

The Mumbai Metropolitan Region Development Authority (MMRDA) is a key agency under the Government of Maharashtra responsible for the strategic planning and development of the Mumbai Metropolitan Region. Its primary functions include urban planning and infrastructure development aimed at accommodating the region's growing population. This involves the design and implementation of comprehensive development plans covering residential areas, commercial hubs, industrial zones, and recreational spaces, along with major upgrades to roads, highways, public transit systems, and essential utilities.
A core focus of MMRDA is enhancing public transportation through large-scale investments in metro rail, monorail, and other urban transit systems to ease traffic congestion, reduce pollution, and connect remote areas with economic centers. Additionally, the authority emphasizes environmental sustainability by encouraging green spaces, energy-efficient construction, and conservation of natural ecosystems. MMRDA also plays a crucial role in promoting affordable housing for low- and middle-income groups, addressing the city's real estate challenges. Furthermore, to ease the pressure on Mumbai's core, the development of satellite townships like Navi Mumbai, Thane, and Kalyan-Dombivli is being pursued, ensuring balanced regional growth through decentralization.

Objectives

The objectives of this study are to evaluate the feasibility of expanding the Mumbai Metro network by assessing its financial viability, environmental sustainability, and economic benefits in alleviating traffic congestion; to analyze the role of public-private partnerships (PPP) in the Metro's funding structure and long-term sustainability, particularly through commercial revenue generation; and to investigate the integration of the Mumbai Metro with existing transportation systems to enhance regional connectivity, increase ridership, and support urban development around metro corridors.

Scope of The Study

This study focuses on conducting a comprehensive feasibility analysis of the Mumbai Metro project, with particular attention to the expansion of its network. The research aims to evaluate the financial viability, environmental sustainability, and socio-economic impact of proposed metro lines. Central to this investigation is determining whether the expanding metro infrastructure can effectively alleviate traffic congestion in Mumbai while ensuring its long-term operational and financial sustainability.
A significant aspect of the study involves examining the role of public-private partnerships (PPP) in funding the Mumbai Metro. The research will analyze how the PPP model supports risk-sharing, facilitates financing, and contributes to revenue generation through the commercial exploitation of metro assets. Furthermore, the study will explore the environmental benefits of metro expansion, such as reductions in air pollution and increased energy efficiency, along with the social impacts on urban mobility and accessibility.
The research will assess the integration of the metro with existing transportation systems, including buses and suburban railways, to understand its contribution to seamless urban connectivity. Finally, the study will address the regional development effects of the metro, such as stimulating real estate growth, job creation, and economic activity in both urban and peripheral areas. In sum, the scope of

this study encompasses a multi-dimensional analysis that provides insights into how the Mumbai Metro can serve as a transformative force in urban transport and regional development.

LITRATURE REVIEW

Kassiani Tsimplokoukou, Eleni Sfakianaki & George Metaxas, ‘’ A feasibility study approach for underground railways - a case study: Line 4 of Athens metro” 2012

This article introduces a methodology for conducting feasibility studies for underground railways. The study addresses the factors that determine station location, the attributes that enhance rail use through passenger satisfaction. It incorporates the principles of CBA and financial analysis, presents the social impacts and their requirements for the achievement of the social objectives, and discusses the benefits (social, economic, environmental) that are accrued from the existence of underground railways that render them crucial elements for developing sustainable cities. The case study based on Line 4 of the Athens metro has been used to provide an overall description of the implementation of this methodology by using qualitative and quantitative data. The study reveals that the feasibility of a project is improved by assessing its aspects on a global scale, while the perception of its utility by the target-market is integral in its success. This article introduced a new methodology for conducting feasibility studies for underground railways, through which diverse factors that could positively influence the education of engineers and the engineering culture overall were examined. It has been framed from economic, environmental and social attributes, while the factors which stimulate the rail use, through the passengers' satisfaction, were incorporated into this methodology.

Analysis of the factors that determine station location revealed that locations that enable access to health, education services and important places, as well as points within densely populated areas should be considered as possible locations for metro stations. In relation to the quality of the project services, ten elements that contribute to passengers' satisfaction were determined, while reliability is considered to be one of the most prominent. The study further shows cost overruns that occur in projects with a long implementation phase vary between 40% - 200%, while the average overestimation in demand forecasts in rail projects is about 106%. As far as the environmental benefits are concerned, the large-scale tendency is that underground railways contribute to minimizing the negative effects of environmental pollution.

With respect to the second part of this study, the new methodology was applied to the case study of Line 4 of the Athens underground railway. By comparing the economic performance of the project in relation to the benefits on a social, environmental and economic perspective, as well as through the analysis of social criteria (affordability, accessibility, safety) the feasibility of the Line 4 was evaluated. The study reveals that the feasibility of a project is improved by assessing the project aspects on a global level. It is recommended that the attributes that synthesize the quality of an underground railway project, as well as the identification of factors that increase railway usage should be an integral part of a feasibility study, since the success of a project is determined by the degree of its utility to those for whom it is constructed. The new methodology is based on three main directions and their components, which support sustainability. It is of great importance to promote and incorporate into the process of any feasibility study, elements that come along with the principles of sustainable development. In this respect, professional practice will be able to meet future demands, and the quality of life can be improved.

Akshay. M. Ramteke, Prof. Vishal Gajghate, "Feasibility Study of Metro Rail Project In Nagpur City":

The growing demand for public transport in cities has serious effects on urban ecosystems, especially due to the increased atmospheric pollution and changes in land use patterns. An appropriate mix of alternative modes of transport resulting in the use of environmentally friendly fuels and land use patterns can be obtained by an ecologically sustainable urban transport system. Transport, because of its pervasive nature, occupies a central position in the fabric of modern urbanized society. In most of the countries, this has been a story of evolutionary change with new transport development replacing

the old transport system in response to perceived socio-economic needs of the people. Implementation of such modern transport system of Metro Rail facility to NAGPUR city is the ultimate aim of this project.
The population of Nagpur had already exceeded 35 lakhs and in 2021 it will cross 50 lakhs. We can say that, at the time of2016 PHPDT of this route will exceed the limit of 8000PHPDT, so mass rapid transit system is necessary. As per TVC survey the studied phases are feasible and the phase 3 will be after a decade. The revenue generated within 3 years will be equal to total cost of project (9408 crore) when 13% of the population will use metro rail. It is the fast mode of transportation with maximum carrying capacity in less time. So, we can conclude that Metro Rail will be feasible in Nagpur by 2016.
S.M. Subash, K. Chandrabose, U. Umamaheshwari, T. Maharajan, "Feasibility Study of Metro Transport: Case Study Madurai":
The growing demand for public transport in cities has serious effects on urban ecosystems, especially due to the increased atmospheric pollution and changes in land use patterns. An ecologically sustainable urban transport system could be obtained by an appropriate mix of alternative modes of transport resulting in the use of environmentally friendly fuels and land use patterns. Transport, because of its pervasive nature, occupies a central position in the fabric of modern urbanized society. In most of the countries, this has been a story of evolutionary change with new transport development replacing the old transport system in response to perceived socio-economic needs of the people. Implementation of such modern transport system of Metro Rail facility to MADURAI city is the ultimate aim of this project. Metro Route Maps are created as per traffic study and evaluated in accurate manner by using GIS, Global Mapper and find out shortest feasible route. Metro provides multiple benefits: reduction in air pollution, time saving to passengers, reduction in accidents, reduction in traffic congestion and fuel savings. There are incremental benefits and costs to a number of economic agents: government, private transporters, passengers, general public and unskilled labor. The cost-benefit analysis of Madurai Metro is done in this paper tries to measure all benefits and costs. Planning of the work done by using software PRIMAVERA and suitable commissioning of the work be planned at 2021.The financial internal rate of return and the economic rate of return on investments in the Metro are estimated. Those estimates are made to be more acceptable and beneficial for financial and economic status regarding the evaluation of metro rail project.
Prateek Malhotra, Ajay K. Duggal, "Feasibility Study of Metro Rail Project In Chandigarh City" 07-July-2016:
The developing interest for public transport in urban areas has seriously affected the urban ecological systems, particularly because of the increased air contamination and changes in area use patterns. Evaluation of modern transportation framework of Metro Rail facility proposed in Chandigarh city is the primary aim of this study. For the first phase of construction two Corridors have been identified i.e. N-S Corridor (Capitol Complex to Gurudwara Singh Shaheeda, Mohali) and E-W Corridor (Transport Terminus Mullapur to Grain Market, Panchkula). Primary study on alignment of both the corridors has been done in this paper. Traffic Volume Count (TVC) was performed on the E-W Corridor at Sector-26 and Timber Market locations, which are considered to have highest congestion, for obtaining Peak Hour Peak Direction Traffic (PHPDT) data. Further public survey was conducted to obtain a general opinion in regards to introduction of metro in the city. The traffic data and the data collected from the public surveys was compared to the DPR prepared by DMRC and RITES collectively, to obtain the disparity between the proposition and the demand. Metro is without a doubt a fast mode of transportation with maximum carrying capacity in less time, but larger capacity and greater speed does not necessarily generate higher demand and ridership. It can be concluded that in order to make a city like Chandigarh smart it seems unnecessary to introduce metro as it should be more feasible than desirable.
The population of Chandigarh according to Census of India 2011 is 10.55 lakhs with just 17.10% growth in the past decade. At present the population of the city is 11.65 lakhs. Considering the same growth rate of the previous decade, the projected population for the year 2021 will be nearly 12.34

lakhs. But according to DPR the projected population is considered to be 23 lakhs which seems highly unlikely, as there are no indicators of such a phenomenal growth. Also, in 2016 PHPDT at the most anticipated congested locations on the E-W Corridor is 3500 PHPDT which is almost 50% of the projected value in the feasibility report prepared by DMRC, so a rail-based mass rapid transit system seems impractical and unnecessary. As per Traffic Volume Count (TVC) survey the studied E-W corridor is not feasible and the further phases there hence. The revenue generated within the first 10 years will not be anywhere equal to total cost of the project when not even 10% of the population will choose metro rail, as it was expected from Delhi metro which still remains under-achieved. Further, considering parameters such as availability of land for construction, feeder mode services for last mile connectivity and aesthetics of the city beautiful should also be taken into account before implementing such a huge project. It is without a debate a fast mode of transportation with maximum carrying capacity in less time, but larger capacity and greater speed does not necessarily generate higher demand and ridership. The decision to resort to metro system seems to have been influenced by over ambitiousness of the decision makers which might have put eclipsed some key issues. It can be concluded that in order to make a city like Chandigarh smart it seems unnecessary to introduce metro as it should be more feasible than desirable.

Sujit Kadam, Atul Autade, Hrishikesh Mane, Akshay Chakke, Abdulmalik Chaudhari, Prof. V. R. Turai, "Feasibility Analysis of Pune Metro from Ramwadi to Ranjangaon" April-2018:

The objective this project is to provide feasibility study of extension of PUNE metro rail in areas like Wagholi, Ranjangaon MIDC's etc. by carrying out demand analysis, traffic survey. This extension of Pune metro rail will boost the economic growth of remote areas. The increasing level of congestion of Pune-Nagar Road coupled with high private vehicle usage. This Fast-growing transportation in these areas has serious effect on public health as well as surrounded ecosystem due to the increased air as well as noise pollution. An ecologically sustainable urban transport system could be obtained by the appropriate mixture of road & rail transport. Implementation of such modern transport system of metro rail facility to industrial areas of Pune city is the ultimate aim of this project.

Pune metro will add an extra charm to the historical city of Pune. One can commute with ease from one place to other, avoiding road traffic and reach desired destination on time. Pune metro will add a new direction to the transport system. For successful implementation of metro project, high costs are involved and the need to maintain on a fare structure within the affordable reach of ordinary citizen, metro projects are not ordinary financially viable. But considering the overwhelming economic gains to the society and fact that cities with such a great population. As Pune is fastest growing industrial city of the country will need expansion of metro network.

Gabriele Banoa, Zilong Wangb, Pierantonio Faccoa, Fabrizio Bezzoa, Massimiliano Baroloa, Marianthi Ierapetritou, '' Dimensionality reduction in feasibility analysis by latent variable modelling":

We propose a systematic methodology to exploit partial least-squares (PLS) regression modelling to reduce the dimensionality of a feasibility analysis problem. PLS is used to project the original multidimensional space of input factors onto a lower dimensional latent space. We then apply a radial basis function (RBF) adaptive sampling feasibility analysis on this lower dimensional space to identify the feasible region of the process. A simple low-dimensional representation of the feasible region is thus obtained with this combined PLS-RBF approach. The performance of the methodology is tested on a mathematical example involving six inputs. We show the ability of this PLS-RBF approach to reduce the computational burden of the feasibility analysis while maintaining an accurate and robust identification of the feasible region.

We proposed a methodology to identify the feasible region of a multiple-unit process by applying a combined PLS-RBF adaptive sampling feasibility analysis. We first used a PLS model to obtain a linear transformation between the original set of input variables and a reduced set of latent variables. We then applied RBF-based adaptive sampling feasibility analysis on the lower-dimensional latent space and we assessed the quality and robustness of the results with three metrics, that describe how well the feasible and infeasible regions are identified by the RBF model, and how large is the portion of overestimated feasible region. We tested the methodology on a mathematical test example involving two units and a total of 6 input factors. We proved the ability of the proposed approach to reduce the overall computational burden while maintaining a good accuracy and robustness of the results, with a correct estimation of the feasible region greater than 93%. In our future work, we will focus on the assessment of the performance of the methodology with real experimental data coupled with the original process model.

Yuchen Wena, Xiaowei Yuea, Jeffrey H. Hunt b, Jianjun Shi, "Feasibility analysis of composite fuselage shape control via finite element analysis" 21 January 2018:

Composite parts have been increasingly used in aircraft industry because of their high strength-to-weight ratio and stiffness-to-weight ratio. Due to the diversity of suppliers and fabrication process variation of composite parts, dimensional variability of composite fuselages inevitably exists. In order to improve the dimensional quality and increase the productivity, a new shape control system has been proposed to conduct dimensional shape adjustment before the assembly process. By using finite element analysis, we conduct the feasibility analysis of this new shape control system. Firstly, we develop a finite element model with detailed material property, ply design, fixture structure, and actuators installation considered. The finite element model is then validated and calibrated by physical experimental data. Feasibility analysis via FEA includes single-plane dimensional control capability analysis, double-plane scheme analysis, stress/strain analysis, and failure test. We conclude that the single-plane with ten actuators scheme is feasible for the shape control, and the actuators do not damage the fuselage.

Amanda Rogers, Marianthi Ierapetritou, "Feasibility and flexibility analysis of black-box processes Part 1: Surrogate-based feasibility analysis" 2 June 2015:

Feasibility analysis is a useful technique for evaluating the operability and ultimately the flexibility of chemical processes. However, it is difficult to solve the feasibility test problem for process models involving black-box constraints. This issue can be addressed through the use of surrogate-based methods for feasibility analysis. These techniques rely on the creation of a reduced-order model that approximates the feasibility function for a process. The feasible region for the process can then be evaluated based on the surrogate model. In this work, a novel method for surrogate-based feasibility analysis based on kriging metamodels will be presented. This algorithm differs from previously published approaches in the way that the expected improvement function is evaluated. In addition, the proposed method explicitly considers surrogate model prediction uncertainty. The algorithm is also extended to problems of dynamic feasibility analysis, where the shape and size of the feasible region may change with time. A series of test problems will be used to demonstrate the surrogate-based feasibility algorithm, including those with nonconvex and disjoint feasible regions. Finally, the algorithm will be used to evaluate the feasible region for a dynamic roller compaction process.

Atharv Bhosekar, Marianthi Ierapetritou, "Advances in surrogate-based modeling, feasibility analysis, and optimization: A review" 19-9-2017:

The idea of using a simpler surrogate to represent a complex phenomenon has gained increasing popularity over past three decades. Due to their ability to exploit the black-box nature of the problem and the attractive computational simplicity, surrogates have been studied by researchers in multiple scientific and engineering disciplines. Successful use of surrogates shall result in significant savings in terms of computational time and resources. However, with a wide variety of approaches available in the literature, the correct choice of surrogate is a difficult task. An important aspect of this choice is based on the type of problem at hand. This paper reviews recent advances in the area of surrogate models for problems in modelling, feasibility analysis, and optimization. Two of the frequently used surrogates, radial basis functions, and Kriging are tested on a variety of test problems. Finally, guidelines for the choice of appropriate surrogate model are discussed.

Mumbai Metro Network

Fig 1. Mumbai Metro Network Diagram

Mumbai Metro Master Plan

Table 1: Mumbai Metro Master Plan

Lines	Corridors	Length (km)
1	Versova – Andheri – Ghatkopar	11.4

2A	Dahisar - D.N. Nagar	18.6
2B	D. N. Nagar - Mandale	23.6
3	Colaba - Bandra - SEEPZ	33.5
4	Wadala – Kasarvadavali	32.3
4A	Kasarvadavali - Gaimukh	2.7
5	Thane – Bhiwandi – Kalyan	24.9
6	Swami Samarth Nagar – Vikhroli	14.5
7	Andheri (East) - Dahisar (East)	16.5
8	Airport Line (CSMIA - NMIA)	35
9 & 7A	Dahisar - Mira Bhayander & Andheri – CSMIA	13.5
10	Gaimukh – Shivaji Chowk (Mira Road)	9.2
11	Wadala – CSMT	12.7
12	Kalyan - Taloja	23.76
13	Shivaji Chowk (Mira Road) – Virar	23
14	Kanjurmarg - Badlapur	45
	Total	337.1

The Mumbai Metro Master Plan presents a comprehensive blueprint for the expansion of the city's metro network, covering a proposed total of 337.1 kilometers. This ambitious plan features multiple corridors designed to significantly enhance urban mobility by connecting central Mumbai with its suburban and outlying regions. Key lines include the Versova-Andheri-Ghatkopar corridor (11.4 km), Colaba-Bandra-SEEPZ (33.5 km), Wadala-Kasarvadavali (32.3 km), and the Airport Line (35 km), each serving densely populated and high-traffic zones across the metropolis.

In addition, longer routes such as Kanjurmarg-Badlapur (45 km), Thane-Bhiwandi-Kalyan (24.9 km), and Shivaji Chowk-Virar (23 km) are intended to improve accessibility for residents in peripheral regions. The plan also focuses on integrating remote areas like Mira Road and Badlapur into the larger transit system. By covering the eastern, western, and central suburbs, as well as improving connectivity to both domestic and international airports, the expansion aims to reduce traffic congestion, shorten travel times, and offer a more efficient and sustainable transportation alternative for millions of Mumbai's daily commuters.

Mumbai Metro – Status in Brief (1/2)

Metro Line	Corridor	Length (Km)	Cost (Rs. Cr.)	Daily Ridership (Lakh) (2031)	State Govt. Approval	Status/ Progress
Operational Metro Lines: -						
Line 1	Versova-Andheri-Ghatkopar	11.4	2356	8.0	19-Aug-04	Operational since 8th June, 2014
Line 2A	Dahisar (E)-D.N. Nagar	18.6	6,410	6.09	17-Oct-15	Phase-I operational from 02.04.2022. Phase-II operational from 19.01.2023.
Line 7	Andheri (E) - Dahisar (E)	16.5	6,208	6.7	17-Oct-15	

Industrial Engineering Journal
ISSN: 0970-2555
Volume : 54, Issue 8, No.2, August : 2025

Under Construction Metro Lines: -						
Line 2B	D. N. Nagar-Mandale	23.6	10,986	10.5	25-Oct-16	83.29% of Civil works completed. 40.37% Systems Phase-II Works completed.
Line 4	Wadala-Kasarvadavali	32.3	14,549	12.1	25-Oct-16	77.41% of Civil works completed.
Line 4A	Kasarvadavali - Gaimukh	2.7	949	1.3	25-Jan-19	86.75% of Civil works completed.
Line 5	Thane-Bhiwandi-Kalyan	24.9	8,417	3.03	21-Dec-17	95% of Civil works completed for Phase I (Thane-Bhiwandi).
Line 6	Swami Samarthnagar-Vikhroli	14.5	6,716	7.7	21-Dec-17	77.70% of Civil works completed.
Line 9 & 7A	Dahisar (E)-Mira Bhayander & Andheri (E)-CSMIA	13.5	6,607	11.12	02-Nov-18	Line 9: 94.64% || Line 7A: 50.46% Overall: 67.38%
Line 12	Kalyan-Taloja	23.7	5,865	2.62	06-Sept-19	6.74 % of Civil works completed.

The Mumbai Metro project has witnessed substantial advancement, with multiple lines already operational and several others in various stages of construction. Line 1, connecting Versova, Andheri, and Ghatkopar (11.4 km), has been operational since June 8, 2014, and currently accommodates around 8 lakh daily commuters. It was completed at a cost of ₹2,356 crores. Line 2A (Dahisar East to D.N. Nagar, 18.6 km) became partially operational in April 2022, with Phase-II launched in January 2023. By 2031, it is expected to cater to approximately 6.09 lakh daily passengers. Line 7 (Andheri East to Dahisar East, 16.5 km) is under construction and aims to serve 6.7 lakh commuters daily upon completion.

Several other metro lines are also progressing rapidly. Line 2B (D.N. Nagar to Mandale, 23.6 km) and Line 4 (Wadala to Kasarvadavali, 32.3 km) have completed 83.29% and 77.41% of their civil works, respectively. Line 4A (Kasarvadavali to Gaimukh, 2.7 km) has reached 86.75% completion. Line 5 (Thane to Bhiwandi to Kalyan, 24.9 km) has completed 95% of Phase I (Thane-Bhiwandi). Line 6 (Swami Samarth Nagar to Vikhroli, 14.5 km) is 77.7% complete. Progress is also evident on Lines 9 and 7A, with 94.64% and 50.46% of civil work completed, respectively. Meanwhile, Line 12 (Kalyan to Taloja, 23.7 km) is still in early stages, with only 6.74% work done. The cumulative development across these corridors indicates steady momentum in improving Mumbai's urban transit infrastructure.

Mumbai Metro – Status in Brief (2/2)

Metro Line	Corridor	Length (Km)	Cost (Rs. Cr.)	Daily Ridership (Lakh) (2031)	State Govt. Approval	Status/ Progress
Line 3	Colaba-SEEPZ	33.5	33,405	17.0	03-Mar-14	Under Construction through MMRCL. 12.6 km operational from 05.10.2024
Under Tendering Metro Lines: -						

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ISSN: 0970-2555
Volume : 54, Issue 8, No.2, August : 2025

Line 10	Gaimukh-Shivaji Chowk(Mira Road)	9.2	4,476	4.6	06-Sept-19	The metro work will be started after making the road width 60 meters.
Line 11	Wadala-CSMT	12.7	8,739	3.5	06-Sept-19	Project handed over to MMRCL.
DPR Under Preparation: -						
Line 8	Airport Metro (CSMIA-NMIA)	35	15,000 (approx.)	8.90	-	As per the direction of Govt. of Maharashtra, the project is being handled by CIDCO.
Line 13	Shivaji Chowk(Mira Road)-Virar	23.0	6,900 (approx.)	4.8	-	DPR being finalized.
Line 14	Kanjurmarg-Badlapur	45	13,500 (approx.)	7.9	-	Draft DPR received from Milan Metro.
Total		**337.1**	**1,51,083 (approx.)**	**115.86**		

The second phase of Mumbai Metro development reveals a strategic expansion of the city's transit infrastructure through several lines currently under construction, in the tendering process, or in advanced planning stages. Notably, Line 3 (Colaba-SEEPZ, 33.5 km), being executed by the Mumbai Metro Rail Corporation Limited (MMRCL), is one of the most ambitious corridors with an estimated cost of ₹33,405 crores and a projected daily ridership of 17 lakh commuters by 2031. Of this, a 12.6 km stretch is targeted for operational readiness by October 5, 2024.

In the tendering phase, Lines 10 (Gaimukh–Shivaji Chowk, 9.2 km) and 11 (Wadala–CSMT, 12.7 km) are slated for future construction, with preliminary work such as land widening and project transfers already in motion. Line 8, the Airport Express (35 km), will connect CSMIA and NMIA under CIDCO's guidance and is estimated to cost ₹15,000 crores, targeting a ridership of 8.9 lakh. Additionally, Lines 13 (Shivaji Chowk–Virar, 23 km) and 14 (Kanjurmarg–Badlapur, 45 km) are in the Detailed Project Report (DPR) preparation stage. Upon full implementation, the total Mumbai Metro network will span 337.1 km, with an estimated cost of ₹1,51,083 crores and an expected daily ridership of 115.86 lakh, reflecting a transformative step towards sustainable urban mobility for the region.

Methodology

The methodology adopted for this study employed a comprehensive and structured approach, combining both primary and secondary data to evaluate the feasibility of the Mumbai Metro Project. Primary data was obtained through interviews and surveys with key stakeholders, including officials from MMRDA, construction firms, and transportation experts, while secondary data was gathered from government reports, feasibility studies, and project documents. The collected data was categorized into financial, socio-economic, environmental, and technical domains, allowing for focused analysis on cost structures, ridership projections, environmental benefits, and integration with existing transport systems.

The analysis incorporated both quantitative and qualitative techniques, including cost-benefit analysis to evaluate financial viability, social impact assessments to gauge community benefits and accessibility, and environmental impact assessments to understand the project's sustainability. Technical evaluations were also conducted to examine the Metro's integration with Mumbai's existing transportation infrastructure. Furthermore, a case study approach was used to compare Mumbai Metro with other national and international metro systems, providing valuable insights and best practices. The culmination of this methodology was a detailed feasibility report offering actionable

Industrial Engineering Journal
ISSN: 0970-2555
Volume : 54, Issue 8, No.2, August : 2025
recommendations and policy guidance, contributing to the broader discourse on sustainable urban transit development.

Case Study

Case Study 1: Public-Private Partnership Project Case Study on Mumbai Metro

Line 1 Mumbai Metro Overview

- **Location**: Mumbai, Maharashtra
- **Terminal**: Versova, Ghatkopar
- **Stations**: 12
- **Operator**: MOOPL
- **Rolling Stock**: CSSR Puzhen
- **Daily Ridership**: 4 lacs

PROJECT DESCRIPTION

- Government of Maharashtra (GOM) through the Mumbai Metropolitan Region Development Authority (MMRDA) has planned a 146 km long rail-based Mass Rapid Transit System (MRTS).
- The 1st corridor of the project is from the Versova Andheri Ghatkopar line, which shall be elevated with a route length of 11 km, with 12 stations in the car depot at D.N. Nagar.
- The minimum curvature of the line shall be 100 meters and minimum ground clearance 5.5 meters.
- The existing suburban train connects north and south Bombay, whereas this project provides connectivity between East-West rail to central and western suburbs.
- Total time taken would be 21 mins, whereas other modes of transport take 90 mins.
- Mumbai Metro runs on an elevator corridor which is full air-conditioned, with world-class coaches, elevators, and escalators at stations, an automatic fare collection system, and a high-level security system.

Financing Information

- The total estimation of the project was 2356 crores.
- The project was financed on the basis of a viability grant by GOI (20% - 470 crores) and GOM (7.5% - 180 crores).

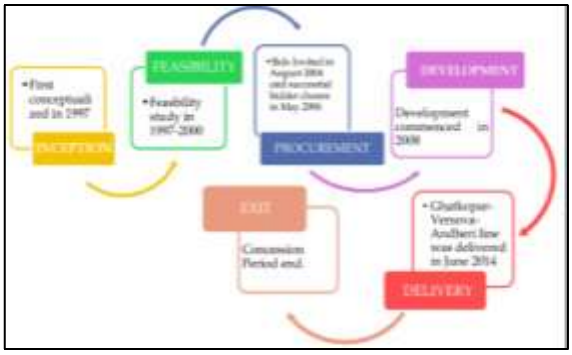
Industrial Engineering Journal
ISSN: 0970-2555
Volume : 54, Issue 8, No.2, August : 2025

- The financing pattern was 70% debt and 30% equity. MMRDA and the private operator contributed 466 crores.
- The consortium banks are IDBI, Karur Vysya Bank, Canara Bank, Indian Bank, and Oriental Bank of Commerce.

Viability Gap Funding
- Viability Gap Funding: 650
- Debt: 1240
- Equity: 466
- Total: 256

The cost of borrowing for the rupee component, which constitutes about 75% of the total debt, the foreign currency loan will be at 3.5% above LIBOR (London Inter-Bank Offered Rate).

Particulars With VGF Support
- Project IRR: 8%
- Equity IRR: 15%
- Debt Equity Ratio: 70:30



Discussion And Conclusion
- Mumbai's metro network will span across 357 kilometres and 14 lines with more than 220 stations, but it is not the silver bullet that will solve commuter woes.
- Importance of MM: The metro will provide for the first time connectivity to the airport, Nariman Point, Cuffe Parade, Kalbadevi, Worli, BKC, Airport, SEEPZ, and MIDC. Besides, two important heritage stations of Mumbai i.e. CSTN and Church gate will also get joined through MML-3 alignment.
- Fadnavis announced on 8 April 2017 that the government was considering a circular metro loop line along the Kalyan-Dombivli-Taloja route. The proposed 15 km line would link Kalyan and Shil Phata with 13 stations, bringing metro connectivity to Kalyan East, Dombivli, Ambernath, and Diva.
- The Mumbai Metro resumed services for the general public on 19 October 2020, after being shut down since March 2020 due to the COVID-19 pandemic.

Case Study 2: Commercial Exploitation of Mumbai Metro Infrastructure for Revenue Generation

The Mumbai Metro project, spearheaded by the Mumbai Metropolitan Region Development Authority (MMRDA), has significantly reshaped urban mobility by offering enhanced connectivity and reducing traffic congestion across the city. In light of the substantial costs involved in constructing and operating such a large-scale transit system, MMRDA recognized the need to diversify revenue sources beyond fare collection. To address this, the authority has strategically implemented various commercial exploitation methods aimed at maximizing the financial sustainability of the metro network.

This case study examines the innovative revenue-generation strategies adopted by MMRDA, including the leasing of retail spaces within metro stations, advertising on metro infrastructure, property development near transit hubs, and leveraging naming rights and station branding opportunities. These initiatives not only supplement operational funding but also contribute to the long-term viability and financial resilience of the Mumbai Metro project, offering a model for sustainable urban transport development in rapidly growing metropolitan regions.

Key Elements of the Case Study

Mumbai, as India's financial capital, faces immense pressure to provide efficient urban transportation for its rapidly growing population. In response, the Mumbai Metropolitan Region Development Authority (MMRDA) initiated the Mumbai Metro project with a comprehensive master plan in 2004, structured into three development phases. Phase 1 was executed between 2005 and 2011, while Phases 2 and 3 extended through 2021. With multiple metro lines now operational, the system plays a crucial role in enhancing connectivity, easing traffic congestion, and supporting urban mobility across key areas of the city.

To ensure financial sustainability, the Mumbai Metro operates under a public-private partnership (PPP) model that integrates innovative revenue generation strategies beyond fare collection. MMRDA has focused on commercial exploitation of metro infrastructure to supplement operational costs. Key methods include advertisement revenue from in-station and in-train spaces and the monetization of station naming rights, allowing private companies to brand metro stations for a fee. These initiatives not only generate substantial non-fare income but also strengthen the long-term economic viability of the metro network.

- **Advertisement on Piers and Viaducts**:

Advertising on structural components of the metro system such as piers, pillars, and viaducts provides significant exposure to brands and generates revenue for the metro authority.

Fig 2: Bevarages Advertisement

Fig 3: Advertisement on piers/pillars

In-Station Advertising: This includes both static and digital advertisements placed inside stations, trains, and on platforms.

Fig 4: Branding outside the station

Commercial Exploitation and Revenue Sustainability of Mumbai Metro

The Mumbai Metro's commercial exploitation strategy has proven to be a financially innovative approach to supporting large-scale urban transit infrastructure. By leveraging advertising spaces and offering station naming rights to private entities, the Metro is projected to generate approximately ₹10.5 crore per station annually from advertisements alone. These revenue streams significantly offset operational and construction costs, reducing financial dependency on the state government. Partnerships with private players for branding and commercial activities are structured to ensure that income generation does not interfere with passenger services or the Metro's core functionality.

Broader Benefits and Implementation Challenges

Beyond revenue, commercial activities provide enhanced brand visibility for businesses and support transit-oriented development (TOD) by stimulating commercial and residential growth around metro corridors. The reinvestment of commercial income also contributes to infrastructure maintenance and future expansion, bolstering the system's long-term sustainability. However, the implementation of this model has not been without challenges. Issues related to land acquisition, legal hurdles, and environmental concerns had to be addressed carefully. Additionally, maintaining public perception was crucial—ensuring that commercialization did not compromise the Metro's primary mission of providing accessible, efficient transportation. This case study underscores the success of the Mumbai Metro in using commercial exploitation and public-private partnerships (PPP) as a sustainable funding model, offering a valuable reference for other cities planning urban transit systems.

Conclusion

The Mumbai Metro Project represents a transformative solution to the city's longstanding transportation challenges, including severe congestion, pollution, and inadequate public transit infrastructure. With a planned network of 337.1 kilometers, the metro aims to provide fast, efficient, and eco-friendly urban mobility while significantly enhancing the quality of life for commuters across Mumbai and its suburbs. This study's feasibility analysis highlights the importance of sound financial planning and the effective use of public-private partnerships (PPPs), which have been instrumental in mobilizing resources and ensuring long-term sustainability. Despite challenges such as land acquisition delays and regulatory bottlenecks, the consistent construction progress and rising commuter usage suggest a promising future for the project.

In addition to addressing transport needs, the Mumbai Metro also brings significant environmental and socio-economic benefits. By encouraging the shift from private vehicles to public transport, it is expected to reduce air pollution, energy consumption, and noise. Furthermore, the metro plays a vital role in promoting inclusive urban development by improving access for marginalized communities and supporting regional economic growth through increased access to jobs, education, and healthcare. Real estate development around metro stations is also likely to contribute to urban regeneration. However, the project's ultimate success hinges on continued stakeholder collaboration, timely execution, and effective integration with other transport modes. Public sentiment, as observed in this study, remains largely optimistic, with strong support for the metro's potential to improve accessibility, sustainability, and economic opportunities.

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