Challenges Faced In Planning Of A Mumbai Metro

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Abstract- *'Mass rapid transit system' is a rail based system which has been widely accepted as an urban transportation mode with BRTs and Monorails. It is worldwide solution for ever- increasing traffic generated pollution and congestion. The Metro rail carries large volume of passenger in quick time thus considerable saving in cost and fuel. The Metro rail projects are under construction in big scale in India. The projects such as Delhi Metro, Kolkata Metro are being expanded where as new metro line is being proposed for metro cities like Ahmedabad, Bengaluru, and Hyderabad. The present paper focuses on challenges faced during planning of Metro projects case study of Mumbai Metro.*

Keywords- Public transportation, Mass Rapid Transit System, urban traffic, planning, passenger ridership, critical issues.

I. INTRODUCTION

Mumbai is a cosmopolitan city, known as 'financial capital of an India'. It is heart of the commercial and trade market of a country, the job opportunities offers thousands of immigrants from hinterland of Maharashtra and other part of a country travel to Mumbai. Over 11 million people travel daily by public transport including BEST and local trains. Though the existing rail transport and BEST services are being upgraded regularly based on traffic demand, is under extreme pressure. There is a limitation to expansion to road ways and railways. Thus, Mass rapid transit system is best suitable for present traffic situation for a city like Mumbai.

Mumbai Metropolitan Region Development Authority (MMRDA) is an authority body aims to solve traffic problems and improve traffic scenarios in Mumbai. The proposed project 'Mumbai Rail Project' has been sanctioned by state and central government of India. Mumbai metro rail corporation limited (MMRCL) comes under Mumbai Metropolitan Region Development Authority (MMRDA) is a joint venture of a Government of India and government of Maharashtra.

II. LITERATURE SURVEY

In [5] author have stated that the importance of an infrastructure project for development country and critical issues faced by it. According the author, these infrastructure projects are mirror of any country's development. However, the nature of impact of such mega project could be either positive or negative, depending upon their potential to favorably or adversely affect the surrounding environment and also the resident community. The construction of a Delhi Metro Rail brought out several important environmental, social and other issues which need to be studied and addressed carefully to make this mega infrastructures projects not only environmentally and socially acceptable but also technically and financially viable.

In [1] author studied the challenges in construction Industry in India and found out that the construction Industry is second largest industry in India after agriculture. It makes significant contribution in nation's economic growth. The use of various technologies and deployment of project management strategies has made it possible to understand project in mega scale. However, the industry has still faced with major challenges, including mass transportation. Technocrats associated with the Indian construction Industry need to employ innovative technologies and skilled project handling strategies to overcome the challenges.

The various critics argue that these metro rail projects are very costly, subsidized, require excessive land densities, are generally ineffective in solving most of transportation problems and favor rich people. The studied carried out by Carla Lopez del Puero (2016) [4], has concluded that most of criticism of rail projects are not based on actual facts rather based on omissions, errors misrepresentations. It was observed that if various benefits (namely congestion, pollution reduction, vehicle km travel etc.) are considered individually then the cost of the metro rail projects will definitely be higher as compared to other public transportation system. But if these benefits are combined together then metro rail projects is least costly visa-a-versa other than transportation project.

III. METHODOLOGY

The every construction project has their unique properties. Thus every project face different challenges depending upon their uncommon social, environment issues and existing land use pattern. The Mumbai city has different geography and geology depending upon it, the following challenges was identified.

1. Underground Vs Elevated

To cater the increasing traffic demand and traffic congestion, the Metro rail system were introduced in Mumbai city. The topic that gathered lot of attention is whether the metro rail should be elevated or underground among engineers and stakeholders. The study shows that the construction cost of an underground corridor is more than twice expensive as constructing an equally long elevated section, in case if a Delhi metro being Rs. 275 crore and Rs 110 crore per km respectively. Similarly, the cost of construction of per km of underground and elevated corridor in Mumbai has been estimated to be Rs.635 Crore and Rs.235 crore.

The higher cost of metro corridor in Mumbai is due to higher land acquisition costs and absence of various incentives exemptions which government has provided to other metro projects but not extended the same to Mumbai metro. The second factor in deciding choice between an elevated platform and underground corridor is technical feasibility. Because of engineering complexities and associated risk of cost and time overruns is very much less in elevated corridor an elevated platform is much preferred than an underground corridor.

Thus, despite the high cost of underground corridor due to practical difficulties in carrying out construction in CBD areas and technical issues such as land acquisition, resettlement and rehabilitation of a residential and commercial area along proposed alignment, it is convenient to go for an underground corridor for Mumbai metro line 3.

2. Muck Disposal

The Mumbai metro line 3 is entirely an underground rail project. Hence, a large volume of muck will be generated during the construction the project. The major source of muck generation is construction of stations (Cut & Cover and NATM), Bore tunnels, NATM tunnels, and various shafts.

Table 1. Muck dumping option

SR No.	Alternate option	Capacity of Dumping site Mm3	Remarks
1	JNPT Terminal 4	4	Avg. Depth of fill taken as 2.0 m
2	Ports/ Jetties at Rajauri Creek, Vill Rohini,Dist. Raigad	7.8	As communicated by project proponent
3	Abandoned Quarries Raigad and Thane	16.13	Avg. Depth of fill taken as 1.0 m
4	Recycle and Reuse	-	
5	Deep Sea Dumping	-	Detailed Investigations Required

Source: Updated EIA Report, Mumbai Metro Line 3

About 10.54 Mm3 of muck will be generated. Out of all these five options, the abandoned quarry option sees to be the most feasible. Thus, cost estimate for muck disposal quarry sites were done.

3. Enviornmental Issues

1) Air Pollution

The Construction work of the metro rail has impact on the air quality at station and at depot only since metro alignment is constructed at an average depth of 18-20 meters. The environmental impacts could be positive, negative, direct or indirect, local, regional or global. The existing condition of air quality along the alignment was observed to be below the national standards described by CPCB. The dust concentration monitored as 2 times higher than standard value. Hence, dust could be the problem when the project is under construction. Any changes can have indirectly or directly impact on health of a people residing along the alignment line from due to construction the project. The air pollutants such as particulate matter, sulphur dioxides and nitrogen oxide have adverse impact on human health. The impact of air pollution aggravates bronchitis, respiratory diseases, emphysema, cardiovascular diseases and eye irritation. However, the air pollution during construction is localized and only around the station construction sites only.

2) Noise Pollution

During the operation phase the main source of noise will be from running of metro trains. Noise radiated from train operations and track structures generally constitute the major noise sources. The main sources of noise from the operation of trains include: engine noise, cooling fan noise, wheels. No major impacts are anticipated due to noise pollution as the major construction works are underground only.

Table 2. Noise Levels at 50 feet from source for various construction equipment

Sr No.	**Machine**	**Noise Level in dB(A) without noise control at 50 feet**
1	Excavtor	85
2	Dumper	84
3	Crawler dozer	85
4	Heavy Duty Jack Hammer	85
5	Compressor	80
6	Crane	83
7	Generator	81
8	Rock Drill	98

Source: Updated EIA Report, Mumbai Metro Line 3

The noise monitoring were carried on site one before start of construction and second during construction to determine noise pollution. The analysis were done and some recommendation were given about it.

Vibration pollution

The whole alignment of the Mumbai metro is underground and will be carried out by Tunnel Boring Machine (TBM). TBM is the worldwide accepted machine having less impact of vibration. The vibration that could be generated due to TBM has been calculated at each monitoring location and the values were as follows:

Table 3. Vibration at Key Location

Sr No.	***Site Location***	***Approximate Vibration due to Train***	***Approximate Vibration due to TBM***
1	*At the Lady Willingdon Building*	*85-90 Vdb*	*144 db*
2	*At Central Assurance Building, opp. to Commissariat Building*	*65-75 Vdb*	*147.8 db*
3	*At Bhikha, Behram, Parsees Well, Hutatma Chowk*	*65-70 Vdb*	*143 db*
4	*At Chhatrapati Shivaji Terminus*	*90-95 Vdb*	*147.3 db*

Continuous effect of vibration on the buildings can cause damage to the buildings. For a person in their residence the lower threshold for annoyance is 72 VdB. Building subjected to the vibration effect with more than 154 VdB would receive structural damage. Historic buildings are more susceptible to vibration effect due to type of building material and design. Old structures generally lose structure strength over the period are also subjected to impacts of vibration especially those come under heritage category.

3) Loss of Green

During construction of any infrastructure project trees have to be cut, resulting in disturbance biodiversity of an area. The trees are getting affected at station and at depot location only as proposed metro corridor is underground. The loss of green cover may result in climatic changes and affects aesthetics of the area. For Mumbai metro project, the total number of trees observed on project site area is 2080. Out of which 1050 trees are to be replanted to suitable location and 1750 trees have to be cut. And for every tree going to cut 3 times trees are planted. For Delhi Metro 50,000 tees were cut, but 1.5 lakh trees were planted in lieu of that.

The cutting of trees would have short term Heat-Island Phenomenon and it would be mitigated after construction due to afforestation. With removal of these trees the process of CO2 absorption and O2 production will get affected and the losses are reported in table below.

Table 4 .Oxygen deficit due to tree loss

Sr No.	**Description**	**Quantity**
1	Total no of trees to be cut	1030
2	Increase in CO2 @ 21.8kg/year/trees	22454 kg
3	Decrease in Oxygen production @49kg/year/tree	50470 kg

4. Land Acquisition and Rehabilitation & Resettlement

The construction of a new Metro Line III requires land acquisition. The land acquisition will be mainly for rail tracks, station buildings, entry/exit structures, traffic integration, car shed, power substations, ventilation shafts, administration buildings, property development, maintenance and construction depot at work sites etc. the details of land required for the project is given in table 8.

Table 5. Land requirement

Sr No.	Land Requirement	Area in ha	Temporary Use (in ha)	Permanent Use (in ha)
1	Govt. Land	41.087	12.079	28.297
2	Private Land	4.72	1.29	3.43
	Total	**45.81**	**14.08**	**32.727**

This acquisition of land shall displace people from their home and business base. Though the land acquisition is unavoidable, it is practiced to keep land requirement and project affected people (PAPs) to minimum. The total affected people and commercials are 5940 and 236 respectively in count. But compensation for land acquisition, resettlement and rehabilitation shall be considered as per the provisions of Resettlement and Rehabilitation Policy for Mumbai Urban Transport Project (MUTP) 1997, as amended in December 2000.

5. Utility Works & Diversion

The proposed Metro alignment is passing through underground, hence utilities like sewers, water mains, storm water drains, telephone cables, electrical transmission lines, electric poles, traffic signals etc. would not get affected except at locations where construction of stations is proposed through cut and cover method. These utility services have to be maintained in working order during different stages of construction by temporary / permanent diversions or by supporting in position. As such, these may affect construction and project implementation time schedule/costs, for which necessary planning / action needs to be initiated in advance.

The Organizations / Departments responsible for concerned utility services are reported in table below. While planning for diversion of underground utility services e.g. sewer lines, water pipe lines, cables etc., during construction of Metro rail, the following guidelines could be adopted: Utility services shall be kept operational during the entire construction period and after completion of project. All proposals should therefore, ensure their uninterrupted functioning.

6. Traffic Diversion

Traffic is most likely to be affected during construction of metro rail project. Hence Traffic Diversion Plans are required in order to look for options and remedial measures so as to mitigate any traffic congestion situations arising out due to acquisition of road space during Metro construction. As the whole alignment of proposed metro is underground little disturbance will took place at the station locations only. In order to retain satisfactory levels of traffic flow during the construction period; traffic management and engineering measures need to be taken. They can be road widening exercises, traffic segregation, one-way movements, traffic diversions on influence area roads, acquisition of service lanes, etc. Various construction technologies are in place to ensure that traffic impedance is at the minimum.

IV. RESULTS & ANALYSIS

1. Muck Disposal

As construction of metro corridor is fully underground there will be huge amount of muck generation. The five options have been already suggested for muck disposal. The capacity of all five options is described in detail in below.

Table 6. Capacities of the Muck dumping sites

Packages	*Avg. Distance (km)*	*Travel time*	*Muck Disposal*	*Capacity in Mm3*	*Cost in Million*
1	*60*	*115*	*Kalwar*	*0.9*	*0.53*
2	*43*	*90*	*Mhape*	*0.25*	*0.14*
3	*48.1*	*95*	*Dhapode*	*0.73*	*0.43*
4	*42.5*	*70*	*Dhapode, Ovale*	*0.73*	*0.43*
5	*52.2*	*80*	*Waliv*	*0.54*	*0.31*
6	*57.8*	*90*	*Waliv, Ovale*	*0.54*	*0.31*
7	*52.2*	*80*	*Ovale, Wehle*	*1.07*	*0.63*

The capacity is not enough to accommodate all muck which will be generated during construction. The total muck volume is 10.54 Mm3 which is twice the capacity available. Hence, more options for muck disposal sites need to be identified. Also, the cost analysis for dumping sites shows it

will require about 3 Million Rupees for transportation which is lot more cheaply and feasible among all.

2. Environmental issues

Air Pollution

The atmospheric concentration of air pollutants were monitored during preliminary surveys conducted in the year 2012 and in July 2017 by setting up ambient air quality monitoring stations along the alignment. The air monitoring included determining the concentration of PM10, PM2.5, NOx, SOx, CO, CO2 and HC. The comparison analysis was done.

Table 7. Ambient air quality Results

Location	Date	PM10	PM2.5	NO_x	SO_x	HC	CO
Standards		100	60	80	80	-	2
BKC	11/1/2012 to 12/1/2012	138	81	26.5	5	3.0	1.28
Sahara Station	1/7/2017 to 2/7/2017	105.2	78.1	16.7	9.2	2.8	0.5

The result shows that concentration of PM10 and PM 2.5 exceeds the standard at BKC location whereas all other parameters are within permissible limit. Though air quality during construction shows insignificant impact, certain mitigation measures should be adopted to reduce the air pollution are presented below:

- The Contractor shall take all necessary precautions to minimize fugitive dust emissions from operations involving excavation, grading, and clearing of land and disposal of waste. He shall not allow emissions of fugitive dust from any transport during handling of materials, construction or storage activity.
- The Contractor shall use construction equipment to minimize or control of air pollution. He shall maintain evidence of design and equipment to make these available for inspection by Employer.

3. Noise Pollution

The following noise monitoring data were taken using sound noise meter one before construction on 11/01/2017 and 12/01/2017 and second during construction ie on 1/07/2017 and 2/7/2017.

Table 8. Noise readings and Results

Time	Hourly Leq dB(A)	
	At BKC	At CSIA International Airport
6:00- 7:00	61.3	70.2
7:00- 8:00	65.3	72.1
8:00- 9:00	68.2	73.7
9:00- 10:00	72.4	66.5
10:00- 11:00	69.7	75.3
11:00- 12:00	74.3	67.8
12:00- 13:00	72.6	71.7
13:00- 14:00	73.1	91.0
14:00- 15:00	68.3	76.3
15:00- 16:00	72.8	70.3
16:00- 17:00	71.4	68.6
17:00- 18:00	70.1	63.7
18:00- 19:00	69.9	67.7
19:00- 20:00	68.6	76.5
20:00- 21:00	59.3	74.5
21:00- 22:00	52.7	67.8
22:00- 23:00	50.8	71.7
23:00-00:00	51.2	62.3
00:00- 01:00	49.4	76.7
01:00- 02:00	48.3	68.3
02:00- 03:00	47.1	72.6
03:00- 04:00	49.6	60.1
04:00- 05:00	52.4	68.3
05:00- 06:00	58.9	76.4

Results			
Leq Day	70.3	Leq Day	74.9
Leq Night	53.0	Leq Night	73.5
Lmax	74.3	Lmax	83.3
Lmin	47.1	Lmin	60.8

A study was conducted by National Physical Laboratory for Delhi metro for noise level in elevated and underground stations. The noise level within building structures due to machines shall not cause any damages to residential structures and commercial structures if below 55 dB and 60 dB respectively. Hence, users only have impact of noise during operation.

Table 9. Adjustment for close in equipment noise measurements

Distance (Feet)	***Level to Estimate Sound Level at 50 Feet dB (A)***
19-21	*8*

22-23	*7*
24-26	*6*
27-29	*5*
30-33	4
34-37	*3*
38-42	*2*
43-47	*1*
48-50	*0*

The above values show that the allowable duration per day of construction equipment. The equipment having sounded level in the range of 90 shall be use for 8 hrs per day and that of having above 110 shall be use for only ¼ hrs per day. The allowable duration of each equipment per day is explained in the following table.

Table 10. Permissible Usage of Construction equipment

Equipment	**Allowable Usage**
Excavtor	Not more than 8
Dumper	Not more than 8
Crawler dozer	Not more than 8
Heavy Duty Jack Hammer	Not more than 8
Compressor	Not more than 8
Crane	Not more than 8
Generator	Not more than 8
Rock Drill	Not more than 6

Vibration Pollution

Federal Transit Administration (FTA) has recommended the typical levels of vibration of construction equipment which are summarized in Table below.

Table 11. Permissible Vibration of construction equipment

Construction equipment	**VdB at 25 Feet**
Rock drilling	115.9
Dump trucks	122.7
Bulldozer	124.0
Excavator	124.0

The actual TBM work is expected start on end of 2017. Thus, actual readings will be taken during construction of underground stations. But prior to construction it is important to get detailed geotechnical investigation done so that there will be any unseen difficulty during tunnel construction. The following measures to be taken during construction of tunnel.

- Detailed vibration investigation should be carried out prior to construction at locations where the alignment is close to historical / heritage structures.
- Continuous vibration monitoring equipment shall be installed during construction. Vibration monitoring shall also be conducted inside as well as on the top of the building mainly for old structures and heritage buildings.

Loss of Green Cover

The carbon dioxide is one of the major greenhouse gases, which directly deplete the ozone layer. To reduce the overall greenhouse gas emission International Emission Trading (IET) Mechanism has been followed under Kyoto Protocol by Mumbai metro. The Mumbai metro line III project as discussed earlier will be cutting down totally 2080 trees. Out of which 1050 trees are to be replanted in the location granted by SC and remaining 1030 trees are need to be cut. The amount of CO_2 absorbed by these 1030 trees is far lesser than reduction in CO_2 due to construction of metro line as there will be tremendous reduction in vehicle trips. The calculations of vehicle trip in KMs with and without Metro Line III and cost cutting in fuel due to construction of new metro line shows the same. Thus this metro line would live positive environmental impact.

To calculate vehicle trip reduction in KMs and savings in fuel consumption in the year 2016, 2021, 2031 and 2041, the traffic data of 2011 year of Colaba-Bandra-Seepz road were taken from RTO, Mumbai.

Table 11. Reduction in Vehicle Trips due to C-B-S

MODE	**Reduction of Vehicle Trip KMs**			
	2016	**2021**	**2031**	**2041**
Bus	93080	113898	138281	165937
Car	905641	1108196	1345437	161524
2/3 Wheeler	3561039	4357496	5290343	6348412
Total	4559761	5579590	6774061	8128873

Table 12. Emission reduction in CO2

Mode	**Year**			
	2016	**2021**	**2031**	**2041**
Bus	35.24	43.12	52.35	62.82
Car	1028.51	1258.55	1527.97	1833.57
2/3 wheelers	4493.52	5498.54	6675.66	8010.79
Total	5557.27	6800.20	8255.98	9907.17

Carbon credits per year will be achieved through this project in the 2016, 2021, 2031 and 2041 respectively. In economic terms it will valued as Rs. 23.01 lakh (5557.27 (Caron Credit) X 6 (Amount in Euro) X 69 (Amount in Rs.), Rs. 28.15 lakh (6800.20 (Caron Credit) X 6 (Amount in Euro) X 69 (Amount in Rs.), Rs. 34.18 lakh (8255.98 (Caron Credit) X 6 (Amount in Euro) X 69 (Amount in Rs.) and Rs. 41.02 lakh (9907.17 (Caron Credit) X 6 (Amount in Euro) X 69 (Amount in Rs.) for year 2016, 2021, 2031 and 2041 respectively. From all above calculation it can be concluded that tree cutting will impact more positively than not cutting it and changing metro alignment just for sake of it.

V. CONCLUSION

Construction of metro rail projects in Mumbai has brought out several important technical, environmental and social challenges insight. These challenges are need to be studied and monitored thoroughly during planning, pre-planning and construction phase to make mega construction projects not only environmentally and socially viable but also financially feasible.

The public transportation system should be such convenient to use that people will shift from private vehicle to public transportation. A good transportation system should ideally be a combination of all transportation system. If benefits mainly congestion reduction, vehicle kilometer travelled from metro rail projects are considered individually then the cost of metro rail projects will definitely be higher than public transportation but if these benefits are combined together then metro rail project will be least costly than other public transportation system. Further, the experienced gained from other similar projects on various aspects related to pre-construction and construction phase can suitably use for the project to ensure projects are environmentally and socially acceptable.

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