COMPARATIVE EVALUATION BETWEEN ELEVATED AND UNDERGROUND METRO CASE STUDY - MUMBAI METRO

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Abstract

This paper is a technical study to evaluate the elevated metro (EL) and the underground metro (UG) system to make a rational decision about which is feasible and in what way. The decision will consider all kinds of impacts on the quality of life of the beneficiary as well as those affected directly by the elevated alignment of the said metro. Underground metro plays a pivotal role in decreasing excessive sufferings of the people in the region during the construction phase and the charges of operation and maintenance, as the roads are decongested thus leading to decrease in the vehicle operation cost during operation period. This study proves the economic viability of the underground metro over elevated metro.

(US $1 million = Rs. 48.62 million)

Keywords: Economic evaluation, Underground Metro, Elevated Metro

1. Introduction

Metro systems usually offer an attractive alternative for mass transit transportation system in most large cities. Metro systems are considered a smart option for transportation systems in outsized metropolitan areas. It is well known that rapid rail transit, as one of the modern public transport modes with greater capacity, speed, safety and reliability, is playing more and more important role in most of metropolitan region [4].

Mumbai is the financial capital of India & one of the most densely populated cities in the world. The total Mumbai Metropolitan Region (MMR) covers an area of 4335 sq.km. Greater Mumbai is divided into three main parts, Island city, Western suburbs, and Eastern suburbs, together sprawling over an area of 468 sq.km. According to the census count, Greater Mumbai has a population of 11.9 million (2001) which is presently 14 million [5]. This high population in Greater Mumbai and also in the metropolitan region is bound to result in phenomenal growth in travel demand. To fulfil such a great demand, Mumbai Metropolitan Region Development Authority (MMRDA) has initiated the process for developing the line-II of Metro from Charkop to Mankhurd via Bandra – Kurla complex. The elevated metro from Charkop – Bandra – Mankhurd is being constructed as a part of the phase 1 of the construction of Mass Rapid Transit System (MRTS) in Mumbai by the MMRDA under a Public Private Participation (PPP) model.

The need of this study came from the point of sustainability for people that are going to be affected directly or indirectly by the occurrence of an EL metro. The proposed elevated metro corridor is passing though highly congested localities and the alignments are mainly passing through 4 and 6 lane roads. This will reduce the capacity of the roads, as during construction at least two and a half lanes (9 meters) will be barricaded. During operational phase, the road width available for the mobility of vehicles is reduced to a greater extent, as the proposed diameter of the pillar of EL metro is around 2 meters. Which will lead to reduction in the road capacity; this reduced capacity will lead to congestion, thereby causing fuel wastage and increase of vehicle operation cost. In the case of the underground metro this problem doesn't arise as the works are carried out at a depth of 20-25 meters below the ground level.

In the case of elevated metro, footpaths are destructed in order to compensate for the reduced road width; and hence leads to inconvenience of pedestrians. Also densification of area with more floor area ratio (FAR) within 250m – 500m will occur due to elevated metro. In the case of the elevated metro, to keep the metro alignment at the median of the roads many sharp turns or curves are required which will lead to inconstant speed. 54% of the length of alignment is on curves. In other words over 17 km. of elevated metro rail falls on curves, thus the speed shall be restricted immensely. Further these curves are at 140 locations, of which as many as 38 locations are less than 500 m radius and at 8 prime locations at 90^o, requiring land acquisition, displacement of people, public amenities, etc. These curves are unavoidable evil for any rail which is prone to derailment, high maintenance costs and accidents.It is a known fact that many times via duct support needs portal frame structure to negotiate peculiar curves which may not align with the Right of Way. This will also reduce speed of train from planned speed of 80 kmph. Whereas in underground metro the curvature part can be minimized to a maximum extent or kept straight as far as possible. Land acquisition is essential at curvature level as well as for stations and depot areas, which will cost about Rs. 4000 crores (US $822 million). Also the cost of shifting of utility services is sometimes 2-3 times the cost of construction. An overall cost due to elevated metro will be as high as about Rs. 17000 crores (US $3496.5 million). In the case of elevated metro, which will need land acquisitions contrary with rehabilitations and resettlement of existing shops and commercial centres. the owners of shops and commercial centres will be highly affected as they will lose many opportunities in terms of business and commerce.

To combat unprecedented growth of vehicles, flyovers have been proposed on arterial roads. If elevated metro is considered as an option, all the proposed flyovers need to be abandoned. Even existing flyovers acts as a barrier during planning, operational and constructional phase of an elevated metro. Due to the present scenario of environmental conditions in terms of the greenhouse gas effect, global warming, subsequent health hazards are becoming worse day by day and now steps are being taken to minimize these fatal effects to save our planet. Thus we should always think of eco-friendly way for every possible work and give priority to sustainability. In case of elevated metro we are fully neglecting the term called sustainability. If elevated metro is built, it will solve problem of travel partially but will add more problems in terms of congestion, pollution, safety etc. These are all basic problems and any new transport system should plan to minimize these tribulations rather than add more. One of the worst impacts is uprooting of 948 trees from 1950 existing trees of several generations. A meager amount of Rs. 1000/- (US $20.5) per tree is estimated as loss to the citizen which is absurd. These trees are priceless. It is expected that Elevated Metro Rail will have 85 to 90 db (A). The noise pollution emitted by the trains on account of engine noise, wheel rail interaction; train speed. Air pollution will increase as land is acquired during constructional phase leading to congestion thereby increasing air pollution. The vehicle operating cost and pollution costs will have its direct impact on fuel Loss of Buses, cars, taxis, autos, etc. not only during construction but forever. In addition it will generate huge amount of air and dust pollution.

All these problems which will occur due to elevated metro will be eliminated if underground metro is built. In the case of underground metro, there will be clean, eco-friendly and unnoticed construction as construction will be done 20-25 meter below ground level. There will not be shifting of underground services like sanitation, water supply etc. as in case of elevated metro 32 kms. of sewer lines, 20 km. of water lines and 12 kms. of gas lines will have to be re-laid in over-congested arterial roads. The curvature part can be minimized to a maximum extent or kept straight as far as possible. Also there will be no problem of land acquisitions and rehabilitation; since there is no land acquisition, the business and commerce will not get affected.

In the case of underground metro, the question of uprooting trees doesn't arise, and will hardly contributes air and noise pollution towards the environment. Improvement in the 'Quality of Life' is a function of ground level Green and Clean areas, minimum congestion and delays, pollution, maximum safety, easy parking, ITS for disaster management, security which will be possible with underground metro. Overall UG metro leads to the term called sustainability which is a need of time.

2.1 Study area

Metro II (Charkop-Bandra-Mankhurd) corridor falls within Municipal Corporation of Greater Mumbai (MCGM). This corridor mainly connects the western region with the business oriented areas of Bandra etc. The MCGM area thus has been designated as study area.

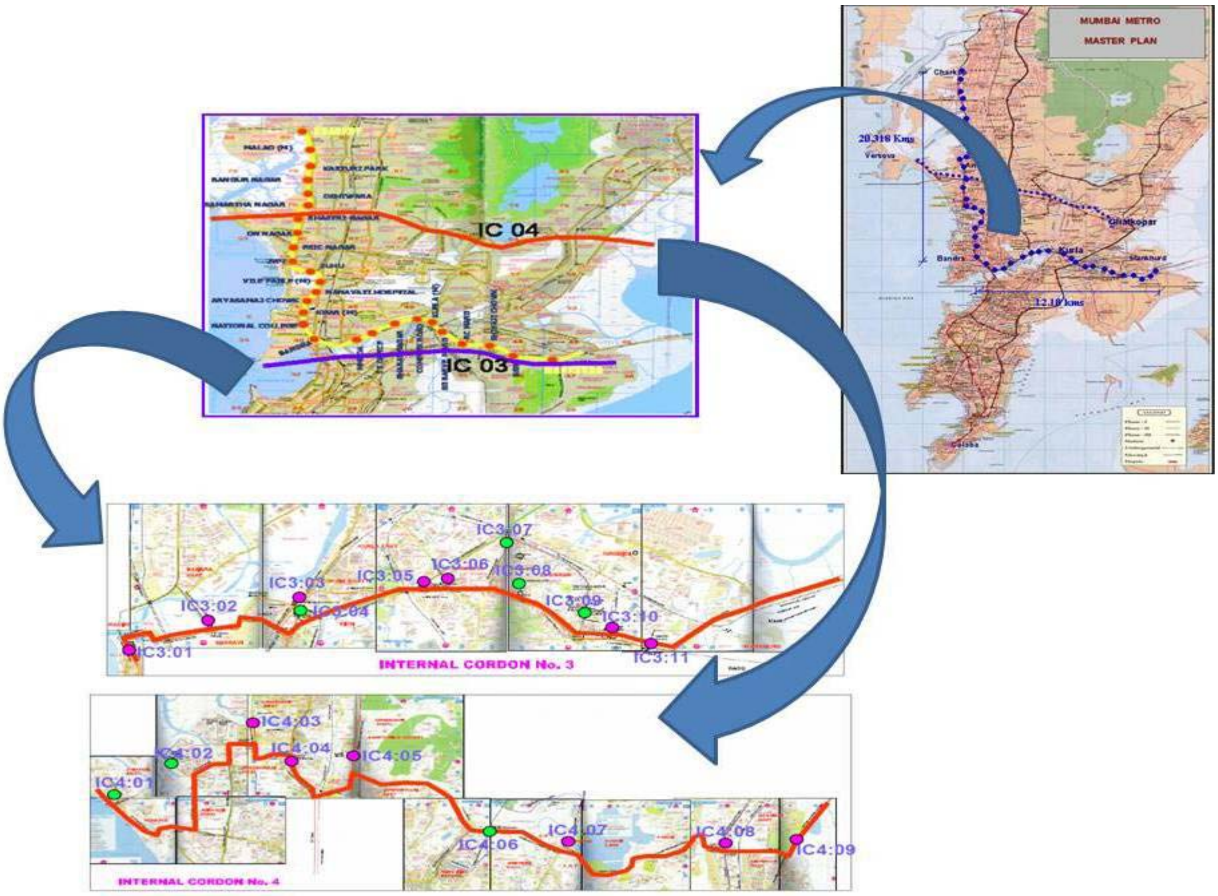

Fig. 2.1 Map Showing Internal Cordon Location 3, 4

The area of MCGM is 468 sq. km .Table 3.1 shows traffic volumes of roads which falls on inner cordon 3 and 4. Traffic volume is function of width of the road, pavement condition, road geometry and which is directly related to the free flow speed and journey speed. It also shows that most of the roads are congested.

3. Traffic Data and Level of Congestion

The alignment of the metro line II is proposed on 4-lane and 6-lane roads .The present journey speed on this road is about 18 kmph. During the construction, a minimum of 2.5 lanes will be barricaded that will result in further congestion and reduction of journey speed.

Table 3.1 Classified Traffic volumes on Internal Cordon 3 and 4

Sr.No.	Name of code	Name of the Road	Cars	Two wheelers	Autos	Taxis	Buses	Cycles	Hcv	Lcv	others	Total Vehicles
1	**IC3:01**	MahimCauseway	70458	44513		43713					11668	170352
2	**IC3:02**	Sion Bandra Link Road	52740	22021	34353	18329					20246	147689
3	**IC3:03**	LBS Road, near Naik Road	14756	9217	15644						16615	56232
4	**IC3:04**	Duncan Causeway Road	1610	1843	2909	1005					1062	8429
5	**IC3:05**	Eastern Express Highway	46901	24678					5832	13988	39938	131337
6	**IC3:06**	S G Barve Marg, U Bappa Chowk	4758	7645	28242						8962	49607
7	**IC3:07**	R C Road	8143	9682	23631						5608	47064
8	**IC3:08**	Sarasvati Marg, Lad Chowk	5629	4448	7687		647				1982	20393
9	**IC3:09**	Patil Marg, near Patil Industrial Estate	4000	2945	5998						1547	14490
10	**IC3:10**	B S Devashi Marg	2254	2285	4288						1449	10276
11	**IC3:11**	Sion Panvel Highway	35288	16270	15409						19990	86957
12	**IC4:01**	Yari Road	2722	3559	6428						2623	15332
13	**IC4:02**	(BMC Road	4426	1083	2119						736	8364
14	**IC4:03**	Link Road, Oshiwara	22356	19976	27984		3003				7651	80970
15	**IC4:04**	S V Road	10193	17035	29833						8912	65973
16	**IC4:05**	Western Express Highway	63557	48086	61699						30756	204098
17	**IC4:06**	Moral Mahroshi Road	1949	4442	3187			644			709	10931
18	**IC4:07**	Saki Vihar Road)	5598	5291	8354		1176				3020	23439
19	**IC4:08**	LBS Marg	9699	13768	17644		3902				5789	50802
20	**IC4:09**	Eastern Express Highway	41492	20002	13000				8747	3854	8287	95382

(Source: 1)

Table 3.2 – Different types of links in network and their characteristics

Link Type	No. of lanes	Divided/ Undivided	Type of flow	Capacity Per Direction (PCU/hr)	Free flow speed (km/h)	Speed @ Capacity (km/h)
1	One Lane	Undivided	One-Way	1650	30	15
2	Two Lane	Undivided	One-Way	3200	40	15
3	Three Lane	Undivided	One-Way	4350	40	15
4	Four Lane	Undivided	One-Way	5300	50	18
5	Five Lane	Undivided	One-Way	6200	50	18
6	Six Lane	Undivided	One-Way	7000	55	20
7	Three Lane	Divided	One-Way	4350	40	15
8	Four Lane	Divided	One-Way	4950	50	18
9	Six Lane	Divided	Two-Way	7000	45	18
11	Two Lane	Undivided	Two-Way	1100	35	15
12	Three Lane	Undivided	Two-Way	1500	35	15
13	Four Lane	Undivided	Two-Way	2150	40	18
14	Five Lane	Undivided	Two-Way	2600	40	18
15	Six Lane	Undivided	Two-Way	3200	45	18
16	Three Lane	Divided	Two-Way	1650	40	18
17	Four Lane	Divided	Two-Way	2600	50	18
18	Six Lane	Divided	Two-Way	3800	50	18
19	Eight Lane	Divided	Two-Way	6200	55	20

4. Stated Preference survey (SP Survey)

This survey would include interviewing commuters on sample basis to have information on personal details, trip characteristics, opinion on service and their suggestions towards improvement. We targeted 219 samples with influence region of 250 meters either side of the proposed metro line. Sample size mapping as per population density is shown in table 4.1.

4.1 Analysis of Stated Preference Survey of Mumbai Metro

If underground metro come into operation, the hidden advantages are more than elevated metro. If we convert those advantages into cost, underground metro is also economical.

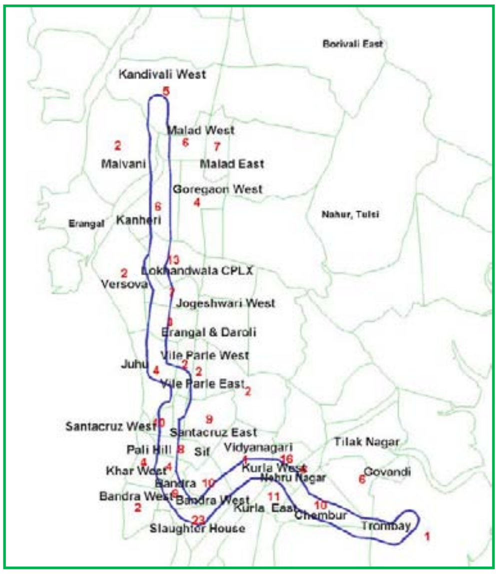

Fig 4.1– Proposed Sample distribution over the influence area of metro corridor

Table 4. 1 Sample size and area description

ID	Name	Population	Area	Density	Sample Size
87	Kurla West	187037	0.69	270072.08	16
71	Goregaon West	132192	1.81	72918.18	4
72	Kanheri	200714	1.89	106034.65	6
68	Lokhandwala CPLX	315053	1.42	222175.32	13
57	Jogeshwari West	111350	2.62	42542.02	3
58	Vile Parle East	24127	0.58	41747.34	2
62	Jogeshwari West	123616	0.95	129605.91	8
61	Erangal & Daroli	56367	1.04	54130.17	3
63	Versova	117173	2.61	44927.45	3
59	Vile Parle West	23190	0.6	38918.41	2
60	Juhu	154756	1.86	83149.52	5
50	Santacruz West	85269	0.47	180615.69	11
92	Govandi	190462	1.7	112302.60	7
89	Nehru Nagar	50989	0.5	101579.55	6
94	Trombay	195390	9.01	21685.84	1
93	Chembur	336398	1.98	169687.59	10
88	Kurla East	120070	0.6	199415.22	12
56	Santacruz East	233255	1.51	154774.78	9
53	Sif	106900	0.72	148524.76	9
51	Khar West	31809	0.39	80976.49	5
55	Vidyanagari	64600	2.29	28227.35	2
39	Slaughter House	385966	0.96	400166.69	24
52	Bandra West	164738	0.97	169343.43	10
49	Pali Hill	56080	0.77	72900.33	4
47	Bandra	129357	0.78	166859.03	10
48	Bandra West	37805	0.98	38629.68	2
41	Pali Hill	28295	0.42	67910.27	4
43	Worli	113363	0.85	133825.22	8
79	Kandiwali	434855	4.03	107827.15	5
74	Malad Waet	119555	1	119449.30	6
77	Malvani	155370	3.89	39924.90	2
75	Malad East	148111	1.02	145097.00	7
					219

After explaining the merits and demerits of both kind of metros and how the respondents quality of life will change, most of the respondents co-operated in carrying out the SP survey.

Survey sheet has been designed and as a starting point, pilot survey has been done. After pilot survey, based on respondents' behaviours and suggestions the survey sheet has been modified. Finally, trained professionals have done the survey at various locations.

The respondents sample comprised mostly of households but also 15% establishments to represent city wide coverage. The survey team interviewed 1070 respondents. From their responses we came to know that around 90% of people want underground metro to sustain their quality of life. If underground metro comes they are willing to pay on an average two times more than the elevated metro fare. The SP survey consists of a total of three sheets. Sheet A contains socio-economic background of respondent, sheet B contains details of their travel to work; sheet C contains social valuation and perception of the people towards Metro line-II. In detail, sheet C has more influencing attributes like riding quality, safety, accident scenario, travel time savings and quality of life at both construction and operational phase. Rating has been done on a scale of 1 to 5 to fill these attributes, 1 being immensely improved and 5 being immensely worsened. Some more important attributes to affect the quality of life like air pollution, noise pollution, congestion and delays, parking problems, health problems, property prices have been included. These are also included in the survey sheet at the time of construction and operational phase.

5. Development of SP model

ALOGIT is a computer program for studying and forecasting consumer choices. ALOGIT exploits the ability of 'logit' models to explain and predict many aspects of consumer behaviour, giving insight into the reasons for behaviour. The main variables determining the choices made by consumers and allowing forecasts to be made of what they will choose in the future.

- **Control Lines**

Many of the options of ALOGIT are controlled by control lines. These lines are identified by the character found in the first five positions on the line.

- **Utility Functions**

The utility function gives the main specification of the model to be analysed. For each alternative, a function must be specified that gives the utility of that alternative. The form in which this is done, as illustrated in following example

1. **Utility function for underground Metro**

   u1=p01*d03+p02*d04+p03*d05+p04*d06+p05*d07+p06*d08+p07*d09

2. **Utility function for Elevated Metro**

   u2=p01*d10+p02*d11+p03*d12+p04*d13+p05*d14+p06*d15+p07*d16

- **Coefficient Specifiers**

Coefficient specifiers are entirely optional, but give a useful means for labelling the coefficient on the printed output. For example

```
--------------------------------------------------------
-Specification of Coefficients
-Generic variables
01 RQ
02 SA
03 TTS
04 AP
05 NP
06 CD
07 PP
------------------------------------------------------
-Control Lines
PU      - probability for choosing underground metro
PE      - probability for choosing elevated metro
RQU     - riding quality for underground metro
SafetyU - safety for underground metro
TTSU    - TT savings for underground metro
APU     - Air pollution for underground metro
NPU     - noise pollution for underground metro
CdU     - congestion and delay for underground metro
PPU     - parking problems for underground metro
RWE     - riding quality for elevated metro
SafetyE - safety for elevated metro
TTSE    - TT savings for elevated metro
APE     - Air pollution for elevated metro
NPE     - noise pollution for elevated metro
CdE     - congestion and delay for elevated metro
PPE     -  parking problems for elevated metro
---------------------------------------------------
```

Table 5.1- Control Lines

*PU	PE	RQU	safetyU	TTSU	APU	NPU	cdU	PPU	RQE	safetyE	TTSE	APE	NPE	cdE	PPE
0.9	0.1	2	3	1	3	2	4	3	4	4	3	2	2	1	4
0.9	0.1	2	2	1	2	2	4	3	5	5	4	4	3	2	4
0.9	0.1	2	1	2	4	2	4	4	4	5	5	1	2	2	1
0.1	0.9	2	3	2	3	3	4	4	5	5	4	4	3	1	1
0.9	0.1	1	2	1	3	3	5	5	3	5	3	1	5	2	4
0.9	0.1	1	2	2	3	3	5	2	4	4	5	4	5	2	4
0.9	0.1	1	2	1	3	4	4	3	2	4	4	5	5	3	5
0.1	0.9	2	2	1	2	3	5	3	3	3	3	1	4	3	2
0.9	0.1	1	3	1	3	2	5	3	5	3	2	1	2	3	3
0.9	0.1	2	2	2	3	3	3	3	5	5	5	1	1	1	1
0.1	0.9	1	3	1	3	2	4	5	5	4	3	5	3	2	3
0.9	0.1	1	1	1	3	3	5	5	4	5	5	1	1	1	1
0.9	0.1	2	3	2	5	5	5	5	5	4	2	1	1	1	1
0.9	0.1	2	4	2	4	3	2	4	5	5	4	1	2	2	2
0.1	0.9	2	3	2	3	2	4	1	4	3	5	3	3	1	3
0.9	0.1	1	2	2	3	3	4	1	2	3	2	3	4	1	2
0.9	0.1	2	2	2	4	4	4	4	5	5	5	2	2	2	2
0.9	0.1	2	2	2	4	4	4	4	5	5	5	1	1	1	1
0.9	0.1	1	2	3	5	2	4	4	3	5	5	3	4	2	1
0.9	0.1	1	1	3	3	3	3	4	5	3	4	1	4	2	2
0.9	0.1	2	2	2	3	3	3	2	4	5	4	4	5	4	4
0.9	0.1	2	3	1	3	2	4	3	4	4	3	2	2	1	4
0.9	0.1	2	2	1	2	2	4	3	5	5	4	4	3	2	4
0.9	0.1	2	1	2	4	2	4	4	4	5	5	1	2	2	1
0.1	0.9	2	3	2	3	3	4	4	5	5	4	4	3	1	1
0.9	0.1	1	2	1	3	3	5	5	3	5	3	1	5	2	4
0.9	0.1	1	2	2	3	3	5	2	4	4	5	4	5	2	4
0.9	0.1	1	2	1	3	4	4	3	2	4	4	5	5	3	5
0.1	0.9	2	2	1	2	3	5	3	3	3	3	1	4	3	2
0.9	0.1	1	3	1	3	2	5	3	5	3	2	1	2	3	3
0.9	0.1	2	2	2	3	3	3	3	5	5	5	1	1	1	1
0.1	0.9	1	3	1	3	2	4	5	5	4	3	5	3	2	3
0.9	0.1	1	1	1	3	3	5	5	4	5	5	1	1	1	1
0.9	0.1	2	3	2	5	5	5	5	5	4	2	1	1	1	1
0.9	0.1	2	4	2	4	3	2	4	5	5	4	1	2	2	2
0.1	0.9	2	3	2	3	2	4	1	4	3	5	3	3	1	3
0.9	0.1	1	2	2	3	3	4	1	2	3	2	3	4	1	2
0.9	0.1	2	2	2	4	4	4	4	5	5	5	2	2	2	2
0.9	0.1	2	2	2	4	4	4	4	5	5	5	1	1	1	1
0.9	0.1	1	2	3	5	2	4	4	3	5	5	3	4	2	1
0.9	0.1	1	1	3	3	3	3	4	5	3	4	1	4	2	2
0.9	0.1	2	2	2	3	3	3	2	4	5	4	4	5	4	4

5.1 ALOGIT Analysis

The software ALOGIT is used to estimate the models parameters. The statistics and coefficient estimates for the SP model are presented in Table 5.2 shown below. The Rho-Squared value for this model is found to be 0.48. As a starting point, the model has developed using all attributes. Finally after many trials, significant variables are identified and model was developed by using those attributes. It was observed that on reaching the most optimal model specification, the absence of insignificant variables did not alter the value of coefficient estimates of remaining variables.

Table 5.2- Statistics and coefficient estimates of SP model

Variable	Coefficient	Standard error	t-stat
Riding quality	-0.48	0.44	-1.1
Safety	-1.69	0.62	-2.7
Travel time savings	1	0.59	1.7
Air pollution	0.6	0.36	1.7
noise pollution	0.38	0.38	1
congestion and delays	-0.25	0.4	-0.6
parking problems	-0.98	0.38	-2.6

Above results implies that the respondents care more for their safety, parking problems, air pollution, health, as well time savings. Congestion & delays gets the least preference but these are already very well represented in travel time savings. The entire model clarifies the perception of the people and their choices in terms of the variables indicative of the quality of life.

- **Riding Quality Coefficients**

Negative sign indicates, if Roughness Quality increases, the ridership decreases.

- **Safety Coefficients**

Negative sign indicates that if safety is worsened, people will not choose that mode, means ridership decreases. The coefficient of safety is higher than other coefficients means people in study area are more sensitive about safety.

- **Coefficient of travel time**

Positive sign indicates that as people choose the mode which saves travel time.

- **Coefficient of Air Pollution**

Positive sign indicates that air pollution savings is more, the ridership will be more that means people from study area are more sensitive about Air pollution & they will choose the mode having less air pollution.

- **Coefficient of Noise pollution**

Positive sign indicates that Noise pollution savings is more, the ridership will be more that means people from study area are more sensitive about noise pollution & they will choose the mode having less noise pollution.

- **Coefficients of Congestion & Delays**

Negative sign indicates if congestion and delays is more, the ridership will be less.

- **Coefficient of Parking Problems**

Negative Sign indicates if parking problems are more, then people will choose public Transport Mode or Private Vehicles.

With some assumptions we have found out Economical internal rate of return (EIRR) and Financial Internal rate of return (FIRR). We have skipped the calculation part of EIRR and FIRR and subsequently presented the calculated values in the coming sections, which will clear the comparative analysis between underground and elevated metro in terms of economics.

6. Economic Analysis

It is a well defined approach to determine the optimum use of scarce resources, involving comparison of two or more alternatives in achieving a specific desired objective under the given assumptions and constraints. It takes into account the opportunity costs of resources employed and attempts to measure in monetary terms the private and social costs and benefits of a project to the community or economy. With the following assumptions, EIRR values for Underground and Elevated Metro are calculated:

1. After operation of metro, shifting of buses, car, two-wheelers and auto are 30%, 40%, 50% and 40% respectively.
2. Assumptions of vehicle speed for calculation of Vehicle Operating Cost and Value of Time are given in Table 6.1

6.1 Vehicle Operating Cost

Vehicle Operating Costs (VOC) will be worked out under two scenarios namely "with" and "without" project condition. Under "without project condition", the VOC will be determined year by year, on the existing route with the given value of rise and fall, roughness, traffic volume and composition and the travel distance. Whereas under "with project" condition, VOC will be determined for the proposed route taking into account all the above road and traffic characteristics. VOC savings in "with project condition" will arise first, due to short distance and secondly, on account of less congestion [2].

Table 6.1- Average Speed for different Modes

	Construction Phase			Operation Phase		
Mode	**Without Metro**	**With Elevated Metreo**	**With Underground Metro**	**Without Metro**	**With Elevated Metro**	**With Underground Metro**
Buses	10	8	10	8	20	25
Cars	15	10	15	10	30	35
TW	15	10	15	10	30	35
Auto	15	10	15	10	30	35

Table 6.2- VOC (Rs./km)- Roughness = 3000mm/km (US $1 = Rs. 48.62) (Rs. 1 =US $ 0.02044)

	In 2003				In 2009			
Speed	**Buses**	**Cars**	**Two Wheelers**	**Auto**	**Buses**	**Cars**	**Two Wheelers**	**Auto**
8	29.27				41.52			
10	26.11	6.63	1.98	5.39	37.04	9.4	2.81	7.65
15	21.3	4.94	1.68	3.84	30.21	7.01	2.38	5.45
20	18.25	4.07	1.53	3.07	25.89	5.77	2.17	4.35
25	16	3.55	1.44	2.62	22.7	5.04	2.04	3.72
30	14.61	3.15	1.41	2.6	20.72	4.47	2	3.69
35	13.32	2.92	1.36	2.59	18.89	4.14	1.93	3.67
40	12.18	2.74	1.33	2.36	17.28	3.89	1.89	3.35
45	11.75	2.74	1.3	2.18	16.67	3.89	1.84	3.09
50	11.41	2.74	1.28	2.04	16.19	3.89	1.82	2.89

(Source: 2)

Table 6.2 showing the vehicle operating cost (VOC) per kilometre for different categories of vehicles under different speeds scenarios.

6.2 Value of Time

Money appreciates in value in course of time due to the interest it earns. This concept helps the analyst in reducing all future costs and benefits to a common date and thus evaluate on a common basis. The concept is thus the foundation on which the entire structure of economic analysis is built. Table 6.3 is showing the value of time for different modes, in which first column of VOT shows the VOT in Rs /US $ per hour per person and next column shows the VOT in Rs /US $ per hour per vehicle.

Table 6.3 Value of time for Different Modes (US $1 = Rs. 48.62) (Rs. 1 = US $ 0.02044)

Sr. No.	Modes	VOT(Rs./US$/hour/ person) in 2003	VOT(Rs./US$/hr./Vehicle) in 2003	VOT(Rs./US$/hour/person) in 2009	VOT(Rs/US$./hr./ Vehicle) in 2009
1	BUS	Rs.13.01 / $0.26	Rs.442.34 / $9.04	Rs.15.53/ $0.31	Rs.528.18/ $10.79
2	CAR	Rs.33.18 / $0.678	Rs.66.36 / $1.35	Rs.39.62 / $0.81	Rs.79.24 / $1.62
3	2 W	Rs.20.47 / $0.418	Rs.24.564 / $0.502	Rs.24.44 / $0.50	Rs.29.33 / $0.60
4	3 W	Rs.19.63 / $0.401	Rs.35.334 / $0.722	Rs.23.44 / $0.47	Rs.42.19 / $0.86

(Source: 2)

6.3 Accident Cost

As it is possible to predict the reduction in accidents on account of transport mode and road improvements, the accident cost values evolved from the earlier studies is used after updating using the ratio of the economic cost of different types of accidents and economic cost of vehicle damage. By considering 6 % inflation rate following values of accident are found out considering the base year values. Table 6.4 shows the cost of single accident under different conditions.

Table 6.4: Cost of single Accident (US $1 = Rs. 48.62) (Rs. 1 = $ 0.02044)

Year	Fatal	Serious	Slight
1990	Rs.210000 / $4319.2	Rs.32000 / $658.16	Rs.1100 / $22.62
2003	Rs.447915 / $9212.7	Rs.68254 / $1403.84	Rs.2346 / $48.253
2009	Rs.635376 / $13068.4	Rs.96820 / $1991.36	Rs.3328 / $68.45

(Source: 2@ 6% inflation rate)

6.4 Cost and Benefits gained by process of Land acquisition

Rate of land Acquisition - Rs.75000 Sq. Yard (US $ 1542.57 Sq. Yard)
Rs.90000 Sq. Meter (US $ 1851.12 Sq. Meter)

Table 6.5 – Cost of land acquisition (US $1 = Rs. 48.62) (Rs. 1 =US $ 0.02044)

Item	Length(m)	Width(m)	Area (sqm.)	Cost in Crore/ US $ million)
Station Area	6750	35	236250	Rs.2126.25 / $437.32
Route Excluding Station Area	26000	8	208000	Rs.1872/ $385.02
Total			444250	Rs.3998.25/ $822.34

Cost of land acquisition = Rs.3998.25 crore (US $ 822.34 million)

Assuming present status of station area having tenants

Rate of tenants rehabilitation = Rs.3900 / Sq m (US $ 80.21 / Sq m)

Cost of rehabilitation = Rs.48.75 million / Km (US $ 1.003 million/ km)

6.5 Description of the benefit and cost for underground metro

Description of economic benefits and costs of the Underground Metro requires the identification of the changes brought out by it in the transport sector of the economy. Most importantly, the diversion of current passenger traffic from road to Metro is not much. As a result, there will be a less reduction in the number of buses, passenger cars and other vehicles carrying passengers on roads with the introduction of the Metro. In Elevated Metro there will be reduction in capacity of roads from 3 lanes to 2 lanes. Capacity will remain same in case of Underground Metro. As per result congestion and pollution on road side will be less in Underground metro. Investment in the Underground Metro could result in the reduction on road user cost. There will be reductions in motor vehicles' operation and maintenance charges to both the government and the private sector. Following are the governing factor for recognizing the benefits and cost for underground metro.

Investment

- Investment of Metro
- Investment Cost of Road Infrastructure

Operation and Maintenance (O&M) Charges

- O & M charges of Metro
- O & M charges reduced due to Underground Metro due to decongestion
- Private buses

- Public buses
- Personal vehicles (cars and two-wheelers)

For all the above three categories underground metro pays an pivotal role in decreasing the operation and maintenance charges as the roads are decongested thus leading to decrease in vehicle operation cost.

Benefits

- Acquisition of Land
- Pulling Down the Structure
- Shifting of Utilities Services
- Reduction in Pollution and Health Expenditures
- Due to reduction in congestion on roads
- Savings in travel time
- Due to reduction in travel time for Metro passengers
- Reduction in accidents
- Savings in fuel cost

9. Social Cost Benefit Analysis

1. Experience for construction of mega projects at ground in highly congested areas shows that life almost becomes standstill a hell during the construction period. The vehicle operating cost mount extremely high due to barricading, existing road width up to 9 meters. This reduced road width leads to congestion.
2. The necessity or need for any mega transportation or infrastructure project is felt from urgent social mobility needs of the society.
3. The cost and benefits of different alternatives are calculated considering social cost benefit analysis.
4. Calculation of benefits is very difficult and challenging. That is the reason organizations often resort to only financial analysis, forgetting social needs or expectations of the people, particularly the residents in the influence area of the mega project.

5. As per the analysis – EIRR alone, during construction period of 5 years of Elevated metro a huge financial loss will be incurred as under:

   - As per the table 3.2 Elevated Metro reduces the width of Roads to over 30%. This will deteriorate traffic and congestion on roads.

- About 7000 sq. meter of footpaths are acquired to accommodate Elevated Station. Thus a vital link between vehicular traffic and private properties will endanger pedestrians.

- The massive structure of elevated metro shall change the skyline because it will be enforced over crowded arterial roads with virtually no open space. The impact will be the worst in terms of quality of life for several generations to follow.

6. As per the analysis under EIRR following Socio-economic cost will be incurred during the construction phase alone:
   Analysis specifies actual loss of amount, especially during construction period.

a)	Vehicle Operating Cost	Rs. 732.79 crores per anum
b)	Decongestion Cost	Rs. 41.40 crores per anum
c)	Passenger Time Cost	Rs. 507.98 crores per anum
d)	Pollution Cost	Rs. 129.71 crores per anum
e)	Accident Cost	Rs. 2.40 crores per anum

		Rs. 1414.28 crores per anum (US $ 290.8 million)
		======================

Thus for 5 years of construction duration, citizens will lose over Rs. 7,070 crores (US $ 1454.13 million) It is not clear who shall compensate this huge cost apart from inconvenience to entire suburb!

7. As per the analysis the overhead/maintenance cost will be comparatively higher for Elevated metro in 2021 and 2031 as under:

Table 9.1 Maintenance Cost (US $1 = Rs. 48.62)

MAINTANENCE COST		
	20 Km. Underground Metro in City	**32 Km. Elevated Metro in Suburbs**
2021	80.89 Crores($16.6 million) (4.04 Crores/km)($0.83 million/km)	188.00 Crores($38.6 million) (5.875 Crores/km)($1.2 million/km)
2031	131.76 Crores($27.1 million) (6.60 Crores/km.)(1.35 million/km)	307.0 crores($63.12 million) (9.60 Crores/Km.)($1.97 million/km)

8. Loss of integrated transport plan

- All options for optimizing and interconnection various modes of transport including BRTS are clipped forever.
- All options of wide footpaths and separating pedestrian lanes are lost forever.
- All options of cycling tracks connecting short distances to playgrounds, schools, markets, etc. are vanished forever.
- Elevated metro will be a huge liability to expand Metro rail itself in all future routes.

7. Saving Due to Underground Metro

In the highly congested corridors, the social benefits outweigh for the underground metro compared to the elevated metro. This is obvious on the account of very high direct and indirect cost savings of underground metro compared to elevated metro; we have also calculated the analysis for partially underground metro which is given in table7.1 and 7.2.

Table 7.1 Savings due to Underground Metro (US $1 = Rs. 48.62) (Rs. 1 =US $ 0.02044)

Sr No.	**Particular**	**EL Metro (Cost in Crores/US $ million)**	**UG Metro (Cost in Crores/US $ million)**	**Partially UG (Cost in Crores/US $ million)**
1	Estimated Cost	Rs.7438 / $1,527.77	Rs.19642 / $4039.9	Rs.12109/ $2490.54
2	Over all Saving			
	A) Saving During Construction Phase On account of VOC, VOT, Pollution etc.		Rs.10135/ $2084.53	Rs.5431/ $1117.03
	B) Saving During Operation Phase On account of VOC, VOT, Pollution etc.		7525/ $1547.7	5052/ $1039.08
3	**Total Savings**		**17,660.00 ($ 3627.36)**	10,483.00 ($ 2156.1)

*EL - Elevated Metro, *UG- Underground Metro

Table 7.2 Summary Table

Sr. No.	Particulars	**EL Metro (Cost in Crore/US $ million)**	**UG Metro (Cost in Crore/US $ million)**	**Partial UG (Cost in Crore/US $ million)**
1.	Construction Cost	Rs.7438/$1,527.77	Rs.19642/$4039.9	Rs.12,109/$2490.54
2.	EIRR	16.07%	**22.70%**	20.26%
3.	FIRR	10.41%	4.52%	7.07%

*EL - Elevated Metro, *UG- Underground Metro

8. SENSITIVITY ANALYSSIS

Sensitivity Analysis is a process of identification of changes in result with variation of different inputs.

Table 8.1 Sensitivity Analysis for FIRR

Sr.no.	Particulars	EL Metro	UG metro	Partial UG Metro
1.	Base Scenario	10.41%	4.52%	7.25%
2.	10% increase in Capital Cost	9.75%	4.02%	6.68%
3.	20% increase in Capital Cost	9.16%	3.57%	6.17%
4.	10% increase in O & M	10.17%	4.34%	7.05%
5.	10% decrease in O & M	10.64%	4.69%	7.45%
6.	10% decrease in Capital Cost	11.17%	5.09%	7.90%
7.	20% decrease in Capital Cost	12.06%	5.74%	8.66%
8.	10% increase in Revenue	11.38%	5.24%	8.08%
9.	10% decrease in Revenue	9.35%	3.72%	6.34%

*EL - Elevated Metro, *UG- Underground Metro

Table 8.2 Sensitivity Analysis for EIRR

Sr.no.	Particulars	EL Metro	UG metro	Partial UG Metro
1.	Base Scenario	16.07%	22.70%	20.26%
2.	10% increase in Capital Cost	14.94%	19.49%	17.74%
3.	20% increase in Capital Cost	13.95%	16.94%	15.80%
4.	10% increase in O & M	15.84%	22.86%	20.01%
5.	10% decrease in O & M	16.30%	23.22%	20.49%
6.	10% decrease in Capital Cost	17.38%	28.45%	23.69%
7.	20% decrease in Capital Cost	18.91%	38.41%	28.76%

*EL - Elevated Metro, *UG- Underground Metro

From the above table 8.1 & 8.2 of sensitivity analysis it can be seen that how the cost changes with respect to change in benefits and how it affects the EIRR of UG and Elevated.

10. Summery and Conclusion

The lack of comprehensive integrated transportation plan for the city and the suburbs is leading to conflicts between individual plans. A viability study for underground metro was never considered. Decision to pursue with Elevated metro is thus taken arbitrarily without any comparative evaluation. The Elevated metro plan for Mumbai's suburbs has no future expansion potential. This factor is detrimental to the planning and implementation of any public services, particularly for transportation. Underground metro will at any time have possibility of expansion with additional routes and directions thus having possibility of dealing with future needs and demands.

The people living in the suburbs are being clearly discriminated. Vehicular and Pedestrian accesses could be well dispersed around the open spaces. These open spaces would then act as effective interface between the metro and existing realities. In transforming Mumbai into a better city to live-in then an underground metro system is great option to implement. The underground metro will contribute positively to the quality of life in the city for several generations. In the highly congested corridors, the social benefits outweigh for the underground metro compared to the elevated metro. This is obvious on the account of very high direct and indirect cost savings of underground metro compared to elevated metro. And On the ground of constitutional right of equity and demand of utilizers, UG metro proves to be the best alternative over EL metro.

Additionally, the above discussion proves the economic viability of the underground metro with Economic Internal rate of return (EIIR) about 22.7% for underground metro and about 16.07% for elevated metro. The total saving only during construction phase is around Rs.176600 million (US $3,627.36 million). The estimated cost for elevated metro is Rs.74380 million (US $1,527.77 million) and that of underground metro is Rs.196420 million (US $4,034.47 million). For the social cost of 5 years of construction duration, citizens will lose over Rs.70700 million (US $1,452.18 million), which includes Vehicle Operating Cost, decongestion cost, passenger time cost, pollution cost and accident cost. Maintenance cost for 20 km Underground metro in 2021 will be Rs.808.9 million (US $16.61 million) (Rs.40.4 million/km; US $0.83 million/km) and that for 32 Km elevated metro will be 1880 million (US $38.61 million) (Rs.58.75 million/Km; US $1.2 million/Km).

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