Sustainability Assessment Considering Traffic Congestion Parameters in Nagpur City

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Abstract - *Metropolitan cities of developing nations are attempting execution of rail based transit systems, particularly metro rail, as an answer to problems of swiftly increasing travel demand and urban traffic congestion, keeping in view the target of sustainable development. Traffic congestion is mainly caused due to constantly increasing number of private vehicles, which in turn had primarily attributed for low level of service on roads. Traffic congestion causes social, environmental and economic effects. Therefore there is need to shift commuters from private & public transport on roads to rail based transit system. This paper compares present traffic situation considering parameters like Queue Length, LOS, Delay, Emission and Fuel Consumption with futuristic traffic condition after implementation of metro rail.*

Key Words: Traffic Congestion, Queue Length, Level of Service (LOS), Delay, Emissions, Fuel Consumption

1. INTRODUCTION

Many metropolitan cities are facing serious problems related to traffic congestion, road accidents & environmental pollution due to increasing traffic demand. These problems are more serious in cities of the developing countries. Traffic congestion leads to travel time delay, fuel consumption, environment & health problems and low speed traffic volume. The lack of public transportation facility is responsible for increasing private transportation system which ultimately causes traffic congestion. Many areas in Nagpur city still don't have proper access to Public Transportation System (PTS). Nagpur city faces traffic congestion problems mostly at different road intersections due to rapid infrastructure development & increasing population. This necessitates adopting strategy to debilitate private transit modes and support PTS once the traffic volume along any transit corridor in one way surpasses 8000 people per hour. Execution of rail based Mass Rapid Transit System (MRTS) becomes essential. MRTS provides vast benefits like lowering air pollution levels, travel time saving, accident reduction, traffic congestion reduction and fuel saving. Implementation of Nagpur Metro is aimed to increase use of PTS along with the decrease in usage of private transport and to directly or indirectly benefit people using transportation system.

2. LITERATURE REVIEW

Aditya Sohoni *et al.* (2017) investigated mode shifting behavior for Mumbai Metro. The investigation included drafting, executing and testing Revealed Preference (RP) & Stated Preference (SP) questionnaire surveys. The RP survey was performed on commuters commuting on newly functional east-west metro corridor, while SP survey was performed on commuters residing across the corridor of proposed additional metro. Sequential estimation method was adopted to estimate econometric mode choice model from combined RP & SP dataset.

Manfred Boltze *et al.* (2016) proposed sustainable traffic management approaches to cope with problems like traffic congestion, pollution & accidents in megacities of developing countries. The approaches proposed to address traffic problems are control transport demand, control modal choice, dynamic & situation responsive operation of transport infrastructure, intelligent transport systems, traffic safety, environmental impacts, sustainable financing of transportation system & good institutional framework for intermodal transport.

Vineet Chauhan *et al.* (2016) studied commuters mode choice behavior for Delhi PTS & found out causes for shift of commuters into metro transit system from buses and Private Motor Vehicles (PMV). In order to predict if existing metro commuters have switched from PMV or buses and to estimate mode usage of metro users before metro service commencement, binomial logistic regression model was developed. The cannibalization effect *i.e.* shift of travellers within same category of travel modes like public transport, considering shift from buses to metro was studied.

Niraj Sharma *et al.* (2014) converted the Delhi Metro ridership into equivalent numbers of road vehicles which would have been on road in absence of metro. This concept was used to assess vehicular emissions saved due to reduction in number of road vehicles along metro corridor. Also the sensitivity analysis for emission saved was done considering parameters like engine technology and type of fuel.

Yuanqing Wang *et al.* (2013) evaluated mode shift behavior due to commencement of metro system in Xian city in China. SP survey was performed along metro corridor before metro service commencement. The SP model was compared with RP survey conducted after starting of metro. For work & non-work trips logistic regression model was developed.

Tara Ramani *et al.* (2011) proposed a performance measurement based framework & evaluation methodology for sustainable transportation. This research identified performance measures like safety, congestion, environment to address objectives of sustainable transportation. The multi attribute utility theory decision making approach was applied to quantify & normalize the selected performance measures & calculate sustainability index values for current & future corridor conditions.

3. TRAFFIC VOLUME COUNT (TVC)

Classified Turning Volume Count (CTVC) survey was conducted during peak hour at three signalized intersections in Nagpur city. These intersection viz. Variety square (Location 1), Shankar Nagar square (Location 2) and Priyadarshini T point (Location 3) are on Nagpur Metro corridor.

Table 1: CTVC survey at Location 1

Direction	Motor Cycle	Auto	Car	LCV	Bus	Truck	Total (PCU/Hr)
S-N	733	1018	389	74	458	30	2702
W-E	0	0	0	0	0	0	0
NW-E	1049	501	408	97	76	0	2131
N-S	748	877	341	63	426	20	2475
E-W	1668	716	282	111	39	29	2845

Table 2: CTVC survey at Location 2

Direction	Motor Cycle	Auto	Car	LCV	Bus	Truck	Total (PCU/Hr)
S-N	1232	380	607	46	12	12	2289
W-E	805	315	401	15	48	24	1608
NW-E	794	271	352	38	36	12	1503
N-S	894	401	483	23	48	0	1849
E-W	1196	596	542	30	84	24	2472

Table 3: CTVC survey at Location 3

Direction	Motor Cycle	Auto	Car	LCV	Bus	Truck	Total (PCU/Hr)
W-E	1228	276	324	59	106	132	2125
E-W	1012	144	258	34	53	40	1541
S-N	891	132	276	42	27	0	1368

4. MODE SHIFT ANALYSIS

Nagpur Metro DPR is referred to calculate modal shift. Two conditions i.e. mode share of public & private vehicles before & after implementation of metro are compared for trip length of 6.43 km. From that percentage reduction in different modes after implementation of metro is calculated.

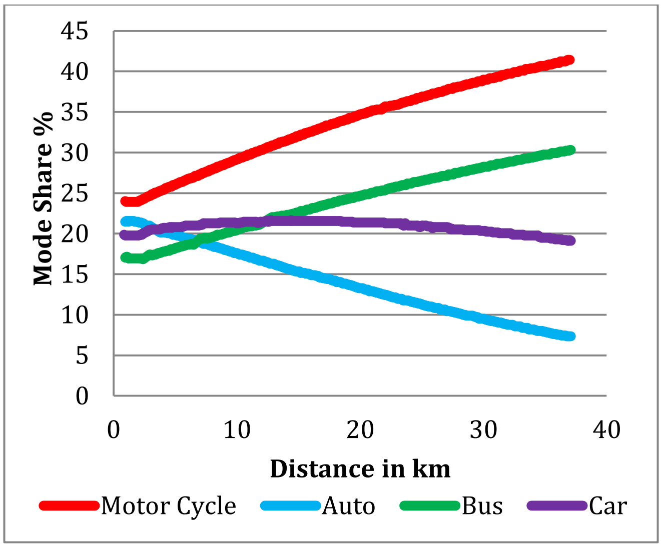

Fig 1: Distance wise Mode Share of Public & Private Vehicles before Metro

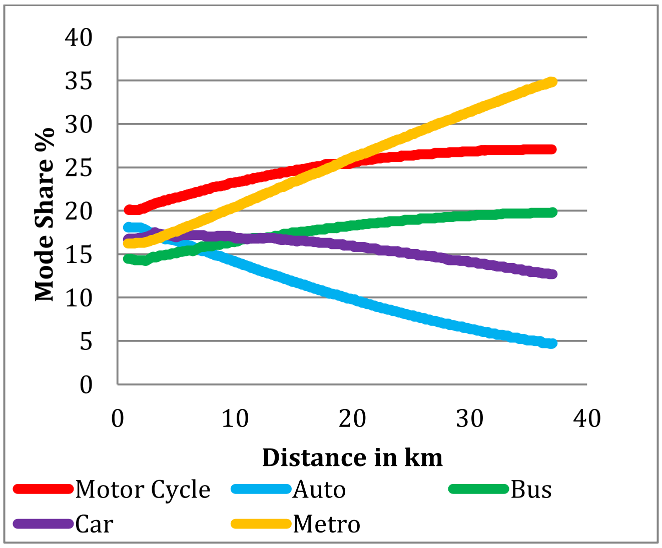

Fig 2: Distance wise Mode Share of Public & Private Vehicles after Metro

Table 4: Modal Shift

Modes	Reduction in Mode (%)
Motor Cycle	18.38
Auto	17.97
Bus	17.87
Car	18.39

The CTVC survey done at intersections for before metro condition is forecasted for after metro condition considering percentage reduction in different modes.

Table 5: Forecasted TVC at Location 1

Direction	Motor Cycle	Auto	Car	LCV	Bus	Truck	Total (PCU/Hr)
S-N	598	831	318	74	372	30	2223
W-E	0	0	0	0	0	0	0
NW-E	839	400	327	77	62	0	1705
N-S	608	717	280	63	346	19	2033
E-W	1360	586	234	111	32	29	2352

Table 6: Forecasted TVC at Location 2

Direction	Motor Cycle	Auto	Car	LCV	Bus	Truck	Total (PCU/Hr)
S-N	1003	310	496	46	10	12	1877
W-E	656	257	328	15	39	24	1319
NW-E	646	222	288	38	29	12	1235
N-S	729	328	394	23	39	0	1513
E-W	974	487	443	30	68	24	2026

Table 7: Forecasted TVC at Location 3

Direction	Motor Cycle	Auto	Car	LCV	Bus	Truck	Total (PCU/Hr)
W-E	1001	225	265	59	86	132	1768
E-W	824	71	211	34	42	40	1222
S-N	725	65	226	42	22	0	1080

Total traffic volume during peak hour at each intersection is calculated for before & after metro condition and represented as follows.

Table 8: Total Traffic Volume at intersections

Intersections	Traffic Before Metro (PCU/Hr)	Traffic After Metro (PCU/Hr)	Reduction in Traffic (%)
Location 1	10153	8313	18.12
Location 2	9721	7970	18.01
Location 3	5034	4070	19.15

On an average reduction in total traffic volume at different intersections on metro corridor is between 18-19 %.

5. PTV VISSIM MODELING & SIMULATION

PTV Vissim software is used to assess present traffic condition and futuristic traffic condition. Models of three intersections are prepared in software and simulation is done for 600 seconds. For each intersection two conditions are considered viz. before metro and after metro. The CTVC survey traffic data is considered in as vehicle input for before metro condition and forecasted TVC is considered as vehicle input for after metro condition. The signal timing at intersections is kept same for both conditions.

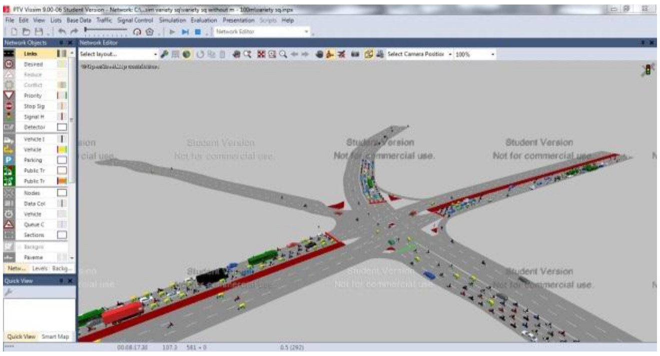

Fig 3: Traffic condition before Metro at Location 1

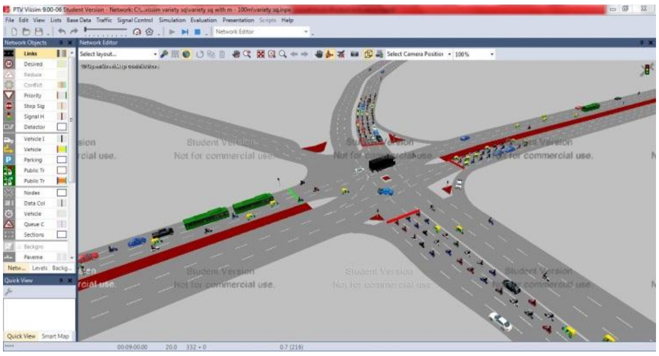

Fig 4: Traffic condition after Metro at Location 1

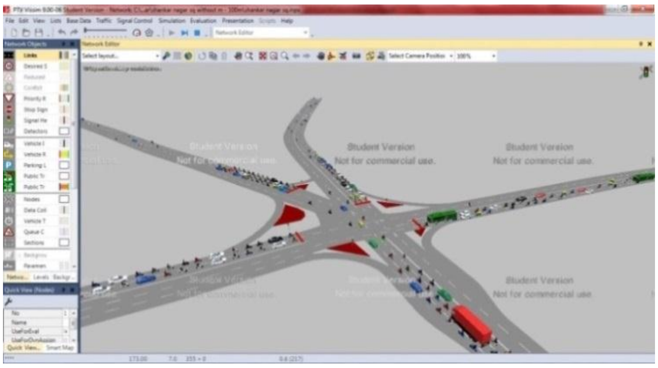

Fig 5: Traffic condition before Metro at Location 2

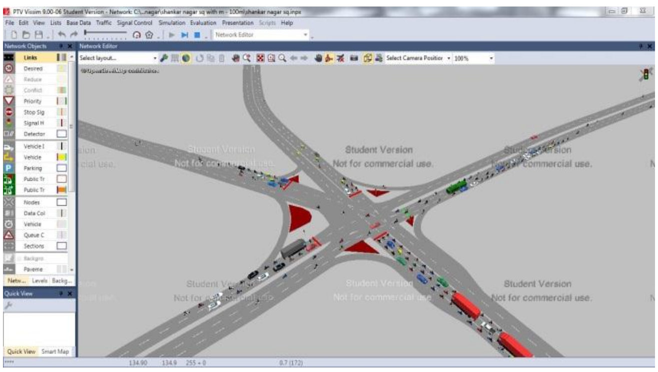

Fig 6: Traffic condition after Metro at Location 2

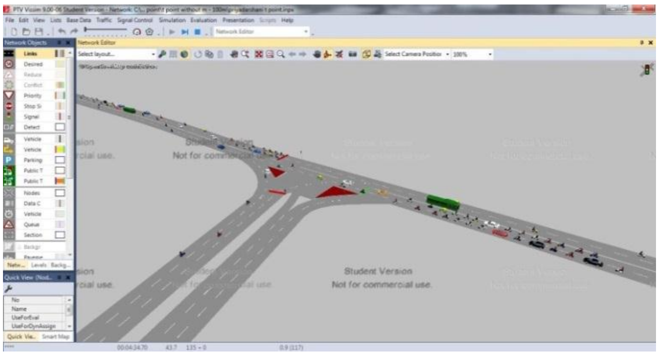

Fig 7: Traffic condition before Metro at Location 3

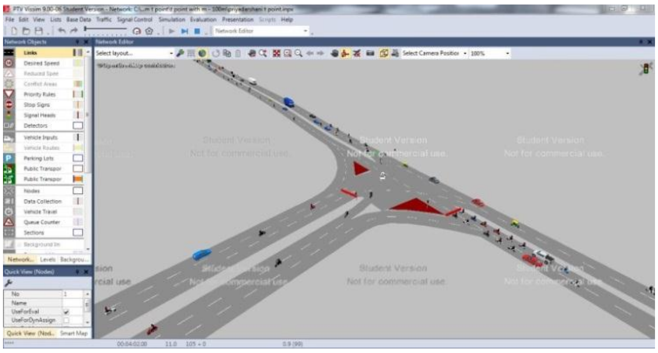

Fig 8: Traffic condition after Metro at Location 3

6. RESULT

Table 9: Traffic parameters at Location 1

	Queue Length	Maximum Queue Length	LOS	Vehicle Delay	Stop Delay
Units	meter	meter		sec/veh	sec/veh
Before Metro	123.14	406.49	F	93.36	74.48
After Metro	71.21	309.60	E	61.69	50.47

Table 10: Environmental parameters at Location 1

	Emissions CO	Emission NOX	Emission VOC	Fuel Consumption
Units	grams	grams	grams	liters
Before Metro	3434.90	668.31	796.07	185.99
After Metro	2263.85	440.46	524.67	122.58

Queue Length of vehicles at intersection reduced from 123.14 m to 71.21 m i.e. by 42.17 %. Maximum Queue Length of vehicles reduced from 406.49 m to 309.60 i.e. by 23.84 %. Improvement in Level of Service from LOS F to LOS E. Total Delay of vehicles reduced from 167.84 sec/veh to 112.16 sec/veh i.e. by 33.17 %. Total Vehicular Emission reduced from 4899.27 gms to 3228.98 gms i.e. by 34.09 %. Fuel Consumption reduced from 185.99 lts to 122.58 lts i.e. by 34.09 %.

Table 11: Traffic parameters at Location 2

	Queue Length	Maximum Queue Length	LOS	Vehicle Delay	Stop Delay
Units	meter	meter		sec/veh	sec/veh
Before Metro	156.52	498.84	F	144.57	127.48
After Metro	103.97	344.12	F	127.88	112.59

Table 12: Environmental parameters at Location 2

	Emissions CO	Emission NOX	Emission VOC	Fuel Consumption
Units	grams	grams	grams	liters
Before Metro	2815.37	547.77	652.49	152.45
After Metro	2517.48	489.81	583.45	136.32

Queue Length of vehicles at intersection reduced from 156.52 m to 103.97 m i.e. by 33.57 %. Maximum Queue Length of vehicles reduced from 498.84 m to 344.12 i.e. by 31.02 %. Total Delay of vehicles reduced from 272.05 sec/veh to 240.47 sec/veh i.e. by 11.61 %. Total Vehicular Emission reduced from 4015.62 gms to 3590.75 gms i.e. by 10.58 %. Fuel Consumption reduced from 152.45 lts to 136.32 lts i.e. by 10.58 %.

Table 13: Traffic parameters at Location 3

	Queue Length	Maximum Queue Length	LOS	Vehicle Delay	Stop Delay
Units	meter	meter		sec/veh	sec/veh
Before Metro	71.62	314.75	D	40.25	28.07
After Metro	19.67	123.66	C	20.80	14.21

Table 14: Environmental parameters at Location 3

	Emissions CO	Emission NOX	Emission VOC	Fuel Consumption
Units	grams	grams	grams	liters
Before Metro	1294.79	251.92	300.08	70.11
After Metro	756.04	147.10	175.22	40.94

Queue Length of vehicles at intersection reduced from 71.62 m to 19.67 m i.e. by 72.54 %. Maximum Queue Length of vehicles reduced from 314.75 m to 123.66 i.e. by 60.71 %. Improvement in Level of Service from LOS D to LOS C. Total Delay of vehicles reduced from 68.32 sec/veh to 35.01 sec/veh i.e. by 48.76 %. Total Vehicular Emission reduced from 1846.79 gms to 1078.36 gms i.e. by 41.61 %. Fuel Consumption reduced from 70.11 lts to 40.94 lts i.e. by 41.61 %.

The three intersections are compared with each other based on different parameters.

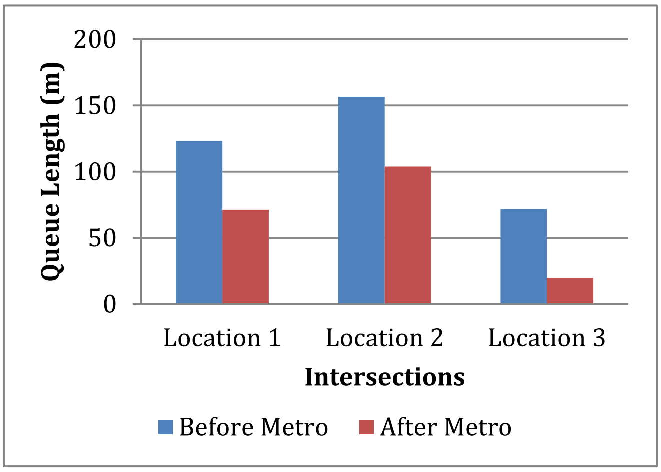

Fig 9: Queue Length

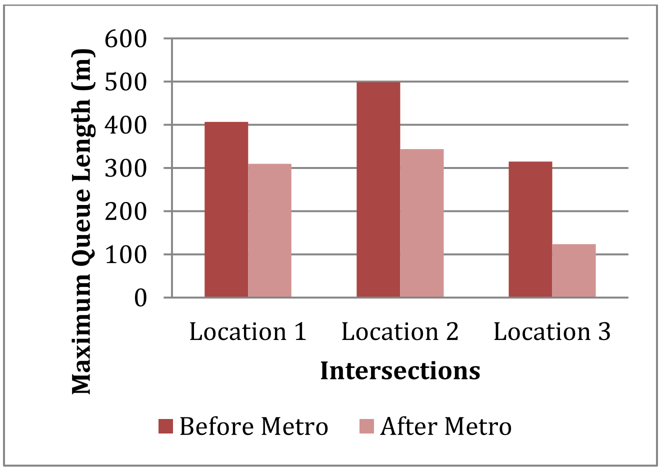

Fig 10: Maximum Queue Length

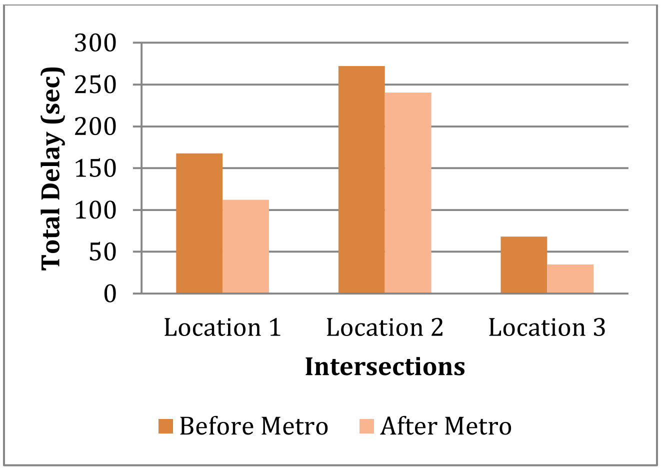

Fig 11: Total Delay

Fig 12: Total Vehicular Emission

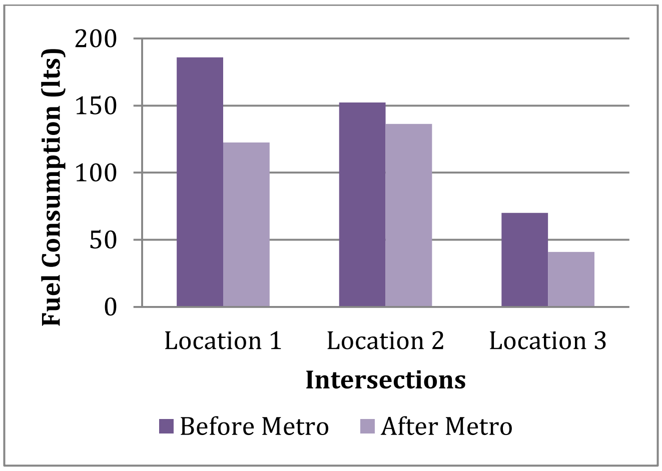

Fig 13: Fuel Consumption

7. CONCLUSION

As per CMP service level bench-marks to assess performance of PTS in Nagpur city are availability and service coverage of organized PTS, average waiting time and level of comfort for PTS users & fleet size of public transport. Report concluded that PTS in city is very poor and requires considerable improvements. Nagpur Metro will considerably improve level of service of PTS in city.

From results it can be stated that Metro Rail system will be very beneficial in reducing traffic congestion on roads. It will reduce the queue length formation at intersections. It will reduce vehicle delay and stop delay. It will reduce the vehicular emissions like Carbon Monoxide, Nitrogen Oxides & Volatile Organic Compounds. It will reduce fuel consumption of road vehicles.

In addition Nagpur Metro has planned to cover 65% of electrical energy requirement using solar power. This will be the added advantage for the metro rail system as it will result in low carbon footprint & will be environment friendly which will be the attempt to move the transportation system towards sustainability.

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