

Sustainability Assessment; Considering Metro Rail Transit System for Nagpur City

Lokesh Mehta¹, Sujesh Ghodmare²

*M. Tech Scholar Civil Engineering Department,
G.H. Rasoni College of Engineering, Nagpur
Assistant Professor, Civil Engineering Department,
G.H. Rasoni College of Engineering, Nagpur*

Abstract – Traffic congestion, delays, accidents, pollution due to traffic are the current main problems all over the world. While in county's like India where traffic is heterogeneous, this problem seems to have more impact due more number of vehicles. While currently due to modern technology there are so many hi-tech solutions which can be used to solve these problems. But in India due to less availability of technique, less knowledge, not so modern transportation systems, and much large number of different vehicles it is difficult to apply those hi-tech solution fast and all over India. In this work MRTS (metro rail transit system) is considered for the sustainability assessment of the Nagpur city considering the METRO as ITS parameter. The main objective of this research work is to evaluate the sustainable transportation for emerging Metropolitan Cities by developing the approach based on performance and measurement. The work is done for current as well as future scenario so that the assessment can be done for both cases. The assessment is done by using tool excel sheet which is easy to use, handle and understand. The final results are compared with each other for base case and future case scenario. The measurements are done for the links first and then applied to complete section. For the study the route covered by the Nagpur metro is considered. Also to is tried to collect the best goals and performance indicators which cover all aspect and for this the transportation authentic persons are also contacted. That is in this work it is tried to assess the sustainability of the metropolitan city by making the framework of the performance measures which are based on the sustainability goals using the MAUT method for current scenario and for base and future case so that they can be compared and for all this work the MRTS system is considered as a ITS parameter.

Keywords- Sustainability, ITS

I- INTRODUCTION

In general sustainable transportation is defined as the development which fulfills the requirement of present without compromising the needs and requirements of future generations. In view of impacts of economical, environmental and social equity on transportation system this issue of sustainable transportation is of great importance. The main aim of the project is to find the parameters assess them in a framework which gives sustainability of the metropolitan city for any given scenario based on the transportation parameters, society, environmental aspects and economy.

Sustainability

Different authors have provided variety of definitions for sustainable development and transportation. Mostly definition proposed by the Brundtland Commission as “sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs” is adopted by many for reference. Sustainability pertains to the recognition and evaluation of system along with attempted mitigation of long-term impacts of human related developmental activity Nemtanu and Schlingensiepen (2017). The performance parameters are identified properly as they are used to make framework for sustainability assessment.

MRTS as a ITS parameter

On traffic problems conventional solutions are not useful hence, a long term solution based on computer programs and electrical and electronics use which is able to handle large amount of traffic without much space and economy. It can be done by using ITS (Intelligent Transportation System). Here Metro Rail Transit System (MRTS) is considered as the medium which represents ITS and hence its impact on existing transportation is tried to evaluate to attain the sustainability for existing base case and for future scenario Manikonda et al. (2011).

II- SCOPE OF WORK

As stated earlier in India more than 50 metro works are ongoing or completed. Also the current trend suggests that the accidents, number of vehicles, congestion increasing rapidly. But many conventional methods are available and metro requires large amount of economy for construction and maintenance, hence it is a general question to arise that is metro essential and is metro sustainable considering safety, congestion, efficiency, economy and environment. To cover all these questions and to make a framework so that sustainability of any metropolitan city can be found out by this framework the scope of the project is restricted to metropolitan city. Also the assessment and framework calculation are included in the scope of the project Ramani et al. (2012). The broad study and literature review has done for the sustainability, sustainability goals, performance measures, and their limitations in order to develop the framework for the metropolitan city.

The objectives of the work can be described as follows:

1. Development of goals for sustainability assessment
2. Development of performance measures and indicators for sustainability assessment
3. Development of framework with tool for sustainability assessment
4. Assessment of sustainability for metropolitan city (Nagpur).

III-LITERATURE REVIEW

For the detail study and to apply the best method with the performance indicators consisting maximum available goals the literature review is focused on the finding of method, performance measurements and framework of sustainability assessment. The three major parts are included in this chapter which covers importance of Intelligent Transportation System, Sustainable Transportation System and Development of

Performance Measures to satisfy the needs of the transportation system Marinov (2017). In literature review it was tried to cover basic concept related to work.

Sustainable Transportation System

The term “sustainable development” was first used as world conservation strategy in 1980. Now a day it has got global prominence due to which it has got the theme of global mission as noted in key note in United Nations Conferences held in 1992 and 2002. Different authors have provided variety of definitions for sustainable development and transportation Marinov (2017). Mostly definition proposed by the Brundtland Commission as “sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs” is adopted by many for reference. Sustainability pertains to the recognition and evaluation of system along with attempted mitigation of long-term impacts of human related developmental activity

IV-SUSTAINABILITY PERFORMANCE MEASURES

It is necessary to identify the best and correct measures for the sustainability assessment as they are used to develop the framework for the sustainability assessment. There are many different performance measures are available for the transportation sustainability assessment but as each type of transportation and sustainability goal requires different measures and hence it is necessary to select the appropriate performance measures. The discussion regarding the selected indicators is as follows:

Goal -1- Congestion Reduction

It is related to reduce the congestion of the road and reduce the required time for the movement of the traffic. The goal is also helps to reduce the fuel consumption, journey time, gas emission etc. hence following indicators are considered for this goal.

Travel Time Index- (TTI)

it is defined as the time required to travel the distance due to congestion. It is the ratio of peak period travel time to off peak period travel time along the stretch.

Program Time Index or Buffer Index - (PTI)

It represents the extra time required to travel the distance with the current traffic than the time required to travel the distance with free flow speed. It specifically reflects the extents to which 95th percentile of travel time

exceeds the mean travel time for the stretch under consideration.

Goal-2- Safety Enhancement

This goal is focused on the safety of the traffic as well as the pedestrians. The goal mainly focuses on the severe accidents and the advance technologies for the surveillance so that all the section of road are covered for any emergency.

Annual Severe Crashes per Kilometer

It represents the crashes occurring on the link throughout the year. For the purpose the prediction model is used and the procedure outlined in Interim Roadway Safety Design Workbook is adopted. The frequency on annual basis is defined as the fatal crashes resulting in the injuries by using the prediction model.

Percentage Lane-Kilometers under TMC Surveillance

This indicates the estimates of presence of Intelligent Transportation System provisions for traffic monitoring and response facilities to cover along the section operated by a Traffic Monitoring Center.

Goal-3-Expansion of Economic Opportunity

For any link to improve economic opportunity means to improve the chances for the travel through the link, covering all types of buildings. It can be done by using land use balance across the link and improving truck movement on the link. Hence following parameters are considered for this goal.

Land Use Balance

Land use balance means the proportion of land used by the type of building across the link. The more equally the link cover the all type of building the more will be the chance of movement of traffic through the link..

Truck Throughput Efficiency

The Truck volumes along the selected section in combination with the travels speeds are reflected by this indicator. Freight movement is an important economic benefit of transportation system and this objective in this work is include to enhance freight throughput without affecting the system performance

Goal-4-Enhancing the Value of Transportation Infrastructure

The impact of declining revenue collection from tax which tends to reduce on the existing corridor is tried to relate through this goal. The existing infrastructure is considered to be maintained while it is focused on collection of maximum funding from the all possible and available sources attached with the proposed MRTS system. This performance indicator tries to define by considering the improvement and maintenance of the existing infrastructure system

Goal-5:- Air Quality Improvement

it represents the decrease in emission of the gases into environment and improving the air quality. The gases like CO, CO₂, NO_x, volatile gases are considered as they contribute in major proportion. The national air quality standards and the motor vehicle emission regulation acts as the reference document for achieving those standards.

Multi-Criteria Decision-Making Process and Its Applications

Sustainability evaluation requires a broader methodology capable of covering the issues related to social equity, safety along with environment. It is necessary that the performance measures defined for the attributes selected should be properly addressed. The various approaches to decision-making in the transportation context were broadly discussed by Meyer and Miller (2015). The most common decision making approach which aims for maximizing utility based on a set of predefined evaluation criteria operation related issues in decision-making would depend on the use of performance indicators in a (MCDM) multi-criteria decision-making process and is called "rational actor".

The multi attribute utility theory (MAUT) was found to effective, safe and useful for sustainability assessment. For any method, performance indicator future economic feasibility in planning process is considered. The goals identifies are shown in table.

V- METHODOLOGY

Site Selection

As in the study of sustainability assessment, MRTS is considered as ITS parameter and Nagpur is becoming a metropolitan city. It is much easier to select the site align with the metro. The Nagpur also under going from the problems like transportation planning failure, high traffic, low speed in city, accidents, congestion etc. The increase in traffic vehicle can be seen from the following table 3.1. The conventional development is not possible

in Nagpur for maximum sections and Nagpur has some advanced technologies which are useful for the study. Hence Nagpur metro is taken into the consideration. The section is divided into six small links and for each link the performance indicators are evaluated and they are collectively evaluated for the section.

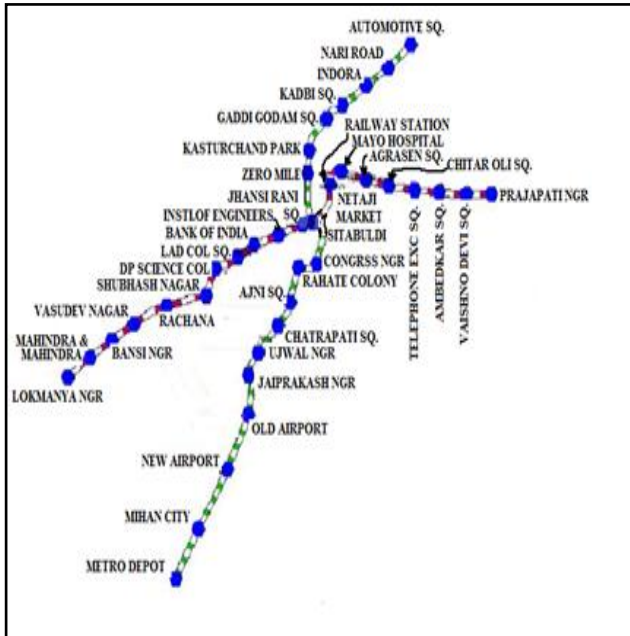


Fig. 1 Proposed Alignment for Nagpur Metro Rail Transit System selected for analysis (Source- DPR, NMRTS, 2013)

LINKING SUSTAINABILITY WITH THE TRANSPORTATION SYSTEM

Major challenge is to select the performance indicators as they must have the connectivity with scope of project. As a part of this the set of objectives was finalized for each goal and was linked with the measurable indicator so as to use it for the evaluation of sustainability. fig. 3.2 shows the flow chare for sustainability assessment using MAUT. It was also tried to define performance indicators related to objective finalized and table 2 shows goals and related objectives for sustainability.

Table 1 Sustainability-Related Objectives associated with Transportation Planning

Strategic Goal	Objective for Sustainability
Congestion Reduction	Improving mobility
	Improving reliability
Enhancement of Safety	Minimize severe crash rates
	Improvement in traffic incident detection and response to it
Expansion of Economic Opportunity	Land use optimization
	Improving freight movement
Enhancement of Transportation Assets	Maintain existing quality of the system
	Minimize cost and impact of capacity expansion
	Generate the non-conventional funding sources
	Minimize use of single-occupant Vehicle (SOV) travel
Air Quality Improvement	Reduce adverse impacts on human health
	Decreasing emission of green g house gases
	Standard emissions to be conformed

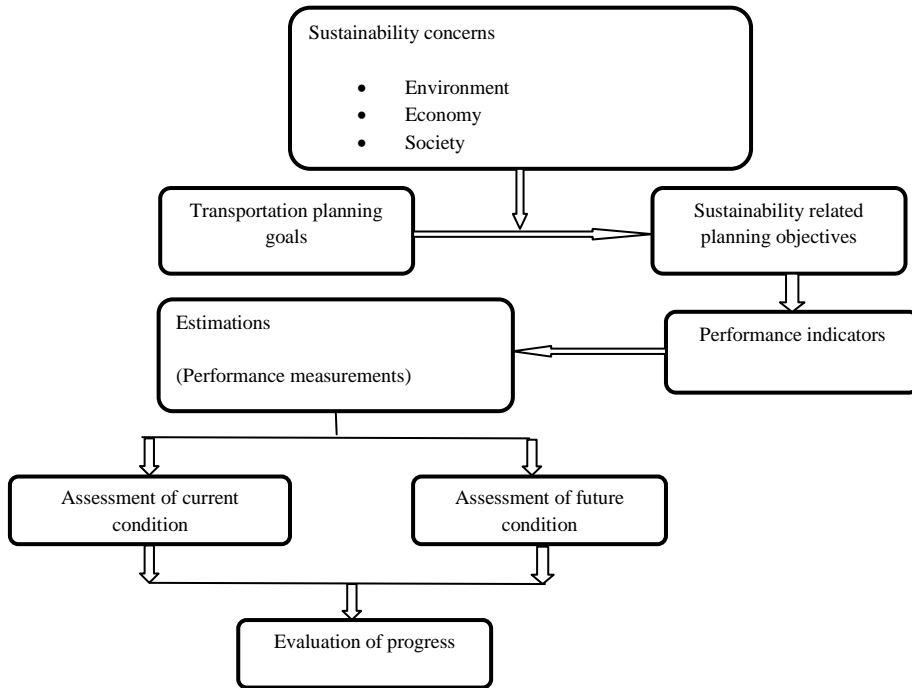


Fig. 2 Flow chart for Sustainability assessment using MAUT

MULTI CRITERIA DECISION MAKING PROCESS

In case of decision making problems it becomes necessary to conform the linking of performance measures to goals and objectives. Here it is to be noted that the multi criteria decision making is utilized as application and not as replacement to the final decision making process. The selected goals and performance measures are quantifies and their best and worst values

are evaluated. The scaling is done in the scale of 0 to 1 as to compare all the parameter into single output and use them for further calculations. Here it is also tried to calculate and select these limiting values which can be utilized for the purpose of scaling. Table 3.4 shows performance indicators with their extreme values.

Table Error! No text of specified style in document. Data Elements for Performance Measures with Extreme Values and Utility Scaling

Data Elements for Performance Measures with Extreme Values and Utility Scaling						
Sr.No.	Performance Indicators	Data Element Required for Quantification	Unit	Extreme Value		Type of Utility Scaling
				Best	Worst	
1	Travel Time Index	Daily Volume(ADT)	Dimensionless	1.00	6.00	Linear Scaling
		Number of Lanes				
		Speed Limit				
2	Planning Time indx	Travel Time Index	Percentage	1.00	5.00	Linear Scaling
3	Annual Severe	Roadway Type	Sever crashes	Depends	on	Linear Scaling

	Crash per Km	Daily Volume(ADT)	per Km per year	Roadway type and number of lanes		
		Geometrics		For urban streets 0 is best and 20 is worst		
4	Percentage lane-Km under TMC surveillance	Weather individual link is monitored by a TMC	Percentage of total lane-Km	100.00	0	Measure represents utility value
5	Land use balance	Area allocated to different land use	Dimensionless	1.00	0	Measure represents utility value
		Classification in zone half mile on either sides of stretch under consideration				
6	Truck Through put efficiency	Truck Percentage	Truck-Km per hour per lane	188000	4750	Linear Scaling
		Daily Traffic Volume				
		Number of Lanes				
7	Pavement Condition score	Score from Authorities	Dimensionless	100.00	0	Measure represents utility value
8	Capacity addition within Row	Number of Lanes that can be added to a link within available row	Number of lanes	1.00	0	Measure represents utility value
9	Cost Recovery from alternative sources	Project Capital Cost and Sources	Dimensionless	1	0	Measure represents utility value
		Annual operating and maintenance cost and sources				
10	Daily Nox, CO and VOC emissions in gram per mile	Emission Rates	Gram per Km per day	107200	4250	Linear Scaling
		Peak and off-peak volume				
		Operating Speed				
11	Daily CO2 emission in grams per mile	Emission Rates	Gram per mile per day	10400000	475000	Linear Scaling
		Peak and off-peak volume				
		Operating Speed				

WEIGHTING AND SCALING PROCEDURE FOR PERFORMANCE INDICATORS

The performance indicators are weighted in order to obtain the value of sustainability of the link. The

weightage is given in such a form that the more important goal and performance indicator keeps more weightage and according to that sustainability is calculated. The table 3.4 shows the weightage percentage

Table 4 Weightage Percentage of Goals for Sustainability

Sr. No	Goal	Measures	Measure Weight (%)	Goal Weight (%)
1	Reduce congestion	Travel Time Index	60	
		Planning Time Index	40	25
2	Enhance safety	Annual severe crash	80	
		% Lane Km under TMC	20	30
3	Expand economic opportunity	Land use balance	50	
		Truck throughput efficiency	50	10
4	Increase value of transportation assets	Average pavement condition	30	
		Capacity addition within row	30	
		Cost recovery	40	10
5	Improve air quality	Daily NO _x , CO, VOC emission'	80	
		Daily CO ₂ , emission	20	25

AREA UNDER CONSIDERATION

The metro construction work in Nagpur is started in 2013 and in 2019 the metro is started for trips. It consists

of two corridors as discussed earlier chapters, and the section from automotive to zero mile is taken into consideration and the section is divided into six links. Total Length of Stretch- 6.15 Km it is shown in table 4.1 and fig. 4.1.

Table 5 Site selection and Traffic data required at initial stage

Link	From	To	Length (Km)	peak hour volume 2016	average daily traffic 2016	% vehicle during peak	Number of Lanes
1	Automotive	Nari Road	0.9758	1882	23357	8.06	4
2	Nari Road	Indora Chowk	1.1639	2037	20176	10.10	4
3	Indora Chowk	Kadbi Chowk	1.0415	1953	19723	9.90	4
4	Kadbi Chowk	Gaddigodam	1.2178	1764	19205	9.19	4
5	Gaddigodam	Kasturchand	0.7496	1832	22789	8.04	4
6	Kasturchand	Zero Miles	1.0269	2126	25411	8.37	4

The data is then converted for the other cases that are for future cases. For future case, year 2021, 2026, 2031 and 2036 are considered with and without metro. The data relevant to the specific years under consideration were

entered as input for the purpose of analysis. Though the data for future case calculations are based on predictions the suitable assumptions and considerations were made relevant to the existing traffic situations.

VI-CALCULATION AND RESULTS

The each parameter is calculated for year 2016, 2021, 2026, 2031 and 2036. The parameters are calculated for with MRTS and without MRTS. The parameters are the

plotted against each other for results in form of graphs. The parameters are then converted into goals so as to find the sustainability of the city for each year. The final calculation of the goal wise sustainability is shown in table 6 for scaled value.

Table 6: Final sustainability goal wise

GOAL	MEASURES	SCALED VALUES FOR 2016	MEASURE WEIGHT (%)	FINAL WEIGHT	BASE CASE GOAL VALUE	GOAL WEIGHT %	GOAL WISE VALUE	OVERALL GOAL
1.REDUCE CONGESTION	TRAVEL TIME INDEX	0.65	60	0.39	0.63	25	0	0.57
	PLANNING TIME INDEX	0.60	40	0.24			0.16	
2.ENHANCE SAFETY	ANNUAL SEVERE CRASHES	0.45	80	0.36	0.49	30	0	
	% LANE KM UNDER TMC	0.65	20	0.13			0.15	
3.EXPAND ECONOMIC OPPORTUNITY	LAND USE BALANCE	0.87	50	0.43	0.45	10	0	
	TRUCK THROUGHPUT EFFICIENCY	0.03	50	0.02			0.04	
4.INCREASE VALUE OF TRANSPORTATION ASSETS	AVERAGE PAVEMENT CONDITION	0.59	30	0.18	0.28	10	0	
	CAPACITY ADDITION WITHIN ROW	0.33	30	0.10			0.03	
	COST RECOVERY	0.00	40	0.00				
5. IMPROVE AIR QUALITY	DAILY Nox, CO, VOC EMISSION'	0.75	80	0.60	0.76	25	0	
	DAILY CO2, EMISSION	0.78	20	0.16			0.19	

If we compare the goal-wise attainment for the situation with MRTS and without MRTS it can be stated that the values obtained for all goal taken into consideration are

favorable as far as the sustainability is concerned. It must be noted that the without MRTS situation at the same time would have been so drastic in terms of

sustainability which is predicted by the attainment value of about 28% for without MRTS situation in predicted year 2036. Similar trend is also reflected from results of years 2016, 2021, 2026 and 2031 also. If without MRTS situation is taken into consideration for future years the condition in terms of sustainability will become very drastic and worst without MRTS. The impact of all transportation related problems will take the severe mode causing the damages to three pillars of sustainability related to social, economical and

environmental issues. The results conforms that if any proper rapid transit system is implemented by authorities the results depends on its implementation. If the result of with MRTS and without MRTS are compare as shown in above graph the difference of 6%, 15%, 22% and 25% is reflected in terms of the scaled values. This indicated that the implementation of MRTS as the parameter of ITS will be very mush favorable in terms of sustainability of transportation system in any emerging Metropolitan city.

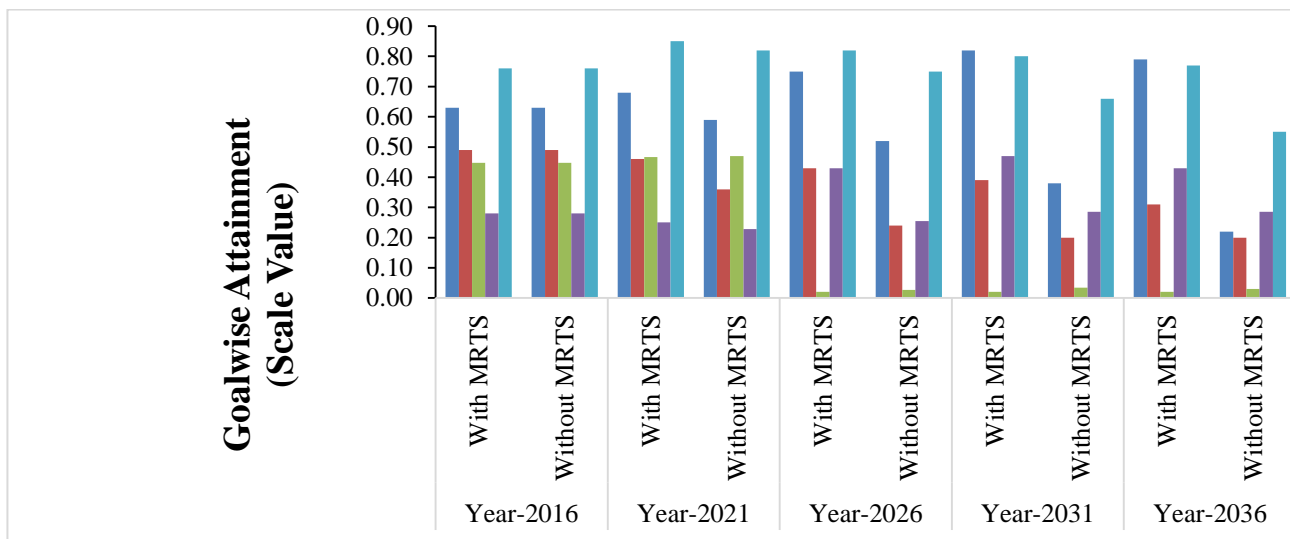


Fig. 3 Graphical Representation of Results for Goal-wise Comparison of attainment for Base and Future Case (With MRTS and Without MRTS)

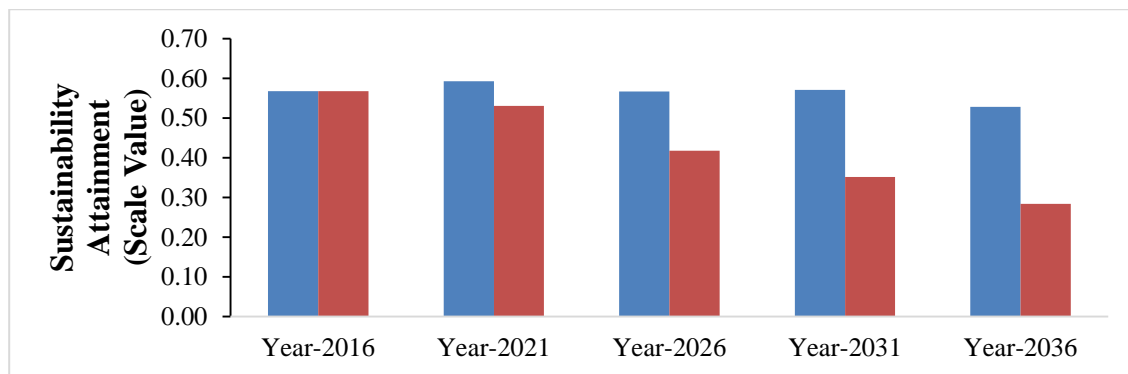


Fig. 4 Graphical Representation of Results for Sustainability Attainment for Base and Future Case (With MRTS and Without MRTS)

Thus the overall sustainability can be assessed along any section for any locality with similar traffic condition by using the tool developed in this work.

VI-CONCLUSION

This assessment framework can be used for the comparative type of analysis for the assessment of the

transportation system to suggest the modification and improvement and to formulate the planning strategies. Hence it can be stated that the overall results with MRTS as a parameter representing Intelligent Transportation System are favorable as far as attainment of the sustainability is concerned.

Following conclusions are made using the results:

From calculations and graphs it can be observed that the sustainability of the Nagpur city will be increase by the introduction of metro.

It can be stated that the overall results with MRT's as a parameter representing Intelligent Transportation System are favorable as far as attainment of the sustainability is concerned.

The framework can be used to evaluate sustainability of any section with basic traffic data.

Graphs also shows that the values for sustainability

The framework can be used for any city for the calculation of its sustainability.

FUTURE SCOPE

The above results and conclusion are showing that the construction of metro is needed in Nagpur. Also it has very good impact on transportation system of Nagpur for better improvement. This work includes only some parameters which are considered for sustainability evaluation. But there are so many other parameters available for the same and can be used.

The following points can be considered for the future work

The more goals can be considered for assessment of the sustainability

The other parameters based on some social, environmental, economical, safety, efficiency can be used for sustainability assessment

The other MCDM methods can be used to make framework

The transportation software based framework can be used for sustainability.

A single framework based on software can be made so as to implement the sustainability for any city across the India.

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