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Sustainable Urban Transport Policies to Improve Public Transportation System: A Case Study of Bengaluru, India

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Abstract

Bengaluru, the Silicon Valley of India and one of the fastest growing metropolitan city in India today is suffering from a severe issue of traffic congestion over last few years. The exponential growth of vehicles and population has resulted in uncontrolled emissions. The bus services by Bengaluru Metropolitan Transport Corporation (BMTC), which is still the backbone of city's public transit, is suffering from losses from last few years. For a city like Bengaluru, sustainable urban transit is a must and it can be achieved in the quickest and the least costly way by improving the ridership of existing public transport as a result of mode switch from private to public transport. This can be done by promoting the use of buses and discouraging the use of private vehicles simultaneously through various policies. This paper discusses about the few of those policies that can be implemented in order improve the ridership of BMTC and proves with the detailed analysis that such policies can result in reducing the overall vehicular emission in the city and hence improving the sustainability. The paper shows that policies as simple as restructuring of bus fare can impact the ridership significantly and will prove to be the paths of moving towards livable Bengaluru.

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1. Introduction

The capital of state of Karnataka, Bengaluru, which was once famous for its pleasant weather and gardens, is now known as an IT hub of India. Due to many IT firms established in the outskirts of the city, Bengaluru has attracted a huge employment from all over India in last two decades resulting in the exponential growth of population. As a result of increasing human and vehicular population, the climatic conditions of Bengaluru and surrounding area are depleting day by day due to excess vehicular emission. With most important metro lines of phase 2, yet to start and complete their constructions, the most dominant public transport mode in Bengaluru is still BMTC buses. Bengaluru Metropolitan Transport Corporation (BMTC) is currently the largest city bus service in India with the fleet size of more than 6500 buses plying the total of 1.15 Million kilometres of service through 45 depots acquiring the traffic revenue of about INR 50 Million a day. BMTC serves extensively in the area under Bruhat Bengaluru Mahanagara

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Palike (BBMP) and also serves to far off suburbs of Magadi, Nelamangla, Dodaballapur, Hoskote, Bidadi, Attibele etc. Though BMTC has been the only profit making public bus transport system in India for decades, the corporation has faced severe losses over the last few years due to stagnated growth of ridership and increasing fuel prices at the same time. The residents of Bengaluru are shifting to private vehicles due to rapid growth in the overall GDP of the city, as a result of which the environmental conditions are being drastically affected. In 2016, Bengaluru reached the record temperature of 39.2°C while the average summer temperature of the place is 33°C. The greenhouse gases which are known to warm the Earth are thrown into the atmosphere majorly due to the vehicular emission. As a result of excess NO_x and CO_x emission, the air quality of Bengaluru is further declining every day. The objective of this paper is to generate, model and test the mitigation policy considering the following goals:

1. Increasing the ridership of Bengaluru Metropolitan Transport Corporation buses
2. To regain the 'profit making' state for the organization
3. Reduction of pollutants such as NO_x, PM, CO₂, CO through reduced vehicular emission.

The policies thus created and tested are mentioned in the paper in detail with the thorough analysis of each attribute corresponding to every policy.

2. Literature Review

Various studies to access and analyse the sustainability of transportation in Bengaluru have been carried over the last one and half decade. In year 2003 - 04, the study carried out for the preparation of Detailed Project Report (DPR) of Bengaluru Metro Rail Project, stated that the total vehicular population is increasing at the rate of 10% per annum while two wheelers alone are increasing at 17% per annum. The study suggests the need of a mass transit system in the city in order to cater the needs of increasing working population. This study includes an observation that majority of the composition of traffic on Bengaluru roads, consists of low occupancy vehicles, i.e. two wheelers. This has been observed and noted again in the report on Bangalore Mobility Indicators 2010-11 carried out by Urban Mass Transit Company Limited and submitted to the Directorate of Urban Land Transport (DULT). While this study suggests the urgent need of walking and cycling infrastructure to be improved in the city, it states that the existing bus network is good with wider coverage and is financially sustainable. In year 2015, a study done by Centre for Study of Science Technology & Policy (C-STEP) it is reported that BMTC (Bengaluru Metropolitan Transport Corporation) bus service which was known as the only profit making public bus operator, has incurred significant losses in last few years (CSTEP, 2015). This report suggests the requirement of heavy investment on bus service in the form of subsidy and the need of improvement in Non-Motorized Transport (NMT). Addressing the problems of scheduling delays and bus bunching, research has also stated the requirement of developing Hub and Spoke model for BMTC and the benefits of implementing it instead of existing destination based model (Verma et. Al., 2017). The CLIMATRANS report (Verma et. Al.,2018) which talks about the detailed mitigation policy bundles to be implemented for sustainable transportation in Bengaluru, emphasizes on policies for better walking and cycling infrastructure and suggests the measures such as congestion pricing, car-pooling and mixed land use development. The study also talks about the positive environmental effects (such as reduced NO_x and CO_x emissions) due to policies like High Occupancy Vehicle (HOV) lanes in the outer periphery of the city including outer ring road, NICE road and other highways approaching the city from all sides showing that the HOV lanes, if implemented, will reduce the overall emissions by considerable amount.

While the research suggests the need for the bus transit in metropolitan cities should be totally affordable for urban poor (Badami et. Al., 2007), there has been no significant research done on the effects of restructuring the fare and its impact on the bus transit mode share. Multiple corridors included in the study regarding HOV lanes have been now considered for mass transit projects and there has been no study on the implementation of Bus Rapid Transit System (BRTS) within the city limits in the city of Bengaluru.

This paper deals with the testing of policies and there modeling keeping into mind the changes required in the fare structure and the possibility of new BRT lanes on heavy traffic holding roads inside the city limits.

3. Motivation for Developing Public Transport Policies

Bangalore Mobility Indicators 2011, a report based on the study carried out by Urban Mass Transit Company limited and submitted to Directorate of Urban Land Transport (DULT), reported an observation that more than 40% of the roads in Bengaluru have public transport buses running at the average speed lesser than 10 km/h. We observed that this average speed has further decreased in past 7 years, becoming as low as 4 - 5 km/h on few major corridors in Bengaluru. Out of these major corridors, few roads like Mysore Road, Tumkuru Road, already have a metro route running parallel to or over them while many roads, such as Outer Ring road have already planned metro lines over them. Apart from these there are few major traffic prone roads with sufficient road width, i.e. more than 2 lanes on either side, were selected, modeled and tested for the potential BRT lanes in this paper. The Bengaluru Metropolitan Transport Corporation buses operating in Bengaluru is a stagecoach bus service. The stagecoach type bus services operate with the stage wise fare collection system. We observed that the existing fare structure is such that the ticket prices increase suddenly in first few stages and then the rate reduces making the plot of fare v/s distance, logarithmic. Such fare structure seems to be promoting the usage of buses for longer distances than short ones. Today, with Bengaluru having a mass rapid transit, i.e. metro service, already in place, the BMTC buses should be used more as a short trip, cheaper mode or as a last mile connecting feeder system instead of long trip provider. We modeled and tested a scenario by reducing fares for short - medium trips keeping a slow and steady fare increment for initial stages. The BMTC considers standard stage distance as 2 kilometers and this standard is used by many public bus operators across India. We observed that more than one third of the total number of BMTC stops across Bengaluru Metropolitan Region (BMR), are assigned as a stage stops. This implies that the average inter-stop distance is around 670 m, which is higher than the international standards of 400 m distance for a city bus service. This is reducing the accessibility of public transit network further along with the decreasing value of acceptable walking distance, with increasing vehicular ownership. With the above mentioned and identified problems, the scenarios were built and modeled to forecast the possible ridership and revenue increment for BMTC, subsequently reducing the overall emission and hence contributing in improving the livability of the city

4. Modeling & Results

The base data used for modelling in this paper was acquired from the Comprehensive Traffic and Transportation Study (CTTS) of Bengaluru for the year 2009. The study area selected for modelling (as shown in fig. 1) were 330 zones where BMTC buses serve at present out of 384 zones of Bengaluru Metropolitan Region (BMR).



Fig. 1: Study Area (330 Zones)

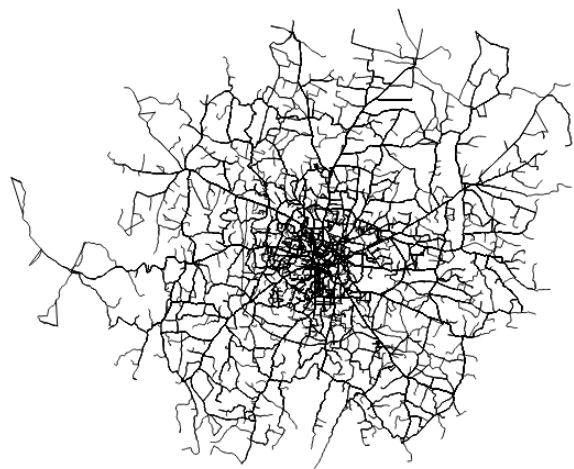


Fig. 2: Road Network served by BMTC

Road network data and public transport route (fig. 2) data obtained from a secondary source was used for the trip assignment purpose. The zone to zone distances were obtained from this data using standard procedure and this distance was used to calculate the attributes of utility functions such as Travel Time (TT) and Travel Cost (TC) with

certain assumptions. For travel cost calculations, the fuel cost was considered for private vehicles while ticket cost was considered for public transport. We used the stage wise fare data of ordinary service obtained from BMTC for the calculation of zone to zone public transport travel cost considering the stage distance of 2 kilometres. For the calculation of private transport fuel cost, we assumed two different values of vehicle mileage for each class of vehicles considered, viz. congestion average and free flow average, the latter being more than the prior. Understanding that the average speed of public and private transport on congested roads must have decreased even below 10 km/h (Bangalore Mobility Indicators 2011) in last 7 years, we monitored the travel speeds on congested roads, major traffic prone corridors and their feeding links in and around CBDs through Google traffic data and assigned the speed of 5 km/h for public transport on congested routes and links in densely populated/heavily employed areas while rest of the links, mostly in the outer periphery of the city were assumed to be having a free flow speed. The speed of 10 km/h was assumed for private transport on the above mentioned corridors and links around it with free flow speed for all other links. With these values and assumptions, the zone to zone travel time and zone to zone travel cost matrices were obtained for each mode or class of vehicles (Bus, Car, Auto, Bikes etc.)

The standard four stage modelling methodology was used to obtain the horizon year travel patterns for current state as well as for the scenarios to be tested for the proposed policies. The analysis for this work is done for three cases which are Business As usual (BAU), Scenario 1 & Scenario 2.

Business As usual Scenario

In the Business As Usual (BAU) scenario, modelling is done considering no new policies will be implemented and the execution of current situation will continue preserving the values of all the attributes for each mode of transport. In Business As Usual (BAU) scenario, all the modelling related parameters and variables are forecasted for horizon year, just with the base year information such as zone to zone skims, etc. The productions and attractions of all 330 zones in the modelling year are predicted using the forecasted population and employment for horizon year using the past data in trend models. The BAU scenario here has been used as a basis of comparison for other policies.

Scenario 1 - Changing the stage wise fare structure of BMTC

The existing fare structure of BMTC, starting from very low fare, increases rapidly in the shorter distances and then has a very small and steady growth for medium and long distances.

Table 1: BMTC fare restructuring

Stage	Distance (in Km)	Existing fare (in INR)	Proposed fare (in INR)
1	2	5	7
2	4	10	8
3	6	15	10
4	8	17	12
5	10	19	15
6	12	20	17
7	14	20	18
8	16	22	20
9	18	22	22
10	20	23	24
11	22	23	24
12	24	24	25
13	26	24	25
14	28	25	27
15	30	25	27
16	32	25	28
17	34	25	28
18	36	25	30
19	38	26	30
20	40	27	32

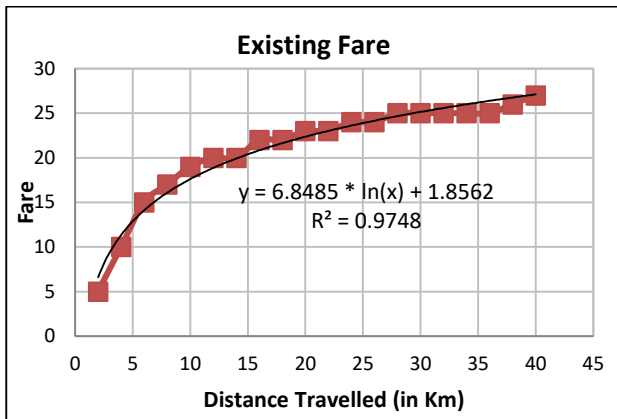


Figure 3: Existing fare structure of BMTC

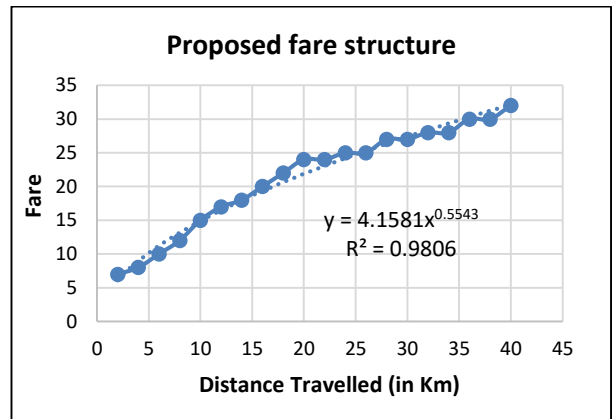


Figure 4: Proposed fare structure

The proposed fare structure is such that it has small and increments for both short and long distances in order to promote the usage of public transport buses for short and short medium trips such as trip lengths ranging from 6 kilometres to 20 kilometres. The existing and proposed fare structures for BMTC are shown in table 1. A Distance vs Fare plots are done for old and new fare structure as seen in fig.3 and fig.4 respectively. The figures shows that there is a steep rise in the fare for a very short distance for old fare structure, whereas the new fare structure has a gradual increase in fare with the distance. The steep growth in the fare for old fare structure is a discouragement for people who do shorter trips which is re structured in new fare structure to encourage shorter trips. This policy will change the travel cost (TC) variable in the generalized cost for every zone to zone cost of public transport, affecting the utility of each mode and hence increasing the mode share of BMTC.

Scenario 2 - Building Bus Rapid Transit Lanes on specific routes

After identifying the most congested routes and links in the city during morning and evening peak time and ignoring those over which there is already a proposed or planned or under construction metro line and after considering only the roads with sufficient width, four potential BRT corridors were shortlisted. Metro lines and BRT corridors are shown in the fig. 5

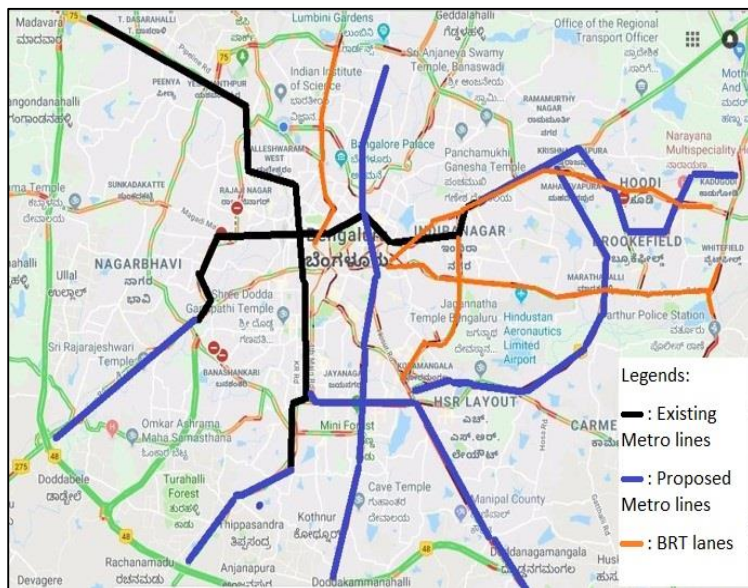


Figure 5: Existing and planned metro lines with proposed BRT lanes

Due to heavy traffic and severe congestion, the present speed of public transport on these corridors is less than even 5 km/h. Adding a BRT lane on these roads, will increase the speed of public transport to free flow speed and simultaneously reduce the capacity of those roads to carry private transport vehicles, hence reducing their speed further. The speed of public transport buses on BRT corridors was assumed to be 30 km/h considering frequent stops and their dwell time along with the free flow speed of the vehicle. This policy will change travel time (TT) variable in the generalized cost for corresponding zone to zone costs of public transport as well as private transport, affecting the utility of each mode and hence increasing the mode share of BMTC.

The above mentioned scenarios are modelled in the four stage travel demand modelling and results are presented for each stage comparing the 3 scenarios.

4.1 Trip Generation:

The data from the 2008 is forecasted to 2017 using the trip end equations for private and public transportation vehicles. The trip end equations were generated using the zone wise population and employment data along with the obtained zonal productions and attractions. The production and attraction equations used for private vehicles and public vehicles are show in table 2.

Table 2: Trip End equations for modelling

Mode	P-A	Trip End Equations	R ²	
Private	Production	0.56 x POP + 1344.34	0.46Eq. 1
	Attraction	0.76 x EMP + 6877.28	0.4Eq. 2
Public	Production	0.42 x POP + 4080	0.43Eq. 3
	Attraction	0.76 x EMP + 6231	0.4Eq. 4

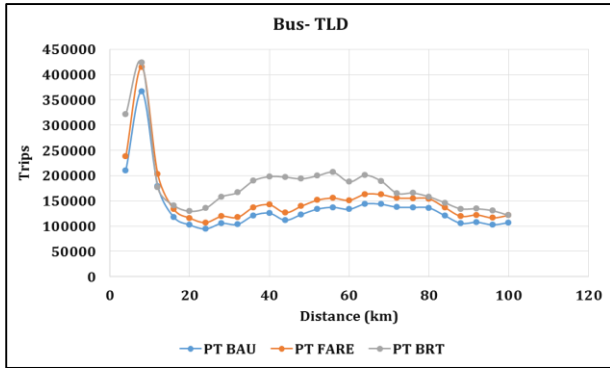
4.2 Trip Distribution:

The doubly constrained gravity model was used for the distribution of the trips between origin and destination zones. The generalized cost function used in the gravity model was a gamma function as shown in Eq. 6 and the OD matrix is generated.

$$T_{ij} = A_i O_i B_j D_j f(c_{ij}) \quad \text{.....Eq. 5}$$

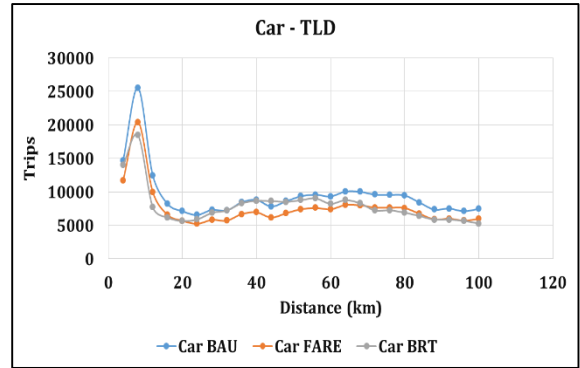
$$f(c_{ij}) = K c_{ij}^{-\alpha} e^{\beta(c_{ij})} \quad \text{.....Eq. 6}$$

The trip length distribution of private and public transport vehicles is estimated and it was observed that the average trip length for private vehicles is 15.5 km and that of for public transportation vehicles is 14.5 km. Moreover, in private vehicles trip distribution, it was observed that the average trip length for Two Wheeler is 13.8 km, which is lesser than that of by the public transport bus. The trip length distributions (TLD) for all motorized modes are shown in the figure 6 to figure 9.



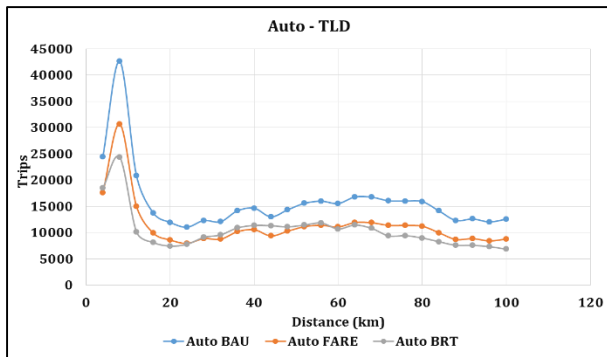
Avg. Trip Length - BUS
 BAU: 14.5 km
 FARE: 14.9 km
 BRT: 15.2 km

Fig.6: Trip Length Distribution for Bus



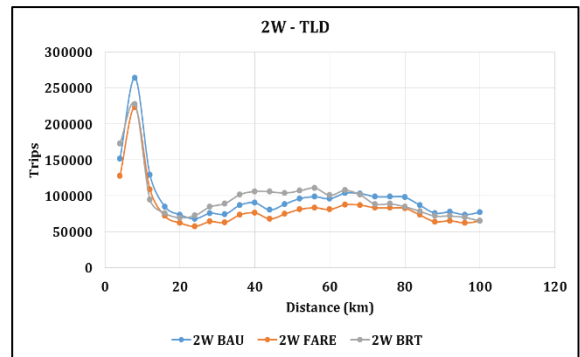
Avg. Trip Length - CAR
 BAU: 15.5 km
 FARE: 14.8 km
 BRT: 14.2 km

Fig.7: Trip Length Distribution for Car



Avg. Trip Length - AUTO
 BAU: 15.9 km
 FARE: 15.4 km
 BRT: 14.8 km

Fig.8: Trip Length Distribution for Auto



Avg. Trip Length – 2 Wheeler
 BAU: 13.8 km
 FARE: 13.2 km
 BRT: 12.8 km

Fig.9: Trip Length Distribution for 2 Wheeler

The trip length distribution plots above indicate that the Scenario 1 i.e. fare restructuring, increases the short and short-medium length trips (6-12 km) of BMTC buses by around 13 - 14 % while decreasing the ridership of other private modes in same trip length range by more than 15%. The BRT lanes (scenario 2) will increase the ridership of BMTC for short as well as medium long trip distances by significant amount due to faster connectivity with dedicated bus lanes. This shows that the BRT can be implemented as a good substitute for metro on many corridors promoting long but faster trips by public transport and it can also act as a complementary service to the upcoming metro lines in the city.

4.3 Mode Choice:

The modal split was obtained using the utility functions consisting of generalized cost of travel values calculated from the travel time and travel cost variables calculated from zone to zone distance matrix as mentioned above and other attributes such as average income, household size and vehicle ownership index. Multinomial Logit model is used to derive the parameter values for the variables used.

The utility functions used for the modelling are show in table 3.

Table 3: Utility functions for all modes

Car	$ASC1 * one + BETA11 * xAA + BETA12 * xAB + BETA15 * x15 + BETA13 * x13 + BETA14 * x14 + BETA19 * x19$
2 Wheeler	$ASC4 * one + BETA31 * xCA + BETA32 * xCB + BETA35 * x15 + BETA33 * x13 + BETA39 * x19$
Auto	$ASC5 * one + BETA41 * xDA + BETA42 * xDB + BETA45 * x15 + BETA43 * x13 + BETA44 * x14 + BETA49 * x19$
Cycling	$ASC6 * one + BETA51 * xEA + BETA55 * x15 + BETA53 * x13 + BETA54 * x14 + BETA59 * x19$
Walking	$ASC7 * one + BETA61 * xFA + BETA65 * x15 + BETA63 * x13 + BETA64 * x14 + BETA69 * x19$
Bus	$ASC8 * one + BETA21 * xBA + BETA22 * xBB + BETA23 * x13 + BETA24 * x14 + BETA25 * x15 + BETA29 * x19$
Metro	$ASC9 * one + BETA71 * xGA + BETA72 * xGB + BETA75 * x15 + BETA73 * x13 + BETA74 * x14 + BETA79 * x19$

Where,

Table 4: Variables used in utility functions

DATA VARIABLE	CODE	DATA VARIABLE	CODE
Age	x13	travel time by auto	xDA
sex	x14	travel cost for auto	xDB
Household monthly income	x15	time of travel by bicycle	xEA
purpose	x19	time of travel by walk	xFA
travel time by bike	xCA	travel time by metro	xGA
travel cost by bike	xCB	travel cost by metro	xGB

The parameter values of variables, which means that the weightage of that particular variable and other variable codes

are shown in the table 5.

Table 5: Parameter values of variables used in utility equation

Variable	Parameter Value	Code	Variable	Parameter Value	Code
ASC (bike)	3.94	ASC 4	Household income (bus)	-0.246	Beta 25
ASC (auto rickshaw)	0.307	ASC 5	Household income (metro)	-0.35	Beta 75
ASC (walking)	7.55	ASC 7	Age (bike)	-0.162	Beta 33
ASC(bus)	2.81	ASC 8	Age (auto)	-0.013	Beta 43
ASC(metro)	2.5	ASC 9	Age (cycling)	-0.082	Beta 53
In vehicle travel time (bike)	-0.005	Beta 31	Age (bus)	-0.038	Beta 23
In vehicle travel time (auto)	-0.078	Beta 41	Age (metro)	-0.041	Beta 73
Walking time	-0.094	Beta 61	Gender (bike)	-0.356	Beta 34
In vehicle travel time (bus)	-0.006	Beta 21	Gender (auto)	-0.421	Beta 44
In vehicle travel time (metro)	-0.006	Beta 71	Gender (cycling)	-0.609	Beta 54
Travel cost (bike)	-0.015	Beta 32	Gender (bus)	-0.517	Beta 24
Travel cost (auto rickshaw)	-0.029	Beta 42	Gender (metro)	-0.674	Beta 74
Travel cost (metro)	-0.008	Beta 72	Purpose-school (bike)	2.11	Beta 39
Household income (bike)	-0.092	Beta 35	Purpose-school (cycling)	0.81	Beta 59
Household income (auto rickshaw)	-0.115	Beta 45	Purpose-school (walking)	2.11	Beta 69
Household income (cycling)	-0.181	Beta 55	Purpose-school (bus)	1.85	Beta 29

				Purpose-school (metro)	1.85	Beta 79
Null log-likelihood: -5701.859 Final log-likelihood: -2084.096 Rho-square: 0.634						

From the mode share comparison charts in fig. 10, it can be seen that the Scenario 1 (Fare restructuring) will improve the ridership of BMTC by almost 2% while Scenario 2 (BRT lanes) will increase the ridership by almost 4% from the existing ridership (i.e. BAU scenario). Both the scenarios will help in reducing the usage of Car as well as Auto in the modes of private transport.

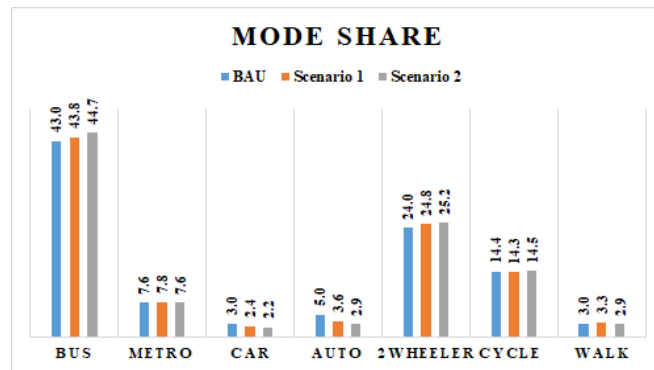


Figure 10: Mode share percentages for all scenarios

The overall revenue of BMTC for all three scenarios was estimated using the zone to zone fare matrix and the predicted zone to zone ridership. From the estimated revenue, it was observed that Scenario 1, i.e. fare restructuring increases the revenue of BMTC by 15% while the introduction of BRT lanes, i.e. Scenario 2 will increase it by more than 23% as compared to that of in BAU scenario.

4.4 Trip Assignment:

The trip assignment was done using the road capacity data obtained from secondary sources and the travel speed data attributed link wise from our observations, as mentioned above. The User Equilibrium method is used to assign the vehicles on the road network and Vehicle kilometres travelled (VKT) have been estimated from the trip assignment. The comparisons in VKT for the 3 scenarios are shown in the figure 11.

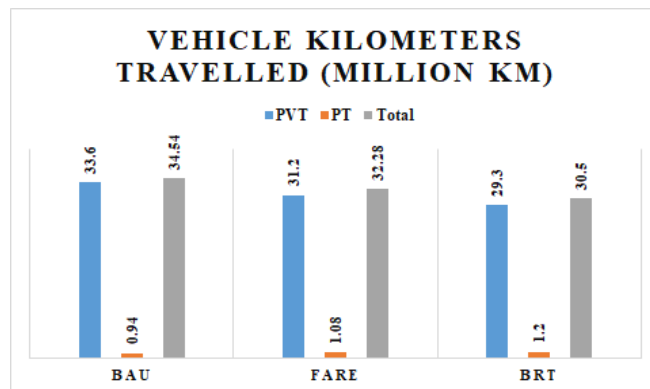


Figure 11: Vehicle kilometres Travelled (VKT) for all scenarios

The volume/capacity plots for the study area after assignment for the three scenarios are shown below.

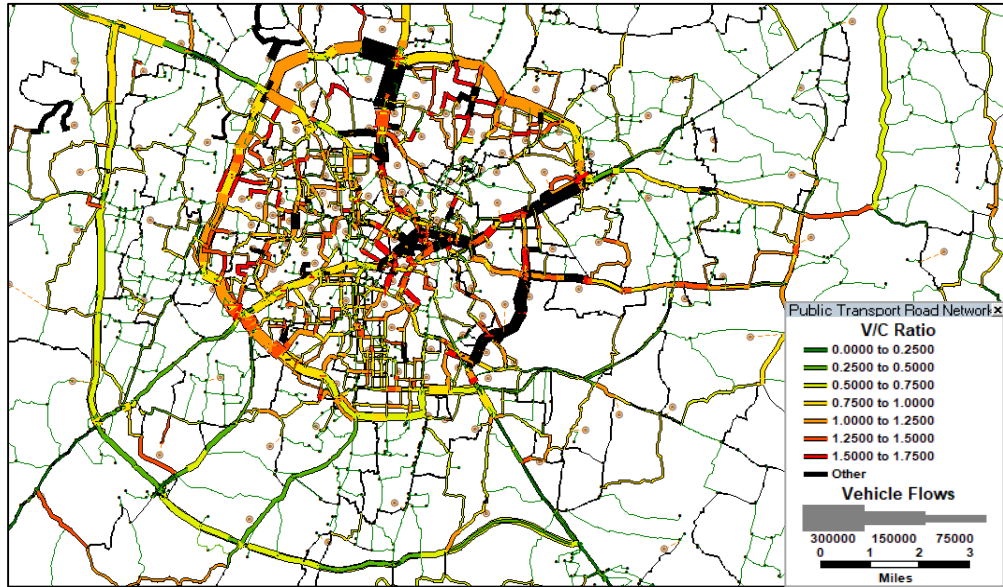


Figure 12: Trip Assignment V/C plot - BAU scenario

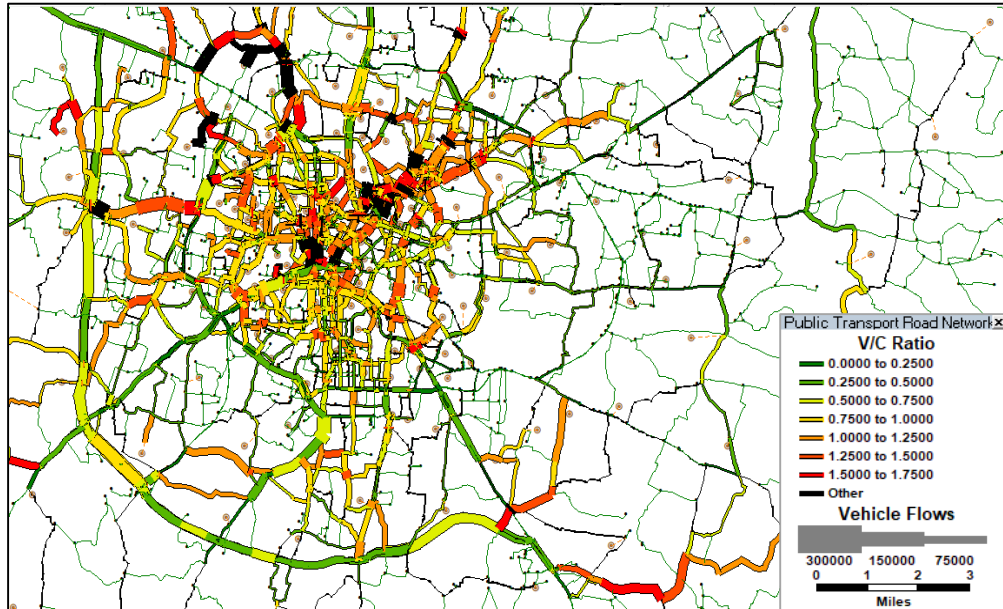


Figure 13: Trip Assignment V/C Plot- Scenario 1 (Fare restructuring)

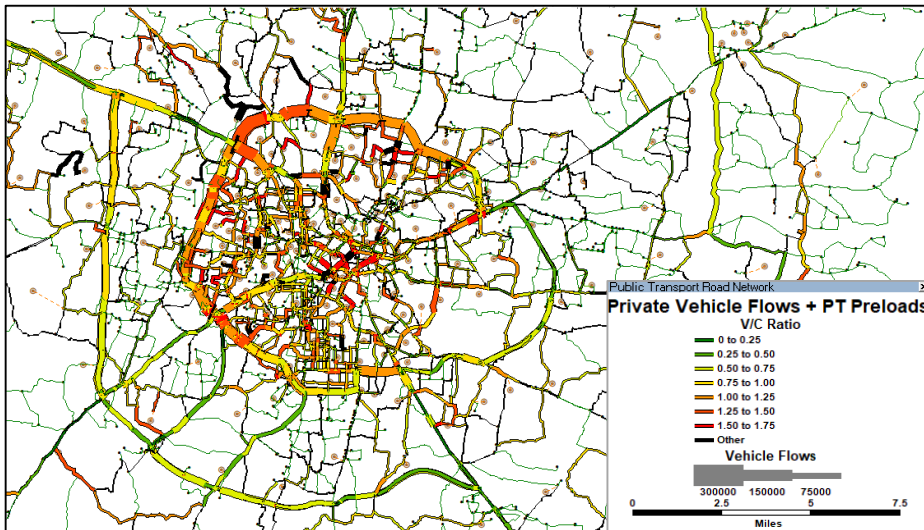


Figure 14: Trip Assignment V/C Plot - Scenario 2 (BRT lanes)

From the figure 11, it can be seen that upon implementation of the scenarios 1 and 2, there is more reduction in vehicle kilometres travelled for scenario 2 where BRT is implemented. Although, vehicle kilometres travelled (VKT) is increasing in public transport, the total VKT is less than other two cases due to more reduction in private transport vehicle kilometres travelled. The same can be observed from the v/c plots (Fig.12 – Fig.14) where roads are less congested when compared with BAU and Fare change scenario (Scenario 1). It is to be noted that though public transport has major mode share its VKT is still less due to the occupancy levels which helps in reducing congestion and emissions.

5. Emissions

Vehicular emissions are estimated for the motorized transport both private public. In a study Chandel M. et al., 2018 presents the emission factors of various vehicles and pollutants which is used as the basis for estimating the emissions from the vehicle kilometres travelled. The comparison of emission between three scenarios and vehicle types is shown in the figures below

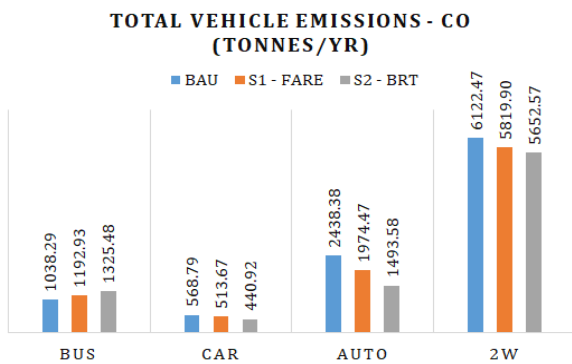


Fig.15: Total Vehicle emissions for CO in Tonnes/Year

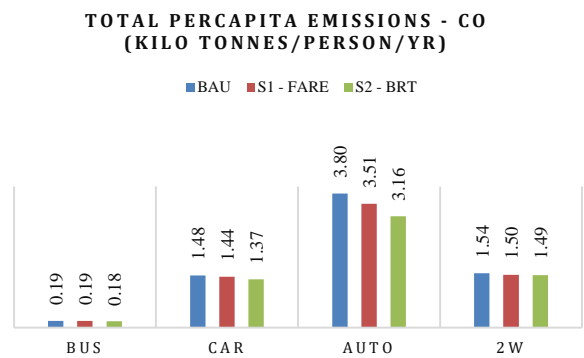


Fig.16: Total Percapita emissions for CO in Kilo Tonnes/Person/Year

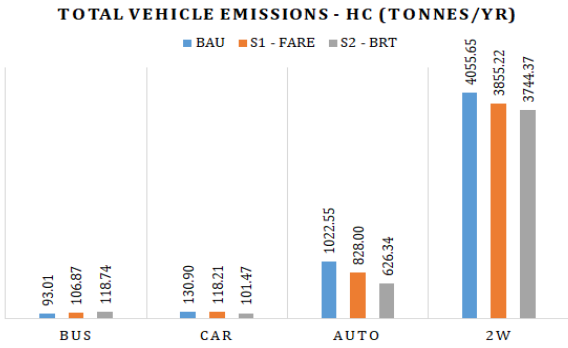


Fig.17: Total Vehicle emissions for HC in Tonnes/Year

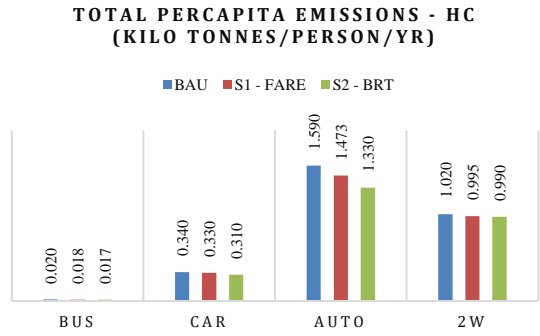


Fig.18: Total Percapita emissions for HC in Kilo Tonnes/Person/Year

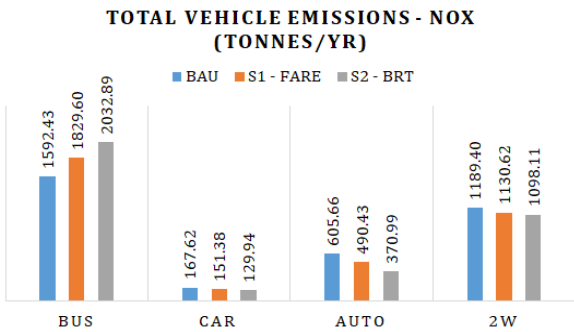


Fig.19: Total Vehicle emissions for NOx in Tonnes/Year

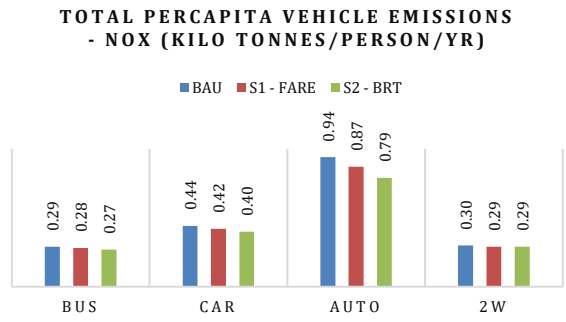


Fig.20: Total Percapita emissions for NOx in Kilo Tonnes/Person/Year

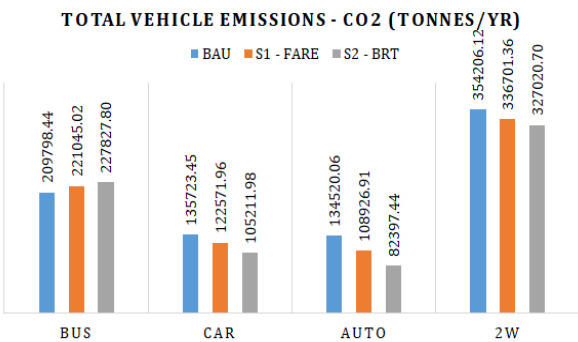


Fig.21: Total Vehicle emissions for CO₂ in Tonnes/Year

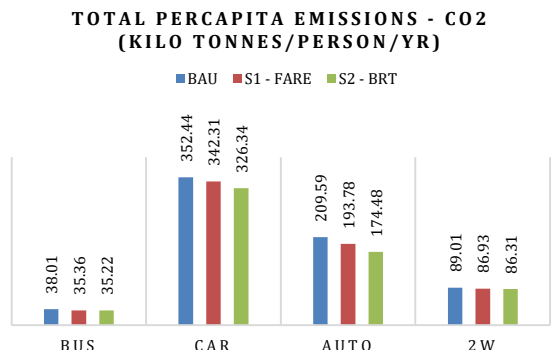


Fig.22: Total Percapita emissions for CO₂ in Kilo Tonnes/Person/Year

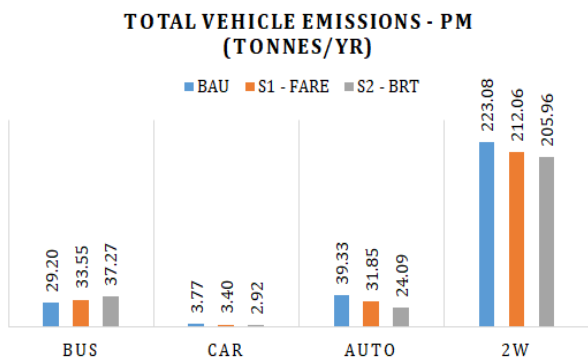


Fig.23: Total Vehicle emissions for PM in Tonnes/Year

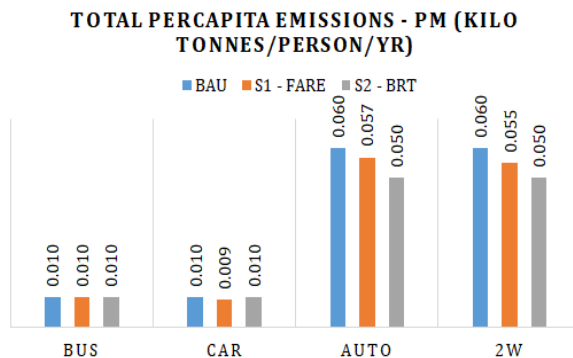


Fig.24: Total Percapita emissions for PM in Kilo Tonnes/Person/Year

From the above figures it is observed that the percentage decrease of Per capita CO₂ emissions from BAU to Scenario 1 is 7 % and from BAU to Scenario 2 is 7.4% for bus transport and for private vehicle the reduction in CO₂ emission from BAU to Scenario 1 is 4.3% and from BAU to Scenario 2 is 9.82%. These values clearly indicate that upon implementing the strategies for public transport there will be reduction in emissions.

6. Summary and Conclusions

This paper provided an insight in to the public transportation system of Bengaluru city and the ways to develop the current public transport scenario by developing two sustainable transport policies which are Fare restructuring policy of BMTC and provision of BRT lanes. The study states that the fare restructuring of BMTC bus service and introducing BRT lanes will be helpful in decongesting the roads in Bengaluru as well as in reducing the vehicular emission. The paper suggest the revision of bus fares after analyzing the present day travel pattern by different mode and finding out that there is a requirement to reduce the rate of increment of bus fares for the trips of small and small - medium distances. The modelling shows the positive effect of restructuring the BMTC fares as it is increasing the mode share of the buses by more than 2% and also increasing the revenue by more than 15%. From emission plots it can be seen that the fare restructuring would actually reduce the total Vehicle Kilometers Travelled (VKT) by all modes combined and will help reducing the emission of NO_x, CO, CO₂, PM, HC into the atmosphere. This paper also suggests the introduction of Bus Rapid Transit (BRT) lanes on few major roads in the city which are not covered under proposed or planned metro lines. The BRT lanes are important in the city considering the increasing unreliability of public transport buses due to severe congestion at every intersection. The BRT lanes will improve the performance of bus transit in the city by increasing its speed on busy and congested roads by a large margin. The analysis output and emission plots show that BRT will increase the ridership of BMTC by more than 4% and will also improve the revenue by almost 23% along with drastically reducing the NO_x emissions as well as the total Vehicle Kilometers Travelled by all modes. Considering both the scenarios (fare and BRT) together, will increase the ridership and revenue of BMTC even more, resulting in better and sustainable urban transport in the city.

Further as a future work, bundling up the above discussed policies with other policies such as ‘improved infrastructure for Non-Motorized Transport (NMT)’ can be tested. This research has considered only one type of services run by BMTC, i.e. the ordinary service which is a limitation to this study. A study, with more trip assignment oriented approach, can be done including other services (Vajra and Vayu Vajra) too. The integration of bicycling lanes and cycle pooling with the BRT lanes proposed in this research can also be explored in future.

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