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Estimation of CO_2 Emission in Context of Urban Transportation for City Surat in India

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Abstract: The motorization growth associated with the mega cities' rapid urban development has serious implications for global climate change all over the world. To forecast CO2 emissions through passenger transport for Surat city, socio-economic and travel data collected in base year and available historical data has been utilized. Passenger-kilometre Travel has been derived by developing Modified exponential, Logarithmic and Linear models and under BAU and SUT scenario, emission forecast is made. By calibrating city level utility model developed by SVNIT, Surat in 2014, with observed data-set of base year, speed based emission study is conducted. Considering speed variation in private and public transport vehicle, four strategies are developed to control emission up to the planning horizon. The result by Modified exponential model seems more reliable as historical growth trend is also exponential. Significant difference in emission found if public transport speed is increased at 5% rate at every 5 years interval.

Keywords: Motorization, Socio-economic, CO2, Public Transport, Passenger-Kilometer

1. INTRODUCTION

Growing energy demand and its link to increasing GHG emissions remains a key global concern. Climate change is a global challenge and transport sector is a significant source that contributes towards increasing GHG emissions. In 2011 the transport sector accounted for 19% of global energy use and contributed 23% to the total carbon dioxide (CO_2) emissions in the world (Source: IEA 2016). This contribution is majorly driven by the road transport sector which increased by 64% since 1990 and accounted for about three quarters of transport emissions in 2016 (Source: IEA).

Urbanization and increasing reliance on personal mode of transport remain a challenge for most of the developing cities particularly in Asia. Growing GDP per capita will continue to drive the demand for mobility and use of personal motorized vehicles. Though per capita carbon emission through urban transportation in developing countries remain many folds lower than developed country cities, it is most certain that developing countries will contribute in increasing emissions proportion to global CO_2 emissions considering the urban growth and vehicular emissions. India is emerging as a strong economy where higher urban density is resulting in higher levels of private motorization. In the light of such trends, rate of growth of GHG emissions would be significant and holistic policy framework that decouple economic growth from growth of personal motorization unlike the developed countries are needed to put the country on a sustainable low carbon growth trajectory.

This research study attempts to review policy instruments that have been instrumental in putting urban transport on a low carbon pathway in cities that have set a benchmark in integrated land use transport planning. The case study of Surat city has been taken up, wherein various strategies in the urban transport sector that directly or indirectly address reduction of carbon emission and adaption are discussed. Purpose wise trip details has been worked out and from the result of the analysis, work trips and education trips found around 85% of total trips. The overall study has been carried out at aggregate level. With the references of previous studies, comparative study of the travel pattern of the city has been carried out at both zonal level and at city level and Passenger Kilometer Travel (PKT) and Vehicle Kilometer Travel (VKT) has been evaluated for the year 2001, 2004, 2011 and the base year (2016). Analyzed sample data has been used for the estimation of carbon emission through urban transportation for the planning horizon i.e.2041 in study area.

2. LITERATURE REVIEW

Various studies have been carried out to express the impact of transport sector on carbon emission in India and all around the world. But few studies have considered city specific travel behavior in detail. In a study for Mumbai and Delhi, Das and Parikh developed a model of transport energy consumption and emission using projected changes in vehicle numbers. In a study for Delhi, Bose and Nesamani estimated emissions from urban transport under various scenarios. Analysis of the study predicts future passenger travel and vehicle ownership based on historical correlations with population and income growth. For the Indian cities- Ahmadabad, Mumbai and Surat, using secondary data and using various mode choice and trip length assumptions Lisa Rayle and Madhav Pai did forecast carbon for three scenarios – Auto mobility Ubiquity, Two-wheeler World, Sustainable Urban Transport. In addition to this Fabian and Gota calculated emissions for 29 cities based on trends in travel demand, city density, and current mode share for a country India. Azadeh Ghadimzadeh *et.al* (2015) reviewed on CO_2 emission from transportation sector in Malaysia. The authors reviewed the existing state of GHG emission from transportation section, the measures that have been initiated in Malaysia for GHG emission reduction in transportation sector. The review shows deceleration of GHG emission from transportation sector globally and Malaysia in recent years. The study reveals that the present measures may not be enough to reduce GHG emission up to the set target. Authors added that Malaysia needs more prudent strategies for climate-friendly development of transportation to achieve sustainability goals. Todd Litman *et.al* (2015) investigated the optimal (best overall, considering all benefits and costs transportation emission reduction strategies. He emphasized the mobility management. Through mobility management total length of travel is to be reduced. The author discussed the benefits and drawbacks of implementation of energy efficient vehicles. Simultaneously, he much concentrated on mobility management by reducing VKT, which ultimately reduce congestion and result in carbon less footprint. Strategies recommended by an author are known as “win-win” strategies which provide multiple benefits.

At the national level, Sanjay Kumar Singh *et.al* estimated the level of energy demand and CO_2 emission from the road-based passenger transport sector in India considering Business as Usual (BAU) and Efficiency Gain Scenario and subsequently projected the energy demand and CO_2 emissions resulting from the road transport up to the year 2030-31 based on the projected values of aggregate traffic volume, modal split, and modal intensities for energy demand and CO_2 emissions. Author used data set of four major motorized modes of transport – bus, cars, two-wheelers and auto rickshaws of 1950-51 to 2000-01. Two models, Logistic and Gompertz functions are used for this study. Schipper et al forecast emissions generated by travel under three different scenarios based on growth in vehicle ownership. Parikh and Ramanathan provided a brief review on Indian Transport Sector in last few decades. PKM transformation from rail based transport to road based transport is studied by authors. Authors estimated CO_2 emission and other local pollutants as a result of fuel combustions. Transport performance in future was projected using co-integrating econometric models. The models project significant growth in passenger and freight traffic in India which would result in increment of energy consumption and CO_2 emissions at equivalent rates. The effects of various policy options aimed at reducing energy consumption and CO_2 emission were analyzed using a scenario approach. Dr. Ashish Verma *et.al* suggested urban transport policies in India in context of climate change. Sushant Sharma *et.al (2015)* has explored the possibility of developing speed dependent emission factor for Indian conditions and vehicles. An onboard test is conducted on typical vehicles; namely, a passenger car, a sports utility vehicle, and a truck and collected data is processed and emission factor is developed in the form of second degree polynomial with speed as the dependent variable. The emission factors for the three types of vehicles and for CO, CO_2, NOX, and HC are developed.

The results of the above analysis concentrates to the magnitude of the emissions problem, but almost all rely on available scarce data and liberal assumptions. With one exception, these all studies derive from vehicle counts rather than city-specific observed travel behavior and consider only nation-wide emissions or the largest cities. Even with limited data, an analysis focused on city-level travel behavior can contribute to our knowledge of emissions from urban travel.

3. METHODOLOGY AND DATA SOURCE

Emissions forecasts are developed using various functions based on observed travel activity. More specifically, data on observed trip rates, travel distances, mode share and vehicle emissions, allow calculation of CO_2 emissions for various scenarios. In addition, the utility model developed by SVNIT, Surat is calibrated to estimate speed based CO_2 emission and different strategies are introduced for CO_2 emission up to planning horizon.

To understand the travel behaviour of Surat city, in base year socio-economic and travel data has been collected through household surveys from all 7 zones of the city. To quantify the vehicular growth in the city, vehicle registration data has been collected from RTO, Surat up to base year. Demographic details of the city were available from Surat Municipal Corporation, a local governing body.

The vehicle registration data from the RTO, Surat has been collected and Statistic shows that average annual growth rate in two-wheelers, cars and auto rickshaw is found around 8.7%, 12% and 7.5% respectively since 2001-2002. The number of two-wheelers, cars and auto rickshaw has increased by 96%, 182% and 51% respectively in last decade (i.e. since 2006-2016). This figure indicates a huge growth in cars in last decade occurred. This desperate increase in cars indicates the economic status of the populace due to the distributed economic growth and it reflects the lack of efficient and adequate public transportation facilities.

As emission standards vary from fuel to fuel, a data of different category vehicle according to fuel type has been collected. Statistic in this case also shows that almost 40% cars registered are of petrol car and 30% cars are of diesel and CNG cars each. Whereas almost 95% auto rickshaws running on the city roads are of CNG and all the busses are registered as diesel vehicles.

4. STUDY AREA IDENTIFICATION

To enable a more generalize analysis of city-level travel, we have selected Surat city which is representative of large areas. Having experienced significant growth in the past two decades, Surat represents more recently emergent city. Surat belongs to a category of cities which are currently undergoing intense growth, making them important targets for sustainable policies. Driven mainly by rural-urban migration, Surat is one of the fastest growing cities in India. Between 2001 and 2011, its population rose from 2.4 to 4.5 million, an increase of 56%. The city is relatively compact, with a density of 13680 persons per square kilometre. The city has been expanding rapidly along the main radial corridors and holds the potential for low density sprawl.

The existing reality, however, is that urban transportation systems in Surat city are far from ideal. The most visible and frequently mentioned transport problem of a city is its traffic congestion, and it is well-known that prominent level of congestion creates significant impact on local and national GDP. Accessible and affordable public transport service is lacking in the city. The number of private vehicles has been increasing continuously and dominates the roads. Almost more than 150 % increment in private vehicles like two wheelers, cars, auto rickshaws occurred up to the year 2011 from 2001 and the same has been increased by around more than 300% to the current year i.e. 2016. (Source: RTO, Surat) This results in heavy emission of CO_2 in the study area. As a result, the transport sector is heavily responsible for public health issues in cities such as air pollution (acidification, smog), noise, greenhouse gas emissions, and road accidents. While transport enables the economy to grow, if not well-managed, it can also retard growth and the efficient delivery of essential social services.

5. DATA AREA ANALYSIS

Travel demand assessment and the transit ridership forecasting are important tasks for transport planners and transit operators. Traveler's behavior with respect to trip making and travel mode choice depends on the geographical area, type of land-use, location of different production and attraction zones, population, demographics, trip pattern etc. In order to estimate the emission of CO_2 from urban transport sector it is necessary to understand the socio-economic characteristics and travel behavior characteristics of the corresponding zones of the study area as these characteristics would lead us to estimate total passenger kilometer travel through various modes for the base year and through forecast modeling for planning horizon. This section will lighten the socio economic and travel behavior characteristics of the city.

5.1 Socio Economic Characteristics

Socio-Economic parameters are analyzed and are summarized in this section. The average family size in the zones of the study area is observed to vary between 4.12 and 4.74 person per household with aggregate level number of 4.45 persons per household. The number of working members in a household varies from 1.21 to 1.63 persons per household in study area zones which is at aggregate level found as 1.33 persons per household. The zonal variation was found between 1.63 to 1.93 persons per household for students. At aggregate level it is found as 1.81 pph. The average number of motorized vehicles (Two-wheelers and cars are considered only) owned by household in city is 2.17 vehicles per household, while the zonal variation from 1.51 vehicles per household in South-East zone to 2.64 vehicles per household in west zone is observed. Bicycle ownership is observed at 0.45 bicycles per household at city level with the highest value in South-East zone and with the lowest in East zone.

5.2 Travel Pattern Analysis

The study of travel behaviour has been carried out in terms of daily household trip rates and daily person trip rate for various trip purposes for various income groups along with the travel time, travel cost & trip length by the different modes used. Considering the census data of 2011, population of Surat city was 4.5 millions. Trip purposes in this study has been denoted as Mandatory trips for work and education purpose, Quasi-Mandatory trips for shopping purpose and Voluntary trips for recreation and social purpose. Travel behaviour according to different age group has been studied. Statistical analysis shows that 83.93% trips are mandatory trips, 4.40% are of quasi-mandatory and 11.67% trips are voluntary trips. Though, quasi-mandatory trips are less than the voluntary trips, these trips contribute more to emission as these are more regular than the voluntary trips.

5.2.1 Mode choice analysis

Data related to intra city travel by different modes for various purposes has been collected from all zones of the study area. Analysis is carried out considering four transportation modes - Two-wheeler, Car, Intermediate Public Transport, and Public Transport. Detailed analysis elaborates that mode share of 2W is with 60% at aggregate level. The noticeable thing is, around 23% of trips are accomplished by IPT mode and around 11% of total trips are made by car. Only 7% trips are made through public transport. If this trend will continue the emission may increase to significant amount up to planning horizon.

Modal share for purpose wise trips have been worked out and same has been tabulated in Table 1. Out of total mandatory trips around 60% trips are made by 2W and around 22% trips are made by IPT.

Table 1 Mode share for each type of trip

Mode	Mandatory	Quasi-Mandatory	Voluntary
2W	59.75%	48.25%	67.57%
4W	9.79%	4.57%	17.56%
IPT	21.90%	46.61%	13.82%
PT	8.55%	0.56%	1.05%

5.2.2 Trip length analysis

The data collected from various households were analyzed and average trip length for the work purpose is found to be 6.08 km. and for education trip purpose it is 4.84 km. As area of the city expanded in the year 2006 to 326.515 km^2, the opportunities for work also increased in this area. Hence the work trip length was found is considerably higher.

In case of educational trip length, there is a considerable rise of around 0.9 km while compared to previous trip length (before year 2006) as previously number of schools and colleges were very less and even those were situated in the centric part of each zone but due to excessive cost of land and considering the requirement of large area for multi activities during academic hours, schools and colleges are structured in the outskirt of the city. This is the reason for significant increase in trip length to 4.84km in a base year. Trip length for various purposes has been worked out from survey and has been tabulated in Table 2. As mandatory trips dominate with around 84%, this has been considered for this research study.

Table 2 Derived trip length for various purposes in base year

Purpose	Average Trip length in Km	Mean (Km)	Std. Deviation (Km)
Work	6.08		
Education	4.84		
Shopping	2.16		
Social	6.50	5.37	2.46
Recreational	9.68		
Religious	5.33		
Sports & Exercise	3.04		

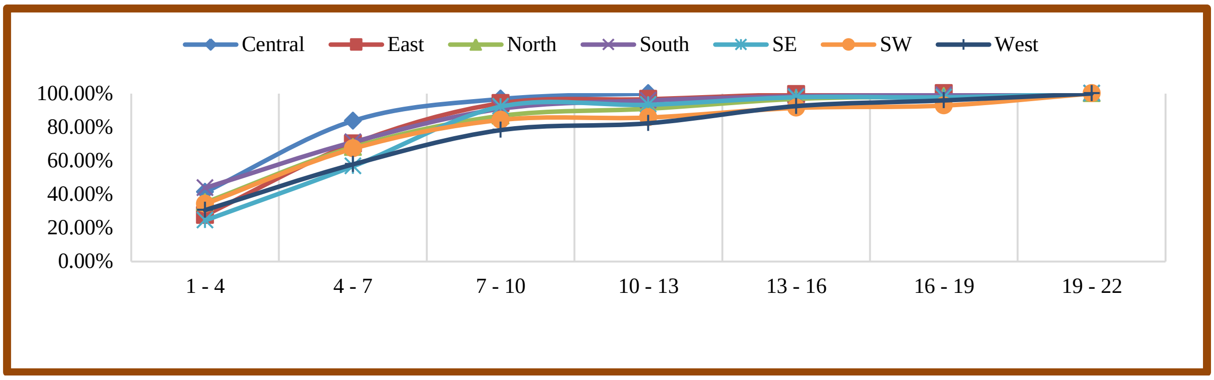

Figure 1 Zone wise trip length distribution for work trips

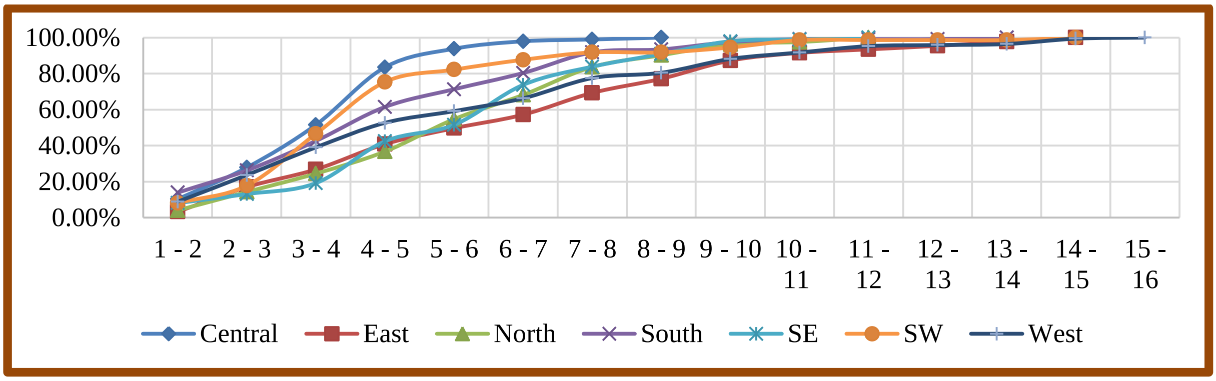

Figure 2 Zone wise trip length distribution for education trips

Above figure spells out that maximum number of work trips are made between 4 km to 7 km and maximum number of educational trips having trip length around 4 km. From these figures, it will be easy to show that CO2 emissions from the mandatory trips might be at considerable amount as around 83% of total trips are mandatory trips and around 85 % of them are made by private vehicles.

5.2.2 Passenger mobility

Forecast of passenger mobility for the planning horizon needs time series data of passenger kilometre travel (PKT). PKT has been worked out for the mandatory trips for each zone for the base year considering the collected data through HIS. Passenger kilometre travel for work (PKTW) and for education (PKTE) has been worked out considering average member of working and school going members and average trip length of respective segment as PKT for work and education dominate around 85% of total PKT.

Difficulties found during the research to obtain data of passenger mobility of the city for the previous years as it is neither available on government portals nor research has been done related to same. This difficulty ended by getting the data from the previous studies carried out by SVNIT, Surat. After referring the past studies, PKT per capita day has been worked out for city and same has been tabulated in Table 3

Table 3 Time series data of PKT/Cap/Day

Year	PKT/Cap/Day
2001	4.52
2006	5.74
2011	6.92
2016	7.52

6. ROAD BASED PASSENGER MOBILITY ESTIMATION UP TO PLANNING HORIZON THROUGH MODELS

The growth in per capita mobility over time typically follows linear up to the year 2004 and then increases an exponentially. There are several different functional forms that can describe exponential growth curves e.g. the logistic, modified exponential, logarithmic, linear, etc. In this study we used modified exponential, logarithmic and linear models to derive road based passenger mobility up to planning horizon.

6.1 Modified Exponential Model

The modified exponential model can be written as mentioned in Eqn. 1.

PKT/Cap/Day = K – [(K-PKTt) (v)n] (1)

Where, K – Saturation level of PKT/Cap/Day

The prediction formula states that the PKT/Cap/Day in t+n period is found by taking the maximum limit, a capacity and subtracting from it some portion of unused capacity. The maximum limit of PKT/Cap/Day i.e. K has been derived by considering saturation density of 25000 person/km^2 before expanding the city area from 112.2 km^2 to 326.5 km^2 in the year of

2006 considering the population based on census data of 2001. The value of K has been derived by considering the population growth as per Table 4. This forecast data of population has been adopted from the work carried out by Rayle and Pai.

Table 4 Projected populations by Rayle and Pai

Year	Population	Year	Population
1961	288,026	2011	3,967,070
1971	471,656	2021	5,950,604
1981	776,583	2031	8,330,846
1991	1,498,817	2041	10,830,100
2001	2,433,785		

Saturation value of K has been derived considering saturation density 25000 persons/ km2 is 23.1 PKT/Cap/Day to forecast PKT/Cap/Day for the planning horizon up to year 2041. Since we are interested in long-term forecast, it was decided to use five-yearly data of PKT/Cap/Day from 2001 to 2041 for the estimation of the models. The variable time is taken as 1 for 2001, 2 for 2006, 3 for 2011, 4 for 2016, 5 for 2021, 6 for 2026, 7 for 2031, 8 for 2036 and 9 for 2041.

6.2 Logarithmic Model

Logarithmic function can be written as,
$Y = a*\ln(x) + b$
Where, a and b are constants and x is the variable (in this case, x = time)
Applying the present data of PKT/Cap/Day in logarithmic function, the logarithmic model is derived as shown in Eqn. 2,

$$y = 2.2342\ln(x) + 4.4454 \quad (2)$$

6.3 Linear Function/Model

Linear function to forecast the PKT/Cap/Day can be written as,
$Y = a*x + b$
Where, a is intercept and b is shape specific constant, x = variable (time)

Applying the present data of PKT/Cap/Day in linear function, the model derived is as shown in Eqn. 3

$$y = 1.0312x + 3.6425 \quad (3)$$

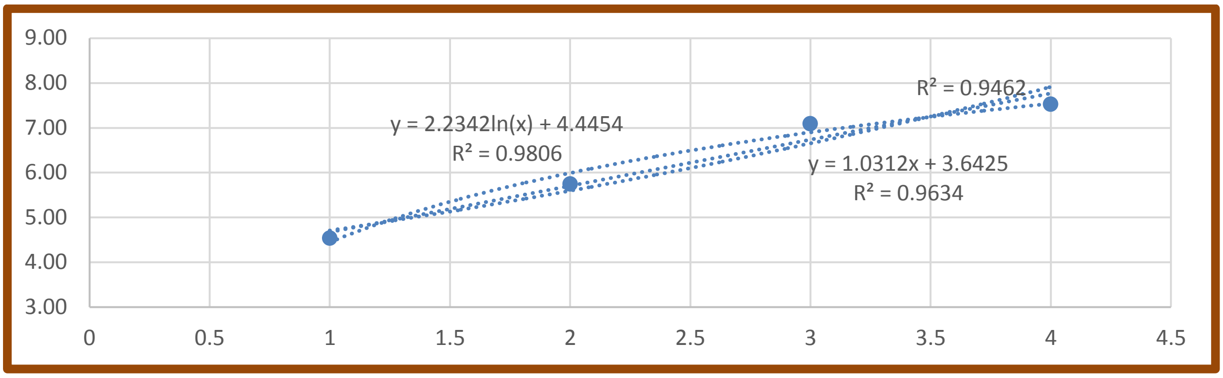

Figure 3 Trend line showing model validity

Applying the above models passenger mobility up to planning horizon has been derived and same is tabulated in Table -5

Table 5 Estimated passenger mobility up to planning horizon

Year	Modified Exponential Function		Logarithmic Function		Linear Function	
	PKT/Cap/Day	PKT/Day	PKT/Cap/Day	PKT/Day	PKT/Cap/Day	PKT/Day
2001	4.53	11031456	4.53	11031456	4.53	11031456
2006	5.74	13965420	5.74	13965420	5.74	13965420
2011	7.08	31527577	7.08	31527577	7.08	31527577
2016	7.52	33478205	7.52	33478205	7.52	33478205
2021	8.40	50424914	8.04	48247237	8.80	52791000
2026	9.23	55409804	8.45	50691294	9.83	58978200
2031	10.02	83153476	8.79	72981505	10.86	90145470
2036	10.76	89286550	9.09	75457693	11.89	98704430
2041	11.45	123706220	9.35	101027943	12.92	139571640

7. VEHICULAR MOBILITY

Carbon emission from transport sector is a result of excessive vehicle mobility in urban area. Hence, there was a necessity to work out Vehicle Kilometre Travel per day to estimate the carbon emission from transport sector in urban area. Vehicle occupancy survey has been carried out by surveying vehicles of each category (i.e. Two-wheeler, car, auto rickshaw and city bus/BRT) during peak hours and off peak hours of week days and weekends in each zone. Average vehicle occupancy for city bus/BRT was found around 36 and same for two wheelers, cars and auto are found as 1.4, 1.5 and 2.6 respectively at aggregate level. Considering vehicle occupancy of, VKT has been worked out for the base year considering proportion of mode share described in the previous section. Total VKT per day for the base year is found around 19.5 million kilometres.

8. CO_2 EMISSION STANDARDS AND EMISSION REDUCTION STRATEGIES

Carbon emission from transport sector can be obtained by knowing the amount of CO2 emission per unit combustion of fossil fuels. Mileage of petrol vehicles are assumed as 50kmpl and 14kmpl for two wheelers and cars respectively whereas mileage of diesel vehicles are assumed as 18kmpl and 5kmpl for cars and bus respectively. CNG operated vehicles' mileage is assumed as 24 km/kg and 30km/kg for cars and auto rickshaw respectively. The emission standards for different category fuels are taken form Transportation Emission Evaluation Model for Projects (TEEMP) managed by clean air Asia and same is tabulated for different category fuel in Table 6.

Table 6 TEEMP standard of CO_2 emission per unit fossil fuel combustion

Fuel	Unit	CO_2 Emission Standard
Gasoline	Litre	2630 g/l
Diesel	Litre	3060 g/l
CNG	Kg	3240 g/Kg

Considering these standards, CO_2 emission is derived and is found to be around 1500 tons per day for the base year

8.1 Scenario For CO_2 Emission Reduction

CO2 emissions are worked out for the planning horizon considering standards for the passenger mobility values obtained through all three models. CFP reduction strategies are developed by applying two different scenarios namely i) Business as Usual (BAU) and ii) Sustainable Urban Transportation.

8.1.1 Business as usual (BAU)

Business as usual scenario assumes that percentage of mode share we observed in the base year will remain same for the planning horizon. Carbon emission up to planning horizon considering this scenario is worked out for VKT value obtained through each model and same is tabulated in table 7.

8.1.2 Sustainable urban transportation (SUT)

This scenario estimates the emission value if the share of public transportation will increase by 5%, 15% and 25% in year 2021, 2031 and 2041 respectively. Carbon emission for the planning horizon considering this scenario is worked for VKT value obtained through each model and same is tabulated in table 7

Table 7 CO_2 emission estimation in ton per day under both scenarios

Year	Business As Usual			Sustainable Urban Transportation		
	Logarithmic	Linear	Modified	Logarithmic	Linear	Modified

			exponential			exponential
2016	1494	1494	1494	1494	1494	1494
2021	2154	2356	2251	2095	2292	2189
2026	2263	2632	2473	2139	2488	2338
2031	3258	4024	3712	2990	3693	3407
2036	3368	4406	3985	2999	3923	3549
2041	4509	6230	5522	3892	5377	4765

8.2 Speed Based Emission and Strategies To Control

Speed based emission has been worked out by all above three models by generating various strategies considering variation in speed. To estimate the CO2 emission based on speed of the vehicle, mode share has been worked out assuming the variation in speed of different category vehicles. Utility function for the city Surat, developed by SVNIT, Surat in 2014 has been used and was calibrated considering the observed data of base year. Observed average speed of 2W, cars, auto and city bus through VBOX tool in the base year are 35kmph, 32kmph, 30kmph and 26kmph respectively. The model has been calibrated by considering Travel Time, Travel Cost and Comfort/ Convenience as variables affecting mode choice. Calibrated model is tabulated in Table 8.

Table 8 Calibrated utility model using observed data of base year

Mode	Utility function
Private Vehicles	U_{pvt} = -5.3-0.048TC-0131TT+2.979CC
Intermediate Public Transport	U_{IPT} = -5.3-0.048TC-0131TT+2.979CC
Public Transport	U_{PT} = -0.048TC-0131TT+2.979CC

Assuming variation in speed of private and public transport vehicles, total four strategies were introduced for CO_2 emission projection.

8.2.1 Strategy -1: Speed of all category vehicles remain same

Strategy assumes that if speed of all category vehicles remains same as base year up to planning horizon, the mode share will also remain same. Hence, the projected CO2 emission will be same as derived in BAU scenarios by all three models.

8.2.2 Strategy -2: Speed of public transport is increased by 5% at every 5 years intervals, speed of all other mode will remain same.

Strategy assumes that speed of public transport i.e. bus, is increased by 5% at every 5 years interval and speed of all other mode will remain same as base year. Assuming this scenario mode share by public transport in 2041 as worked out is 15.89% from current mode share of 7.33%. Also, IPT will share 22.94% from existing 22.05% and significant decrease in private vehicles share is found i.e. from 70.63% to 61.17%. This finally results in to low carbon emission in planning horizon. Projected emission in planning horizon is 4241 tons per day derived by logarithmic model, 5859 tons per day by linear model and 5193 tons per day by modified exponential model.

8.2.3 Strategy -3: Speed of public transport will remain same and speed of all other mode will decrease by 5% at every 5 years interval.

Strategy assumes that speed of public transport will remain same as base year and speed of all other mode will be decreased by 5% at every 5 years interval. Assuming this scenario mode share by public transport in 2041 as worked out is 14.73% from current mode share of 7.33%. Also, IPT will share 28.90% from existing 22.05% and private vehicles share is found 56.38% from 70.63%. Projected carbon emission if the strategy will be implemented is 4237 tons per day derived by logarithmic model, 5854 tons per day by linear model and 5188 tons per day by modified exponential model.

8.2.4 Strategy -4: Speed of public transport is increased by 5% and speed of all other mode will decrease by 5% at every 5 years interval.

Strategy assumes that speed of public transport will be increased by 5% at every 5 years interval and speed of all other modes will be decreased by 5% at every 5 years interval. Assuming this scenario mode share by public transport in 2041 as worked out is 35.41% from current mode share of 7.33%. IPT will share 21.87% from existing 22.05% and private vehicles share is found 42.65% from existing 70.63%. Projected carbon emission if the strategy will be implemented is 3623 tons per day derived by logarithmic model, 5006 tons per day by linear model and 4437 tons per day by modified exponential model.

9. DISCUSSION AND CONCLUSION

The study analysis has been carried out to address the travel mode preference. The analysis performed in this study showed that between 2001 and 2016 many changes have taken place with respect to use of different modes of transport among people living in different zones of the city. In almost all zones, among all the modes, two wheelers seem to be dominating and preferred mode of transport. The share of public transportation is not significant and always remained below 10%. Such increased vehicle ownership naturally results in high increase of vehicle kilometer. This has resulted in increased energy use thereby accentuating higher carbon emission. From the whole study following concluding remarks are noted.

1. Growth trend of PKT from the historical data found exponential. Hence, forecast made with modified exponential model will be more reliable.
2. Historical trend shows that PKT is increasing exponentially and Carbon emission estimated through modified exponential shows significant difference in emission if strategy – 2 is applied i.e public transport speed is increased at 5% rate at every 5 years interval.

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