Towards Sustainable Low Carbon Transport in Surat

Opportunities for Climate Mitigation & Sustainable Development (OPTIMISM)

Report | 2022

Ahmedabad University

ABOUT

This report is part of the OPTIMISM (Opportunities for Climate Mitigation and Sustainable Development) project. OPTIMISM (Opportunities for Climate Mitigation and Sustainable Development) is an international multi-stakeholder partnership and research network funded by the UK Natural Environment Research Council as part of the research council's "Towards a Sustainable Earth" program. The international team consists of four partners: (i) Imperial College London, UK, (ii) Lund University, Sweden, (iii) Waseda University, Japan; and (iv) Ahmedabad University, India. Dr. Darshini Mahadevia (Principal Investigator- India) and Dr. Minal Pathak (Co-Principal Investigator) lead the project team placed in India that is supported and funded by the Department of Biotechnology (DBT), Government of India. The project team in India consisted of Dr. Chandrima Mukhopadhyay, Saumya Lathia, Amitkumar Dubey, Kanika Gounder, Bandish Patel, and Saleem Yatoo.

Adopting a whole-systems perspective, the OPTIMISM project uses the United Nations Sustainable Development Goals framework to analyze (i) the change in human development and the environment amidst rapid and extensive climate action and (ii) the role of insights from sectoral-SDG interaction in creating policies and practices that enable a transformational change. This report stems from the critical assessment Surat's Low-Carbon Mobility Plan and other city-level plans to identify interactions of the city's urban passenger transport sector with UN Sustainable Development Goals (SDGs).

ACKNOWLEDGEMENTS

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ABBREVIATIONS

ARAI	Automotive Research Association of India
ATL	Average Trip Length
ATT	Average Trip Time
BAU	Business as Usual
CAGR	Compound Annual Growth Rate
CMP	Comprehensive Mobility Plan
CPCB	Central Pollution Control Board
CO	Carbon Mono-oxide
CO_2	Carbon Dioxide
EV	Electric Vehicle
FGD	Focus Group Discussion
FY	Financial Year
GhG	Greenhouse Gas
HH	Household
HIG	High Income Group
IPT	Intermediate Public Transport
LIG	Low Income Group
LoS	Level of Service
MaaS	Mobility as a Service
MIG	Middle Income Group
MoUD/ MoHUA	Ministry of Urban Development/ Ministry of Housing & Urban Affairs
NH	National Highway
NMT	Non-motorised Transport
NO_x	Nitrogen Oxide
PCU	Passenger Car Unit
PM	Particulate Matter
PPH	Person Per Hectare
PT	Public Transport
PWD	Public Works Department
RSPM	Respirable Suspended Particulate Matter
ROW	Right-of-Way
RTO	Regional Transport Office
SDG	Sustainable Development Goal
SLB	Service Level Benchmark
SMC	Surat Municipal Corporation
SPM	Suspended Particulate Matter
Sq. km	Square Kilometres
SUDA	Surat Urban Development Authority
TOD	Transit Oriented Development
VKT	Vehicle Kilometres Travelled
2W	Two-Wheeler
3W	Three-Wheeler
4W	Four-Wheeler

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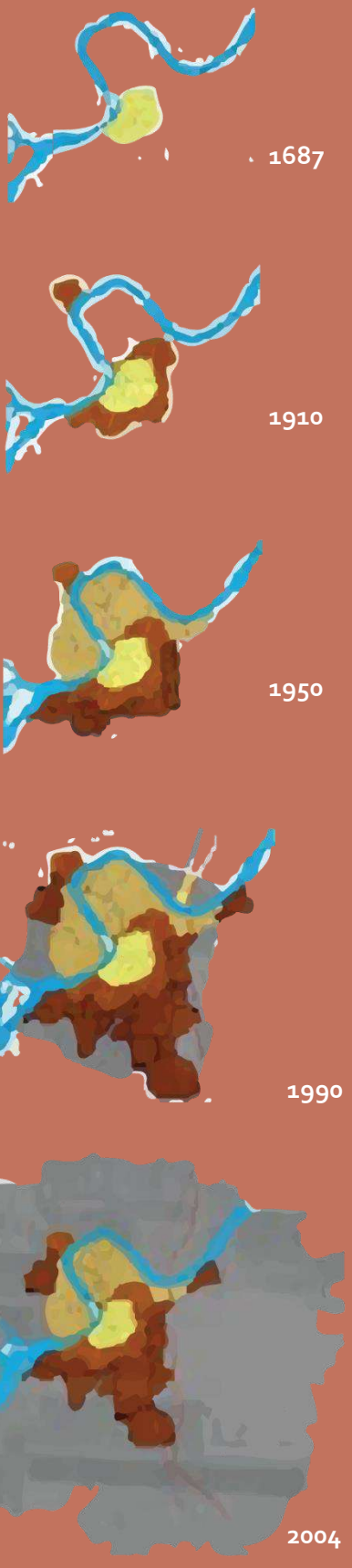
INTRODUCTION

Surat is 265 kilometres south of Ahmedabad and 289 kilometres north of Mumbai. Spread across 985 sq. km, Surat Urban Development Area (SUDA) inhabits a population of 5.9 million. With 92% of the world's diamonds being cut and polished in the city, Surat is known as the "Silk City," the "Textile City," and the "Diamond City of India." It is the second largest city and one of Gujarat's most important trade centres, with a well-established industrial node and visited as a shopping centre for apparel and accessories.

Surat lies along the Tapi River, has one of the earliest ports, and serves as a significant destination for employment seekers due to its robust economic base. It also has a vibrant and valued heritage, where more than 84 countries used this port in the past. The British first landed in India via Surat. The Dutch and the Portuguese established business centres in Surat, preserved in the city. The sex ratio has been declining over the past few decades and is currently the lowest in the state. The large influx of the male-migrant population in Surat- which gives Surat the status of "Migrant City"- is a primary reason for its low sex ratio. According to a study by Oxford Economics, Surat is the world's fastest-growing city (Economic Times, 2018).

Picture 1 Aerial view of Surat City

Figure 1 Urban Sprawl in Udaipur

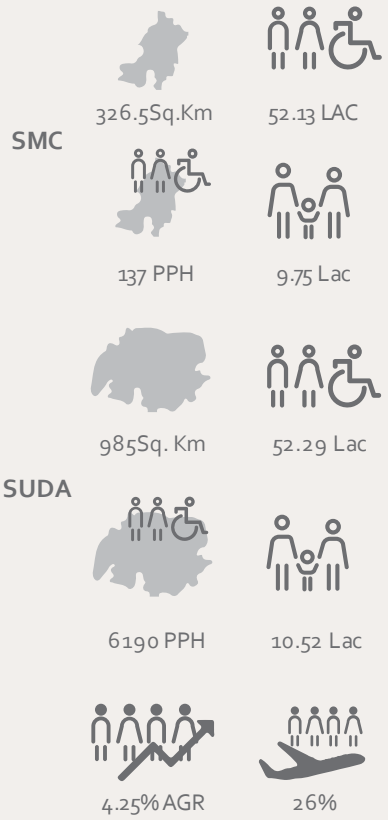


Source: Surat City Resilience Strategy, NIUA (2011)

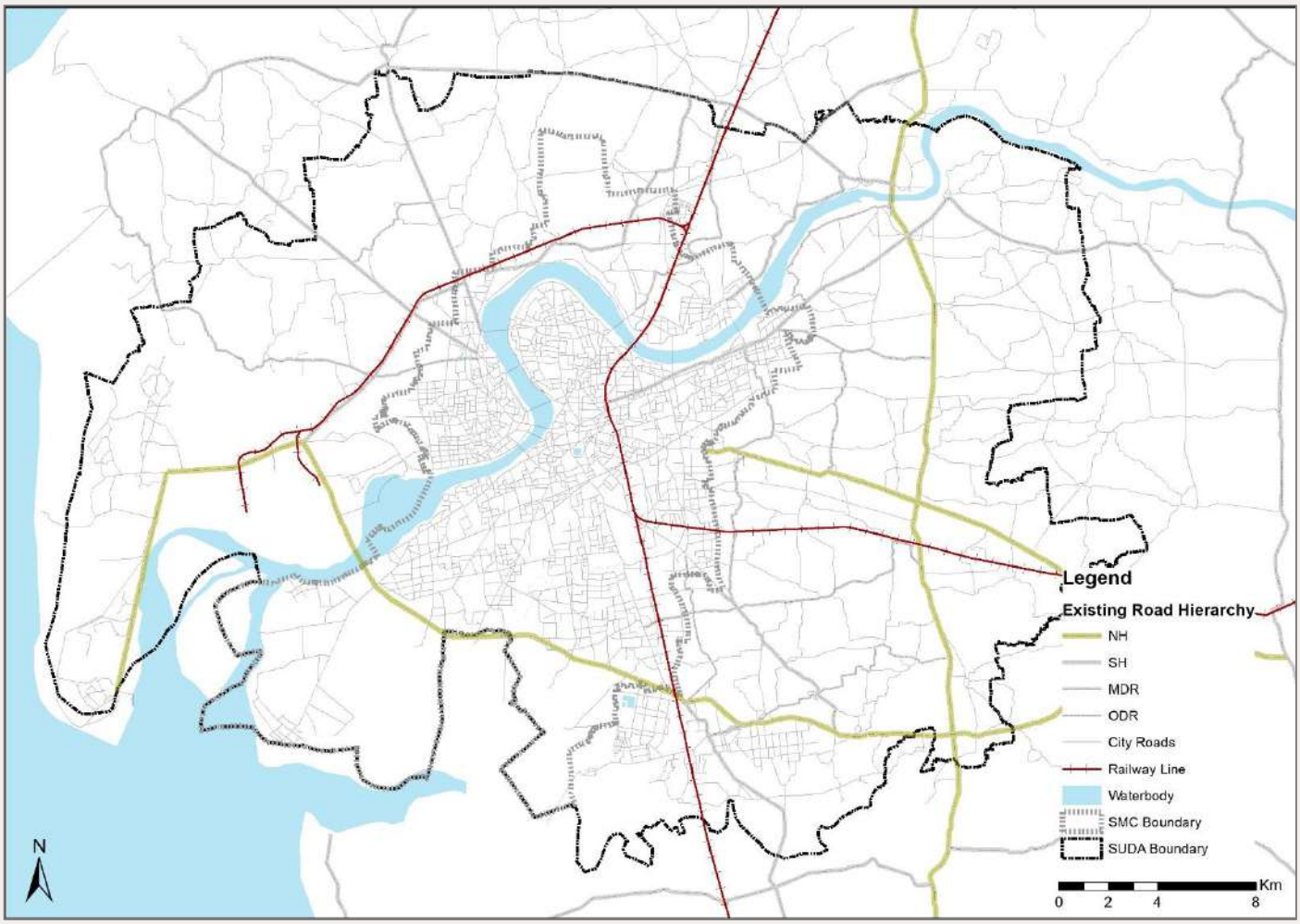
Picture 2: Aerial view of Surat City

Source: Surat Municipal Corporation Website

Figure 2: City's Demographic Profile



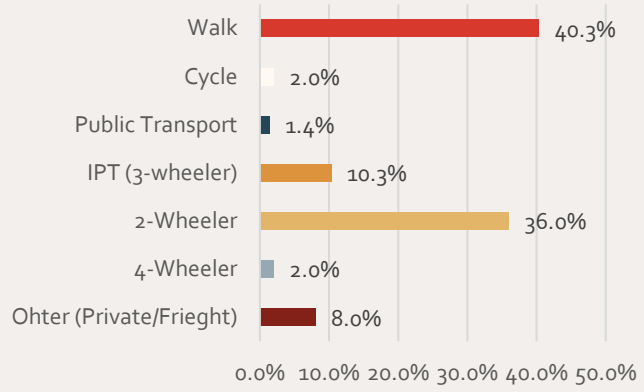
Map 1 Surat Urban Development Area Boundary



TRANSPORT SYSTEMS & KEY CHARACTERISTICS

The per capita trip rate in Surat increased from 1.13 in 2005 to 1.60 in 2016, indicating increased travel in the city. The motorized trip rate also increased from 0.8 to 0.9. Table 3 also shows the overall average trip length to be 5.09 km, comparable to cities like Surat's size. The average trip length (ATL) for walk and cycle trips is about 2.9 km and 4 km, respectively. Similarly, the ATL for two-wheelers and IPT is 6 km. City bus and BRT trips are the longest, more than 10 km.

Figure 3 Mode share of trips in the SUDA Area



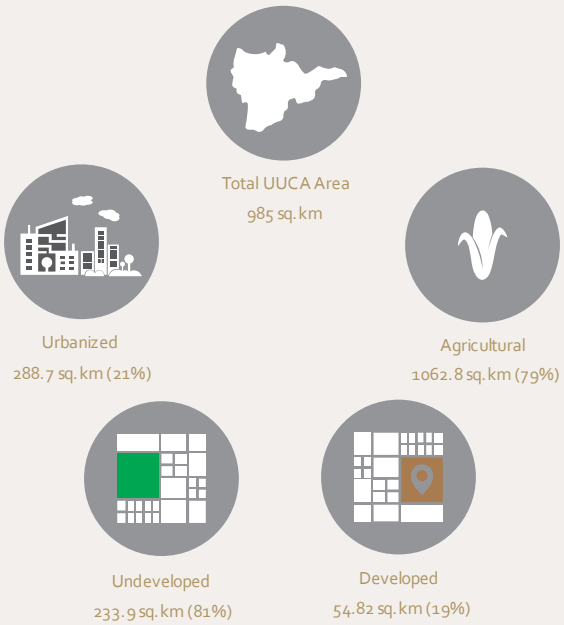
Source: Surat CMP 2016

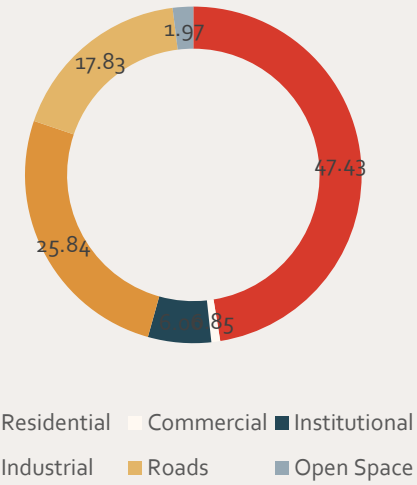
Like most Indian cities, Surat's dependence on personal motorized transport is rapidly increasing. Since 1988, the share of NMT users has decreased from 65% to 43%. Out of which share for pedestrians and cyclists reduced by 10% and 17%, respectively. Similarly, public transport trips accounted for about 5.7% of all trips and have dropped to only 1.4%. This share increased to 3% in 2017, with about 1.6 lakh passenger boarding (12 per 1000 population). Between 2008-2016, auto-rickshaw trips were reduced to half. In contrast, two-wheeler trips increased by 6% (a high decadal growth rate), owing to rapidly increasing average household incomes in Surat.

LAND-USE & DENSITY

Compared to similar-sized Indian cities, Surat is relatively compact and polycentric. 88% of its population resides within the municipal area (Surat Municipal Corporation - SMC) of 326.5 sq. km. Surat witnessed rapid spatial expansion radially along five major corridors in the 1980s (SMC, 2004; SMC, 2017). Since then, the city has continued to proliferate on the southern, eastern, and south-western sides, owing to the development of industrial areas and residential zones in the Surat Urban Development Authority (SUDA) region. The urbanized area in the city tripled between 1978 and 2004, with development within the SMC limits. In 2014, urbanized areas comprised only 21% of the total area; more than 47% comprised residential and mixed-use areas; almost 25% and 18% of this urbanized area fell under industries and transport, respectively; and only 1% attributed recreational land-use, indicating a lack of open/ public spaces.

Figure 4 SUDA's Land Profile





Almost 25% and 18% of the urbanised area falls under industries and transport respectively. Only 1% of the urbanised area is classified as recreational indicating a lack of open/ public spaces.

MOTORIZATION & ROAD INFRASTRUCTURE

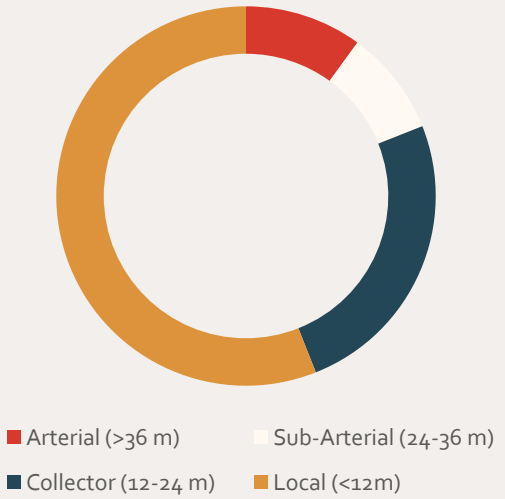
Road Network: The street network in Surat follows an incomplete ring-radial pattern with three rings and 14 radials. The inner ring road carries high volumes of traffic connecting to all significant radials and surrounding major destinations in the inner-city area. In Surat, missing links along the ring roads disrupt road hierarchy and traffic flow in the surrounding areas. The middle ring has inconsistent road widths, and the third ring (SH-168) is a half ring connecting only the western part of the city. All roads in the walled city have constrained widths varying from 12m to 18m, leading to frequent bottlenecks. Surat has a web of 123 existing bridges/ flyovers/ underpasses and 11 under construction and is home to long and frequent traffic congestion issues. 66% of the road network lacks clear lane markings. About 18% of networks reported poor pavement conditions, impacting its overall performance.

41,95,348

9% CAGR

With a web of 123 existing bridges/ flyovers/ underpasses and 11 under construction, Surat is home to long and frequent issues of traffic congestion.

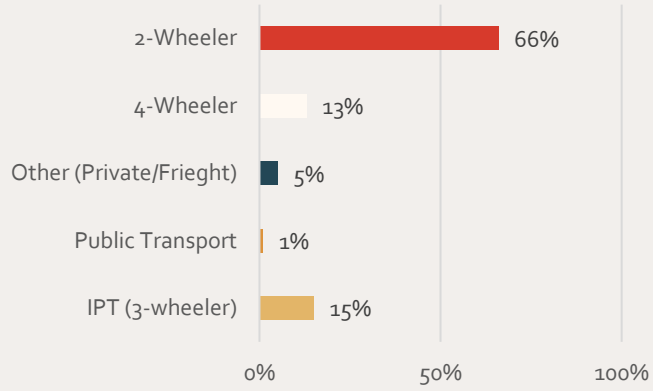
Figure 5 Road Hierarchy distribution in SUDA



Vehicular Growth: The growth rate of vehicle registrations is about 9% per year, with more than 95% private vehicles. The traffic levels increased by 2.5 times in the last decade, with the current demand for private vehicles being about 30.24 lakh PCUs. Rapid motorization has resulted in the rise of CO_2 emissions, with higher RSPM and SPM percentages than the standard norms set by the CPCB.

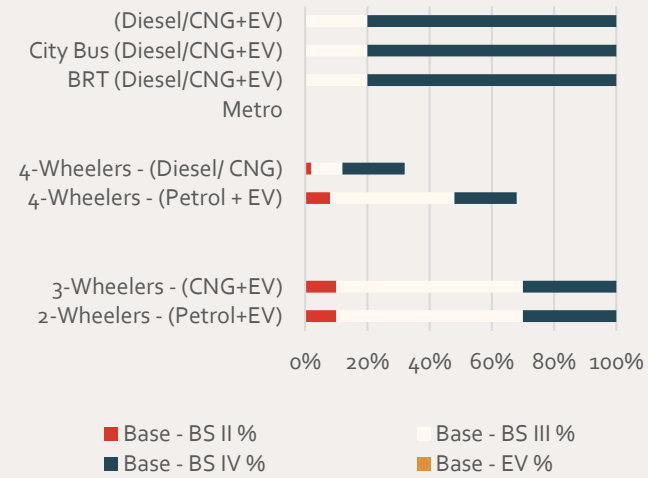
Private vehicles make 79% of the traffic composition, leading to a higher motorized VKT. Surat has a total of 25.75 million motorized VKT per day.

Figure 6 Traffic Composition in SUDA Area



Source: Surat CMP 2016

Figure 7 Fuel Composition by Mode



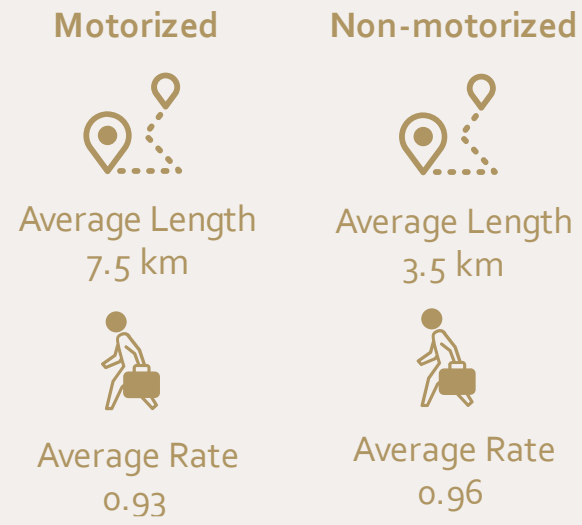
Traffic Composition: Personal motorized vehicles comprise about 79% of the vehicle composition. Two-wheelers contribute to two-thirds of total vehicles in traffic, and four-wheelers and three-wheelers constitute the rest. In contrast, public transport vehicles are almost non-existent, with only 1% of the share. 2-wheelers also contribute to more than 2/3 of the annual vehicle

kilometres travelled (VKT), followed by four-wheelers (17%) and three-wheelers (15%). In terms of parking, the city has increased the availability of paid parking spaces offering a supply of 7775 parking bays to the users.

NMT NETWORK & INFRASTRUCTURE

Like most Indian cities, Surat has poorly developed and maintained NMT infrastructure. In 2015, only 20% of the city roads had footpaths (61 km of footpaths against a total road network of 302 km), and only 7.6% (23 km of the city roads) had cycle tracks (Figure 10). Out of the 115 major junctions in Surat, only 44 (38%) are signalized; half of those have pedestrian crossing with more than 45 seconds of wait time. 25% of cycle tracks are encroached on by unpaid on-street parking. 33% of interchanges had dedicated cycle parking facilities. About 20% of the roads have no tree cover along the network. Of the four major interchanges (Surat railway station, Chowk, Udhana, and Kharwarnagar), only the Surat city railway station has a dedicated cycle parking facility. The overall LoS for pedestrian infrastructure is 3, and that for cycling infrastructure is 4.

Figure 8 Average Trip Length & Rate by Modes



Share of NMT users decreased from 65% in 1988 to 43% in 2016.

The share of pedestrians decreased from 45.4% in 1988 to 41% in 2016, while the share of cyclists decreased from 19.2% in 1988 to 2% in 2016.

The trip lengths for all walk trips in the city are about 2.9 km long. 15% of work trips and 39% of educational trips on foot. 85% of other purposes trips, like shopping, religious, and recreational, are by walking. For cyclists, the trip lengths are about 4.1 km long. About 3% of all work and educational trips are on cycle. Less than 1% of all other purpose trips are by cycling.

Figure 9 NMT Infrastructure Highlights

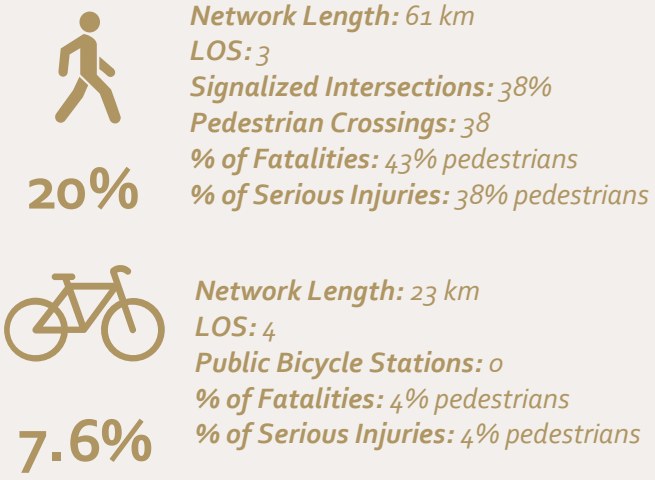
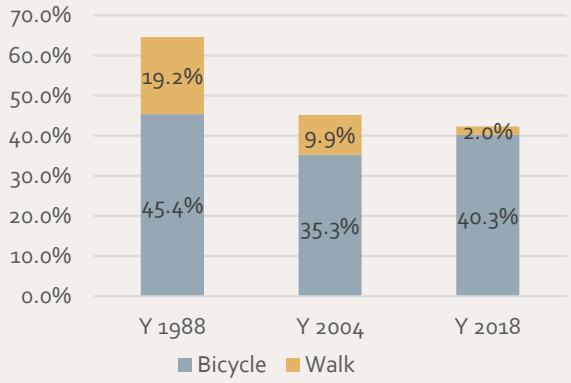


Figure 10 NMT Mode Share over the years in Surat



PT/ IPT NETWORK & INFRASTRUCTURE

The number of IPT vehicles in the city is growing at an annual growth rate of 4% but reducing in *Fleet/ 1000 Population* ratio. The IPT system has failed to change as per the need of the city's growth. Personal and shared autos operate in Surat on 52 designated routes. Out of the 38,000 registered autos operating in the city (85% fuelled by CNG), account for 14 IPT vehicles per 1000 population, and make 8.6 lakh trips. An initial fleet of 40 rickshaws- known as "Pink Autos" (operated for women, by women)- are deployed as a feeder system for the city bus and BRT in the old city. The overall LoS for IPT services is 3.

In 2016, 15% of educational trips, 5% of work trips, and 5% of other-purpose trips were made via IPT. The average trip length for IPT trips is about 6.1 km.

Surat's entire public transport network is spread across 376 km, constituting the city bus and BRT networks. The

city bus service operates along 274 km at 29 routes serving 73% area in the city. A fleet of 236 buses carries about 82,000 passengers per day (as of February 2018) with a headway of 8-20 minutes between two buses. Surat also has the largest BRTS in India, with a 102 km network operational with 116 BRTS buses. It carries about 80,000 passengers per day. It ensures rapid transit and mobility with an average speed of 24 kmph, which is relatively high compared to the existing city bus services and auto rickshaws. However, the overall LoS for PT services are 3.

Due to unorganised operations, auto-rickshaws suffer from problems of overcrowding and poor vehicle quality. Even though they serve better coverage and frequency in comparison to the bus network, they also contribute to issues of high congestion and pollution levels in the city.

Figure 11 PT & IPT Infrastructure Highlights

SMC IPT Network Coverage: *34%*
Fleet: *38,000*
No. of Routes: *52*
Trips/ Day: *8 Lac*
LOS: *3*

34%

Network Length: *376 km*
SMC PT Network Coverage: *87% built up area*
City Bus Fleet: *236*
BRTS Fleet: *116*
City Bus Routes: *29*
BRTS Routes: *35*
Ridership/ Day: *1,62,000*
LOS: *4.0*

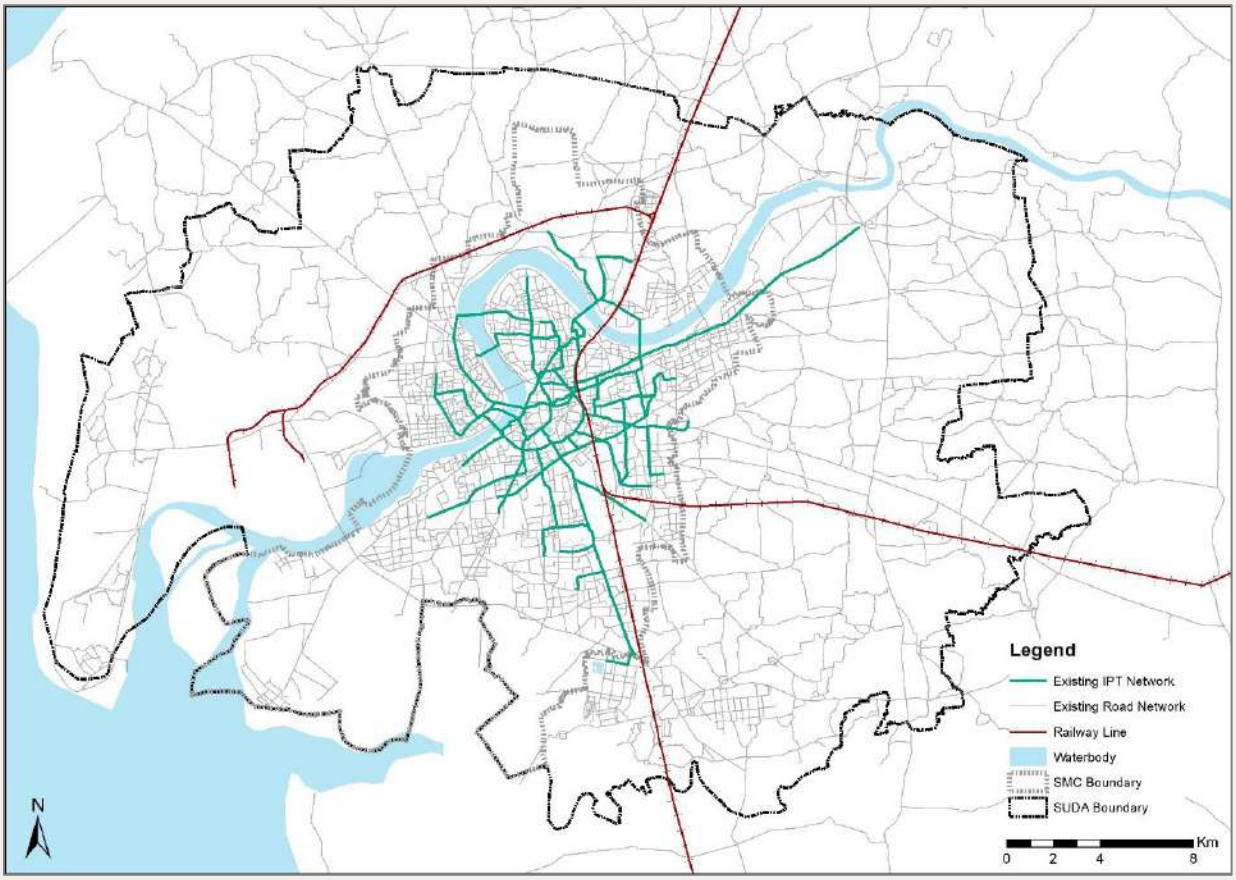
48%

The city observed a growth in the mode share of buses doubling from 1.4% in 2016 to 3% in 2017, highlighting the success of integrating more than 2 modes with an increased supply and an improved quality of service. But, the mode share of PT in the city is still very low and this can be attributed to the non-existent PT system in the city till recently

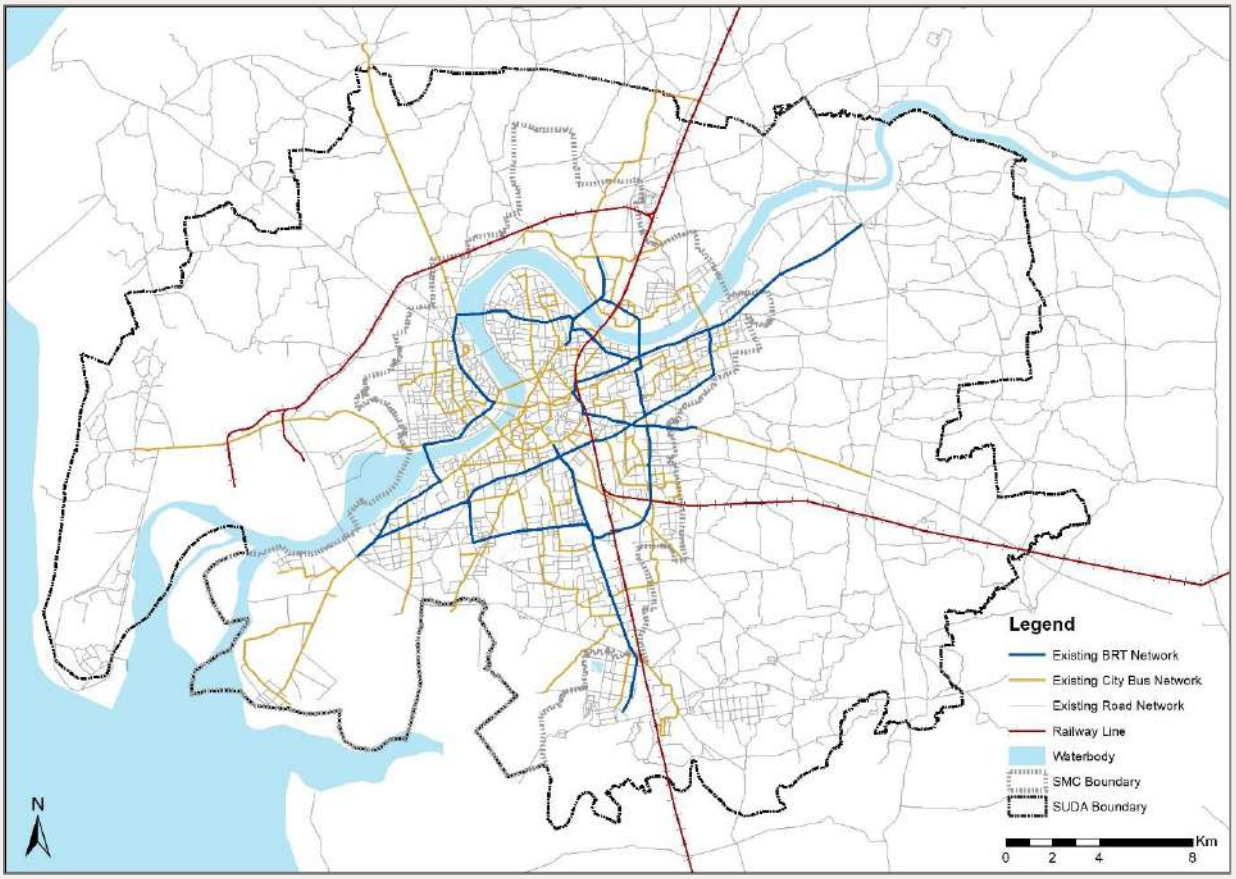
After implementing an integrated city bus and BRT operations in the city, Surat's public transport mode share doubled from 1.4% in 2016 to 3% in 2017. Surat's multimodal integration example shows that improving user experience, ease of transferring modes, and increased frequency can encourage a shift to public transport. Surat's Public Transport Operations Plan outlines 550 km of an integrated city bus and BRT network, with a robust fleet of 1000 buses. The city also acquired about 400 electric buses for the BRT network.

Nevertheless, Surat's public transport mode share is still meager, which can be attributed to the non-existent PT system in the city till recently. City buses and BRT trips only 1% of all work, education, and work trips, indicating a gap in demand and service. The public transport trip rate is considerably low- about 0.01 trips/ capita/ day with an average trip length of 10.3 km.

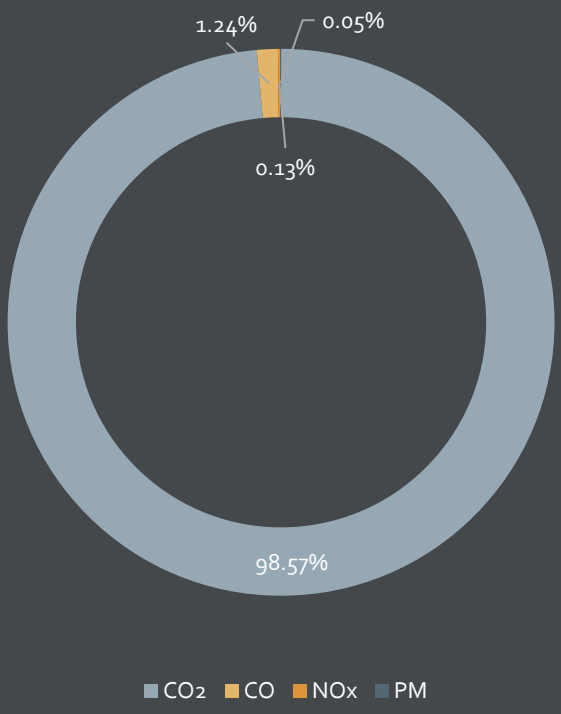
Map 2: Existing IPT Network in SUDA Area



Map 3: Existing City Bus and BRT Network in SUDA Area

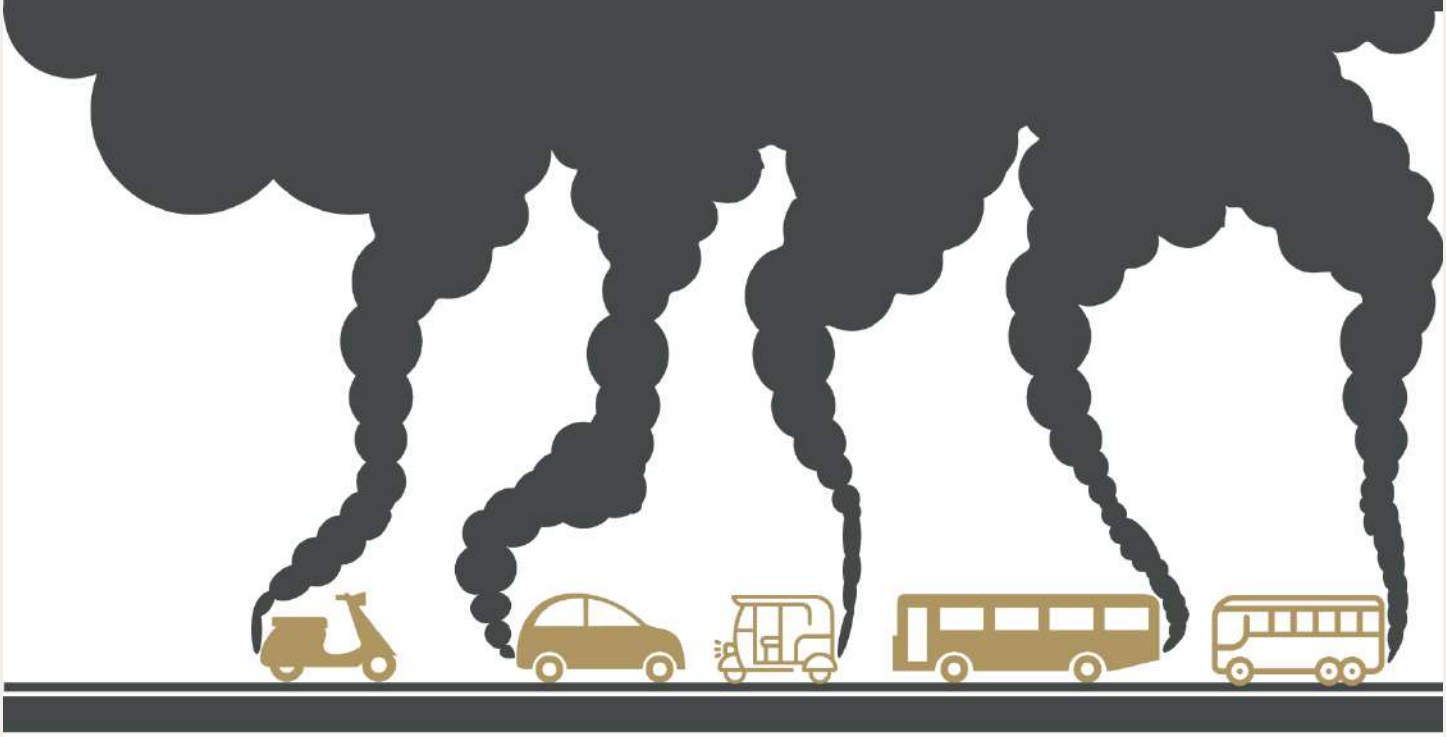


Emissions from Surat's Urban Passenger Transport



346,206 Tons
Total GHG Emissions

52.96 kg
Per Capita GHG Emissions



47.09%	36.65%	15.62%	0.64%	4.36%
2-Wheelers	4-Wheelers	3-Wheelers	Buses (PT)	Other Buses

GHG EMISSION INVENTORY

Adopting a bottom-up approach and the ASIF[1] methodology, a Greenhouse Gas (GHG) emission inventory was calculated from the on-road vehicle exhaust emissions in the city for the base year (2016). The emissions inventory consists of five urban passenger transport modes: 2-wheelers, 3-wheelers (IPT), 4-wheelers, public buses (city bus fleet and BRT), other buses (private), and Metrorail (only applicable for 2030), and four pollutants- particulate matters (PM), nitrogen oxides (NO_x), CO and CO_2. The results do not include inter-city bus, rail or air transport, or freight transport.

Figure 12 CO_2 Emissions in Surat (tons/ year)

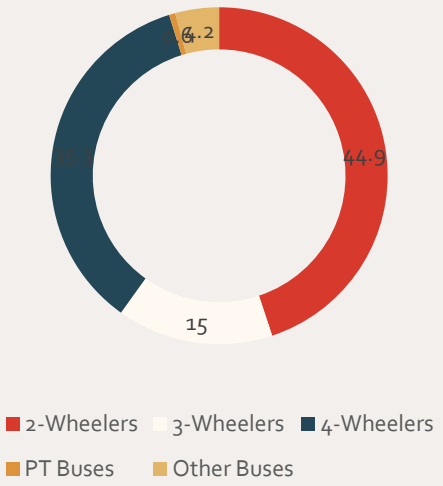


Figure 13 CO Emissions in Surat (tons/ year)

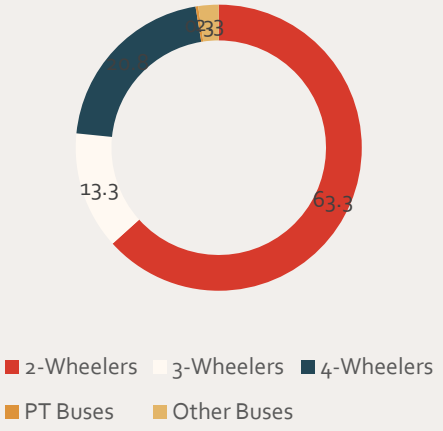


Figure 14 NOx Emissions in Surat (tons/ year)

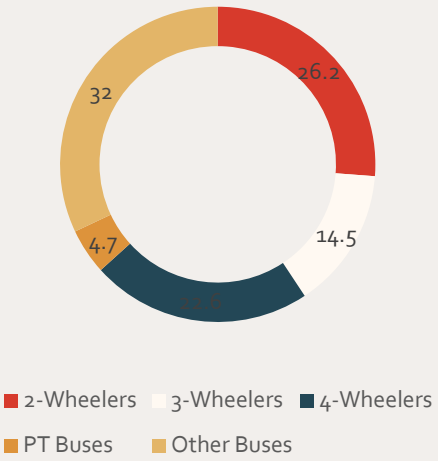
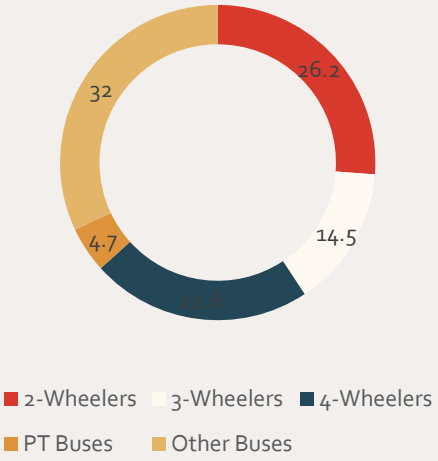


Figure 15 PM Emissions in Surat (tons/ year)



Source: Calculated using data from Surat CMP 2016

Two-wheelers contribute to the highest carbon-dioxide emissions (44.9%), followed by four-wheelers (35.3%) and three-wheelers (15%) emissions (Figure 12). Two-wheelers generate over 60% of CO emissions in the city, followed by four-wheelers (20.8%) and three-wheelers (13.3%). City Bus and BRT generate less than 0.5% of the CO emissions (Figure 13). The largest share of NOx emissions comes from Other Buses, followed by two-wheelers (22.6%) and four-wheelers (26.2%) (Figure 14). Two-wheelers generate the largest share of PM emissions from transport in Surat (76.3%), followed by three-wheelers (12%) and three-wheelers (9.1%). City

[1] ASIF refers to the product of activity (A), modal share (S), energy intensity (I) and fuel/ carbon intensity (F). Activity-based sectoral equation:

*Emissions = Number of Vehicles * Vehicle kilometres travelled (km) * Emission Factor (gm/km)*

Bus and BRT have the lowest PM emissions (0.3%) (Figure 15).[2]

Table 1 GhG Emissions by the transportation sector in Surat (tons/year)

Transport Modes	CO_2	CO	NO_x	PM	Total Modal Emissions
2-Wheelers	159911.50	2789.29	176.55	145.52	163022.86
3-Wheelers	53385.16	583.81	97.74	22.92	54089.62
4-Wheelers	125790.59	916.96	151.88	17.27	126876.70
PT Buses	2170.78	14.70	31.59	0.65	2217.72
Other Buses	14784.01	100.14	215.12	4.44	15103.71
Total	**341258.02**	**4304.76**	**457.75**	**186.37**	346206.90

Source: Calculated using data from Surat CMP 2016

Picture 3 Old City of Surat

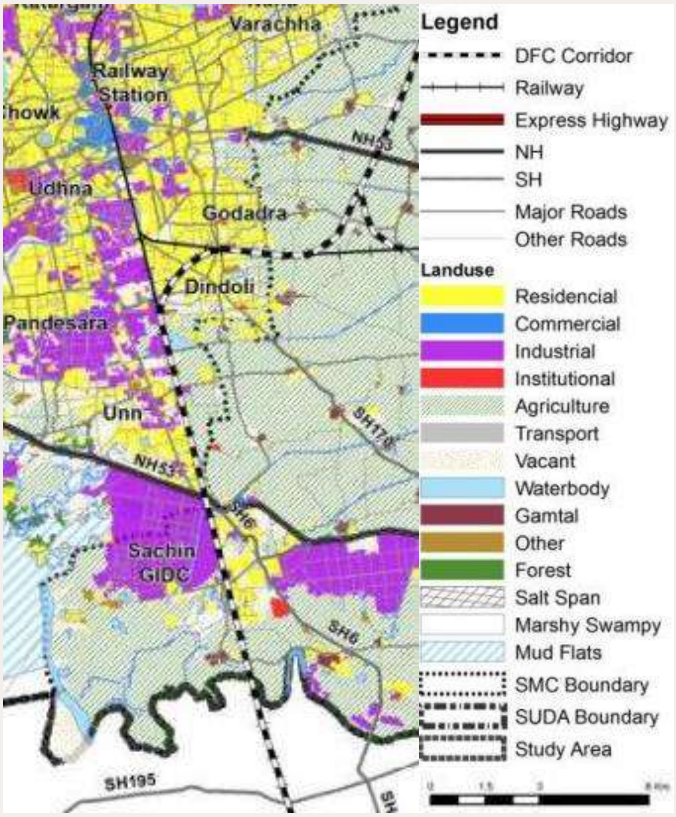
Source: Kanika Gounder

[2] Data sources include Surat's Comprehensive Mobility Plan (CMP), Automotive Research Association of India's (ARAI) Emission Factor Development for Indian Vehicles, Central Pollution Control Board (CPCB) data and 2014 Toolkit for Comprehensive Mobility Plan.

TRANSPORT-SDG INTERACTIONS: EXISTING SITUATION

The interactions discussed here result from a critical assessment of Surat's CMP and fieldwork data analysis. The primary surveys and semi-structured interviews were conducted in December 2020. Detailed Transport User Surveys (sample size of 264) were supplemented with Household Surveys (HH), Low-income Housing Surveys, semi-structured interviews of local shops and vendors, and focus group discussions (FGDs). Transport User Surveys consisted of Non-motorized Transport users (pedestrians and cyclists), Public Transport users (City Bus & BRTS), Intermediate Public Transport users (shared & personal Auto), Private Vehicle users (two-wheelers and four-wheelers), and Taxi/ shared mobility users.

Figure 16 Existing Land use along core spine of the city (2016)



Source: Surat CMP 2016

In this section, each urban transport systems element is discussed in the context of six selected Sustainable Development Goals- SDG1: No Poverty, SDG3: Good Health and Well-being, SDG5: Gender Equality, SDG8: Economic Growth and Employment, SDG11: Safe, Resilient and Sustainable Cities, and SDG13: Climate Action. Their urban transport and SDG interactions are illustrated as positive/ synergies (green), negative/ trade-offs (red), mixed (yellow), or neutral/ no interaction (white).

WITH LAND-USE & DENSITY

Surat has a compact form with high densities in the core city. Higher densities are often linked with better accessibility to public transport, improving economic outcomes. However, Surat's poor public transport coverage, Level of Service (LOS), and unaffordability deprive the vulnerable populations of benefitting from high-density development (SDG1, SDG11). Moreover, with more affordable housing constructed on the city's outskirts, the lack of connectivity to the city center remains a significant challenge for the city's vulnerable groups, especially the urban poor. Lack of transport access often exposes them to negative externalities like time poverty (SDG1, SDG5), increased health costs from pollution (air, water, and noise), and shorter life expectancy (SDG3).

Presence of industrial areas within the city and close to residential areas lead to possibility of air/ noise pollution to residents, along with bypassing freight movement threatening road safety.

Incompatible land uses placed in proximity, like industrial and residential, result in local sustainability challenges like (i) increased air and noise pollution from the constant movement of goods traffic (SDG11, SDG13) and (ii) road fatalities/ injuries from high conflict between passenger and freight movement (SDG3). High-intensity of mixed-use activities causes a concentration of road accidents in and around the central city (SDG3). This conflict also leads to frequent traffic congestion and bottlenecks, increasing exposure to deteriorated air quality, aggravating stress/ anxiety while driving (SDG 3), and reduced workers efficiency and productivity (SDG 8), along with deteriorated air quality (SDG 11). Loading–unloading of goods also creates a haphazard parking situation, resulting in loss of comfort to the other road users, curbed mobility and deteriorated environment quality (SDG 11). On the other

hand, mixed use environments create a perception of safe environments for women due to round-the-clock activities (Phadke 2007; Vishwanath 2009), generating a synergy for SDG 5.

Picture 4 Informal market below a web of flyovers in Surat

Source: Kanika Gounder

SDG Impacts: This category generates both synergies and trade-offs with the SDGs. But it is also the only category with "mixed impacts". Lack of connectivity to the city center, overcrowding (especially in the inner-city area) and incompatible land-uses generate a trade-off in terms of:

- Physical and mental well-being, possibility of road crash fatalities (SDG 3)
- Lack of connectivity and environmental degradation (SDG 11 & 13)
- Time poverty and loss of productivity (SDG 1 & 8).

While mixed use development fosters a synergy with:

- Women's Safety (SDG 5)
- Economic growth (SDG 8)
- Shorter trip lengths and an increased use of sustainable transport modes (SDG 11 and 13).

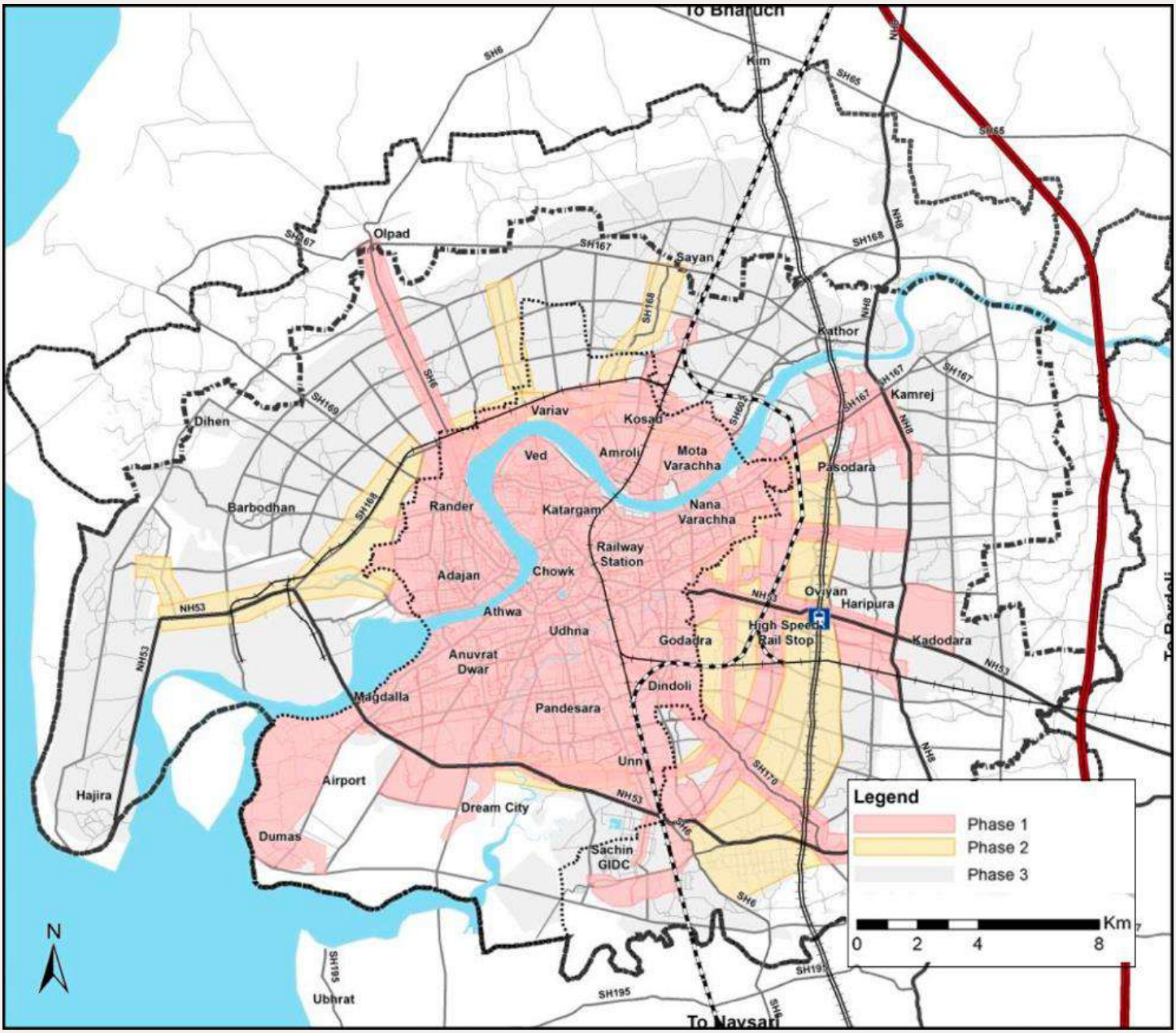
Figure 17 SDG Interactions with Land-use & Density in Surat

SDG	SDG 1: Poverty					SDG 3: Health & Well-Being					
SDG Target	1.1	1.2	1.3	1.4	1.5	3.1	3.2	3.4	3.6	3.8	3.9
Composite Index											
(i)											
(ii)											
SDG	**SDG 5: Gender Equality**					**SDG 8: Decent Work/ Employment**					
SDG Target	5.1 / 5.2	5.4	5.5	5.6	8.1	8.2	8.3	8.4	8.5	8.8	8.9
Composite Index											
(i)											
(ii)											
SDG	**SDG 11: Safe, Inclusive, Resilient & Sustainable Cities**								**SDG 13: Climate Action**		
SDG Target	11.2	11.3	11.4	11.5	11.6	11.7	11.A	11.B	13.1	13.2	13.3
Composite Index											
(i)											
(ii)											
Legend	(i) Population density (SUDA): 62 PPH					(ii) Land-use: Open spaces- 0.85%, Mixed- 62%					

WITH MOTORIZATION & ROAD INFRASTRUCTURE

Over the years, Surat has opted for road-based solutions over PT and NMT to improve mobility; the city invested Rs. 869.70 crore (2016) in the construction of bridges and flyovers. The road-based solution has exponentially increased dependence on personal vehicles with a motorized mode share of 75%, leading to a higher VKT. As per the CMP household survey, the vehicle ownership in the city has drastically increased from 40/1000 people to 296/ 1000, adding to high levels of congestion and emissions (SDG 11 & 13). The wide roads, bridges and flyovers result in various negative externalities, especially for the vulnerable groups (i) evictions, displacement and deepened poverty, reduced resilience of the among the vulnerable residing around/ on road and road projects (SDG 1); (ii) increased congestion and related health issues like stress and anxiety for all from driving in such conditions and (iii) higher risk of developing cardio-vascular/ respiratory diseases due to increased air pollutants exposure (SDG 3). The increased congestion also contributes to time poverty for women, affecting their participation in the society (SDG 5).

Map 4 Area Phasing for Future Proposals for Road Infrastructure Projects

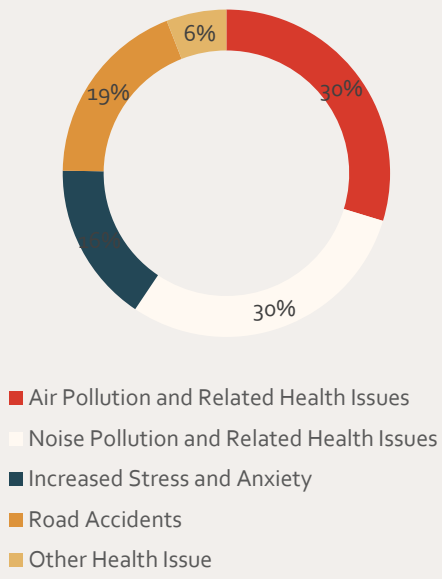


Picture 5 Parking below flyovers in Surat


Source: Kanika Gounder

Poor pavement conditions, lack of adequate street infrastructure discourages the use of NMT modes, resulting in increased risk of road accidents and injuries (SDG 3). As per the inventory surveys conducted for major rings radials and the bus route network roads shows that almost 42 km of the network is used for street vending activities. These street vendors work in an unregulated and risky environment (from conflict with vehicular and freight movement), that affects their mental and physical health and productivity. Additionally, 47.5% of the roads constitute parking encroachments, mainly due to the increase in the paid parking space availability from 78% to 92%, contributing to higher traffic levels. Due to these unregulated activities and traffic flow mismanagement issues, the productivity of workers is affected, violating their notion of a 'decent work environment' (SDG 8).

Figure 18 Households with exposure to negative externalities



Source: Primary Data, December 2020

SDG Impacts: This category mostly generates trade-offs with most SDGs. Overwhelmingly high mode share of personal vehicles (75%), high VKT and massive investments in automobile-based transport solutions generates trade-offs with:

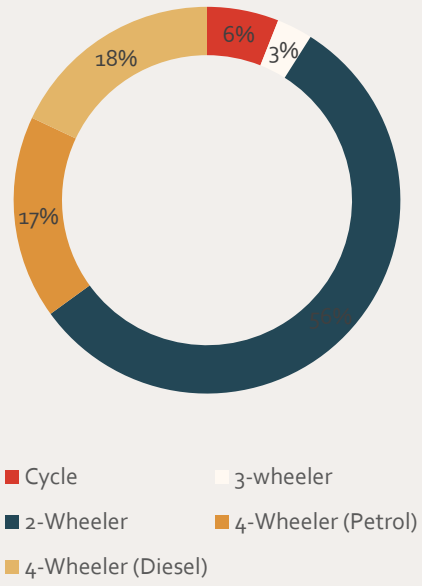
- Sustainable mobility for all (SDG 11)
- Environmental conservation and emission reduction (SDG 13)
- Safe access to employment opportunities and valued paid work under "decent work environment" (SDG 1, 5 & 8).

Road space in Surat is highly contested with heterogenous road users: private bus operators, other motorized vehicles, pedestrians, street vendors, illegeally parked vehicles etc. This causes accidents, severe congestion, and conflict, leading to numerous trade-offs.

A senior government officer stated that "a car parked on the street consumes 15 sq. m, while a car parked off street requires 23 sq. m." They further added that "these figures are startling when seen in the context of minimum sizes of dwelling units specified in Development Control Regulations (DCR) of most cities—18–25 sq. m".

Source: CMP, 2018

Figure 19 Household Vehicle Ownership in Surat



Source: Primary Data, December 2020

Table 2 Current and Desirable Household Vehicle Ownership in Surat

Currently Own	No. of Households (%)	Would like to Own	No. of Households (%)
Cycle	11	Cycle	20
2W	97	Two-wheeler	40
3W	5	Two-wheeler	65
4W	29	Four-wheeler	44
Other	32	Four-wheeler	61
Total	174	Total	230

Source: Primary Data, December 2020

Figure 20 SDG Interactions with Motorization & Road Infrastructure in Surat (2016)

SDG	SDG 1: Poverty					SDG 3: Health & Well-Being					
SDG Target	1.1	1.2	1.3	1.4	1.5	3.1	3.2	3.4	3.6	3.8	3.9
Composite Index											
(i)											
(ii)											
(iii)											
(iv)											
(v)											
(vi)											

SDG	SDG 5: Gender Equality				SDG 8: Decent Work/ Employment						
SDG Target	5.1 / 5.2	5.4	5.5	5.6	8.1	8.2	8.3	8.4	8.5	8.8	8.9
Composite Index											
(i)											
(ii)											
(iii)											
(iv)											
(v)											
(vi)											

SDG	SDG 11: Safe, Inclusive, Resilient & Sustainable Cities								SDG 13: Climate Action		
SDG Target	11.2	11.3	11.4	11.5	11.6	11.7	11.A	11.B	13.1	13.2	13.3
Composite Index											
(i)											
(ii)											
(iii)											
(iv)											
(v)											
(vi)											

Legend

(i) Motorization Rate: 9%; VKT: 25.7 million km/ day

(ii) 2-Wheelers motorized mode share: 62%

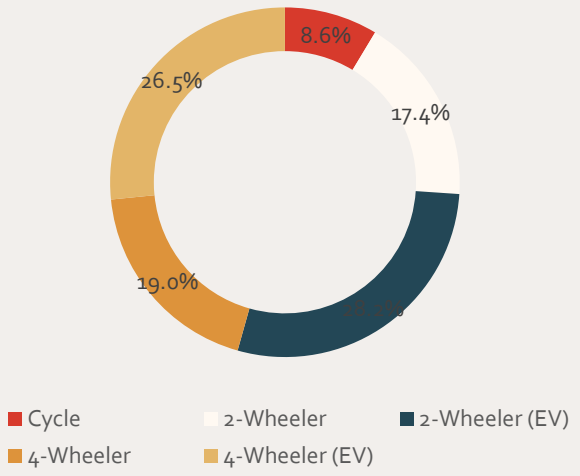
(iii) 4-Wheelers motorized mode share: 13%

(iv) 8 highways and 123 flyovers/ bridges/ underpasses passing through

(v) 57% streets face traffic congestion

(vi) Illegal and unorganized parking: 48% streets have onstreet parking

Figure 21 Desired Household Vehicle Ownership in Surat



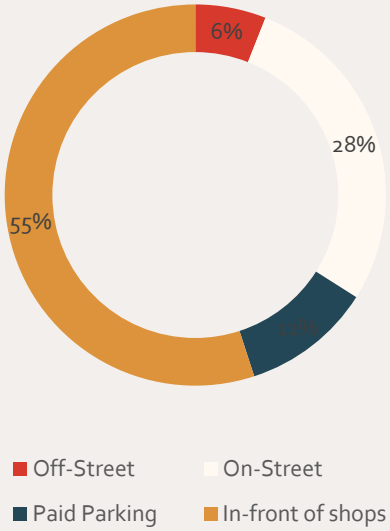
Source: Primary Data, December 2020

"All roads in the walled city are congested due to high volumes of traffic and constrained widths varying from 12 m to 18m." - CMP, 2018

A local from Surat's Police Colony area reported that because of lack of footpaths

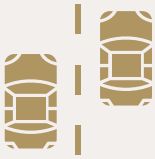
"there are constant conflicts between pedestrians and vehicles, leading to frequent road accidents... this is even worse during monsoon-especially at the crossroads- as roads are often water-logged."

Figure 22 : Commercial parking by type in Surat



Source: Primary Data, December 2020

Road Density 12 (km/km2)



~14%Streets withV/C Ratio > 1

WITH NMT NETWORK & INFRASTRUCTURE

Safe and convenient access to PT/ IPT or to the surrounding areas is a major challenge in Surat, especially for vulnerable groups (women, poor, elderly, disabled, etc.) that are heavily dependent on NMT infrastructure.

"Footpaths in my neighbourhood are narrow or are often interrupted with vendors, pushing us to walk with the vehicular traffic" - Focus Group Discussion (FGD) Participant

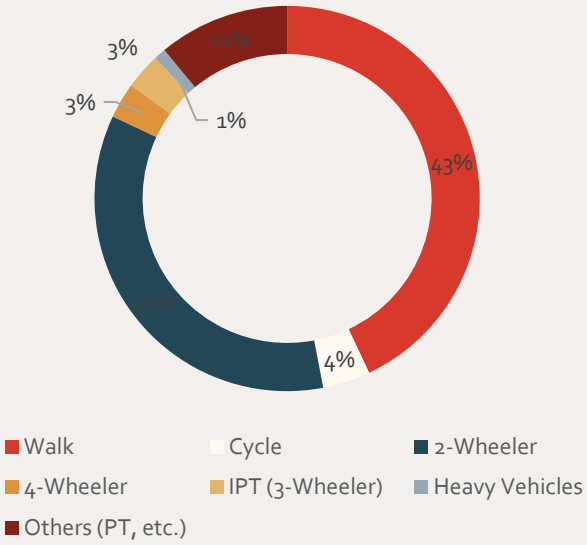
Picture 6 Absence of NMT Infrastructure in Surat

Source: Kanika Gounder

Absent or inadequate NMT infrastructure in the city discourages the use of footpaths and cycles, in turn access to economic opportunities and effective participation in public/ civic life. NMT users are forced to share the carriage way with passenger and freight traffic, as footpaths are discontinuous, of irregular widths and levels and often encroached by parked vehicles or adjacent property owners. This reduces the width of the existing infrastructure, and results in an increased risk of road accidents for NMT users (SDG 3).

Most road crashes/fatalities occur in areas where the activity mix creates unsafe crossings, especially for NMT users; 33% of all fatalities and 43% of all affected modes in the city include pedestrians and cyclists. 42% of all serious injuries are caused to NMT users. Absent or poorly-maintained NMT infrastructure also causes women discomfort, increases their fear of violence, and curbs their mobility (SDG 5).

Figure 23 Share of road users involved in fatalities in Surat



Source: Primary Data, December 2020

18% of all NMT users surveyed feel unsafe while crossing the road on foot or on a cycle due to fear of road crashes. 73% of NMT users feel there is a need of more pedestrian signals.

Although Surat has only 2% of its total trips on cycle, versus the national average of 11% for cities with 40-80 lakhs population (MoUD), 98% of cycle trips are taken to access economic opportunities. The concentration of cycle trips in employment magnets (industrial and commercial areas of Surat) indicates that urban poor/ migrant workers are the predominant bicycle users. Absence of safe/ integrated transport planning (ex. last-mile connectivity, bicycle parking facilities, unaffordable and inconvenient PT) discourages an easy transition from NMT to PT, creating captive NMT users (SDG 11). Additionally, the ATL for cycles in Surat is more than 4 km, a considerably higher trip length on cycle. As per the fieldwork, more than 80% of NMT users spend approximately 5 to 15 minutes walking or cycling as part of their trips, while about 19% spend more than 15 minutes doing so. Considering the vulnerable groups (women, poor, migrants/ laborers, etc.) are

predominantly dependent on NMT, they face greater time poverty and constrained access to opportunities. Hence, the current infrastructure poses a trade-off with the 'decent work' clause, as these areas lack quality footpaths, street lighting, signalized junctions, traffic monitoring, etc. (SDG 8). The fieldwork also suggests that 32% NMT users surveyed miss out on work or education opportunities due to lack of transportation options.

Figure 24 Share of road users involved in serious injuries due to road crashes in Surat

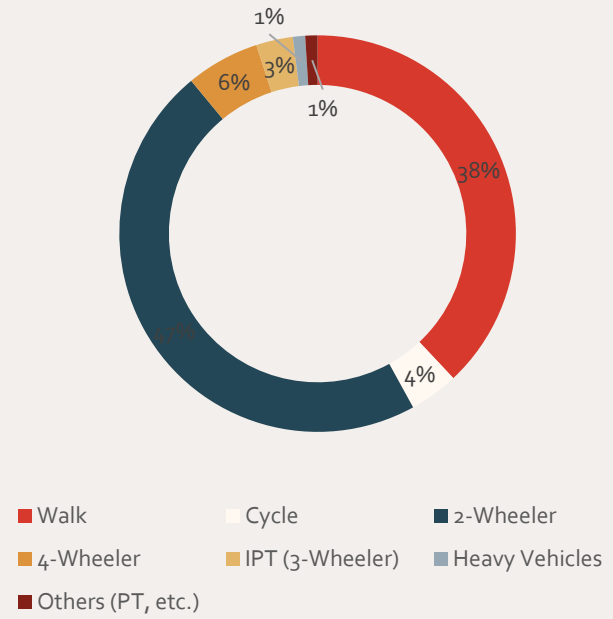
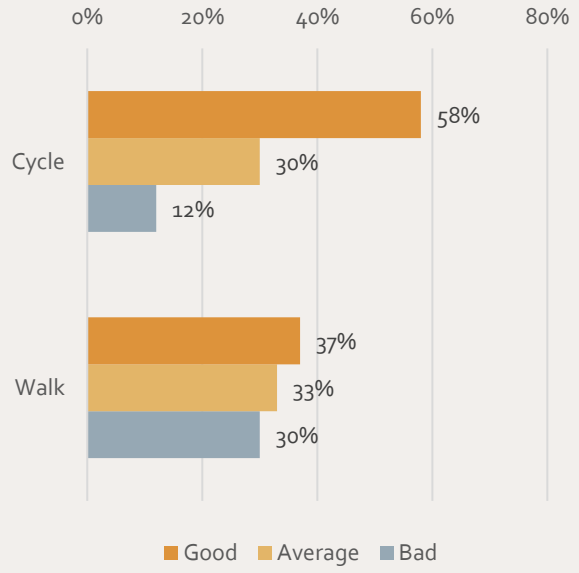


Figure 25 Users' Satisfaction on using NMT Infrastructure



Source: Primary Data, December 2020

Fieldwork indicates that more than 63% NMT users walk or cycle on the road. About 56% users feel that the width of the footpath or cycle track is insufficient, uncomfortable and could be improved.

41% users feel that in times of heavy monsoons, it is not possible to walk or cycle as the roads are water logged, about 21% are captive users to walking and cycling as there are no other modes available and 18% feel it is risky as the visibility of the road is compromised.

Also, more than 52% NMT users surveyed feel that it is uncomfortable to walk or cycle during summers as there is no shade on the streets.

Figure 26 SDG Interactions with NMT Network & Infrastructure in Surat

SDG	SDG 1: Poverty					SDG 3: Health & Well-Being					
SDG Target	1.1	1.2	1.3	1.4	1.5	3.1	3.2	3.4	3.6	3.8	3.9
Composite Index											
(i)											
(ii)											
(iii)											

SDG	SDG 5: Gender Equality				SDG 8: Decent Work/ Employment						
SDG Target	5.1 / 5.2	5.4	5.5	5.6	8.1	8.2	8.3	8.4	8.5	8.8	8.9
Composite Index											
(i)											
(ii)											
(iii)											

SDG	SDG 11: Safe, Inclusive, Resilient & Sustainable Cities								SDG 13: Climate Action		
SDG Target	11.2	11.3	11.4	11.5	11.6	11.7	11.A	11.B	13.1	13.2	13.3
Composite Index											
(i)											
(ii)											
(iii)											

Legend

(i) Inadequate pedestrian infra (80% streets have no footpath)
(ii) No cycling infra (92.4% streets have no cycle tracks)
(iii) Safety: Average speed of 28 km/ hr; 47% fatalities attributed to NMT users

SDG Impacts: The NMT infrastructure conditions create inaccessible streets for most users (other than personal vehicle users) leading to:

- A distorted mode mix and unequal distribution of road space in Surat (SDG 11)
- Compromised personal and sexual safety (SDG 3 & 5)

- curbed access to employment or devaluation of paid work (SDG 8).
- Since most NMT users in Surat are captive, with an increase in income, they are more likely to shift to motorized transport for first-last mile or whole trip (Chidambara, 2016), increasing GHG emissions and related negative impacts (SDG 13).

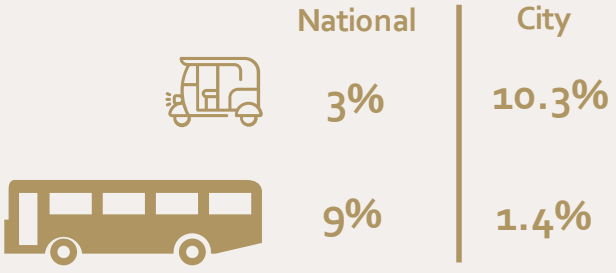
But, the high NMT mode share in Surat fosters a synergy too, as it leads to higher levels of physical activity, often linked to health benefits like reduced risk of premature death from obesity, diabetes, and other non-communicable diseases (SDG 3).

WITH PARA TRANSIT & PUBLIC TRANSPORT

IPT NETWORK & INFRASTRUCTURE

According to MoUD, the average mode share on IPT for cities with population lying between 40-80 lakhs is 7%. In Surat, the share of IPT users is higher than this standard showing dependence on IPT and shared mobility. But, due to the lack of fare structure revision and fair implementation, mode shares in the city have reduced drastically due to motorization and urbanization in the city (SDG 11). Assuming a single driver per fleet, IPT roughly provides employment to approximately 38,000 people in Surat. But most IPT drivers are untrained and engage in rash driving (SDG 8). Women are at higher risk of being victims of crime and violence, and are also known to forgo an opportunity to work outside their neighborhoods if they perceive transport fares and services to be expensive and unreliable. Pink Autos in Surat encourages more women passengers as well as more women drivers. Both passengers and drivers would feel safer on the streets (SDG 5).

Figure 27 Average Mode Share Comparison



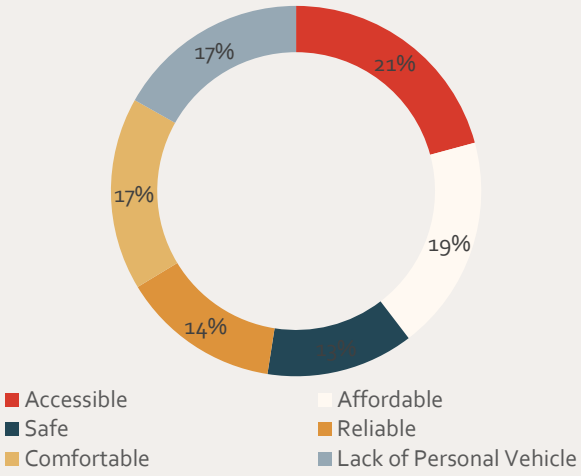
SDG Impacts: The above-mentioned current situations generate many trade-offs with SDGs such as:

- Lack of fair revision and management may lead to overcharging users, generating a trade-off with SDG 1, 5 and 11.
- Auto-rickshaws operate with old fleets, generating a trade-off with SDG 11 and 13.
- In terms of SDG 3,
  - 3% of all fatalities and 6% of all serious injuries consisted of IPT users in Surat
  - Occupational hazard for many IPT drivers involves negative externalities of air and noise pollution and other health concerns
  - They also face headache and stress, back pain, allergic problems, and general stiffness as a result of continuously sitting on the driving seat.
- Limited fleet and network of Pink Autos leaves the rest of the city unsafe (SDG 5).

Some of the synergies are listed as follows:

- The employment generation positively impacts SDG 1 & 8.
- Pink Autos empower women in Surat (SDG 5).

Figure 28 Reasons for choosing IPT



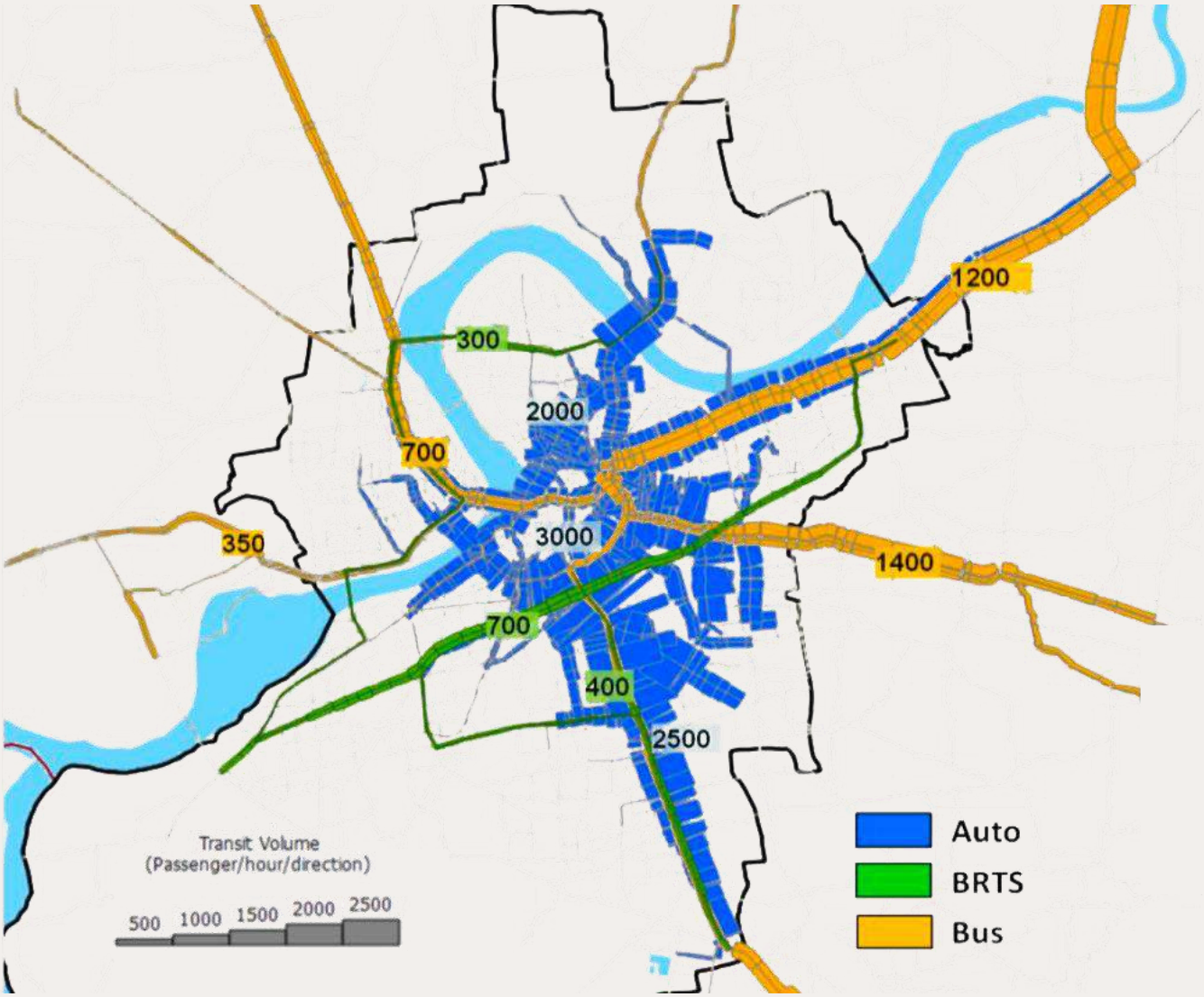
Source: Primary Data, December 2020

Fieldwork suggests that the top 3 purposes to commute via IPT are work (38%), shopping (22%) and healthcare (16%).

Picture 7 Auto-rickshaws & Pink-Auto Rickshaws in Surat

Source: Kanika Gounder and Times of India (2019)

Map 5 Transit Volume along IPT and PT routes in SUDA



Source: Surat CMP (2016)

PT NETWORK & INFRASTRUCTURE

The city bus services and BRTS are operated on a gross cost model by Sitilink Ltd, a fully owned subsidiary company of the SMC. According to MoUD, the average mode share on PT for cities with population lying between 40-80 lakhs is 21%. The PT mode share in Surat reduced from 5.7% in 1988 to 1.4% in 2016 showing a rapid decline in use of buses. 52% of built-up in SUDA and 13% built-up area in the SMC lacks access to the bus network. Less than 1% trips for work, education and other purposes are made on buses showing that use of bus is not preferred by the population of the city regardless of the trip purpose (SDG 11). On an average, bus trips are longer, covering more than 10 km. This suggests that users prefer buses for longer distances as compared to other modes, consequently emitting less carbon and GHG emissions (SDG 3 and 13).

Picture 8 City bus and BRT in the SUDA area

Source: Kanika Gounder

When inquired about why respondents prefer PT, accessibility (21% of total responses) was reported as the leading reason, followed by affordability (19%), comfort (17%), safety (13%), reliability (14%). 17% of the total responses indicated that respondents prefer PT due to unavailability of a private vehicle for their trip or lack of private vehicle ownership (Figure 30).

In terms of alternate mode choices, respondents stated that Personal Auto and shared autos were one of their top preferred modes as they are more accessible and comfortable than other modes (SDG 11). In Surat, buses are the least responsible mode in terms of fatalities and serious accidents mainly due to the segregated corridors for BRT at various locations (SDG 3).

Table 3 Reason for mode preference of modes other than City Bus/ BRTS

Reasons for Mode Preference	Walk (1st Rank)	Shared Auto (2nd Rank)	Personal Auto (3rd Rank)
Accessible	198	212	206
Affordable	194	183	162
Safe	145	105	150
Comfortable	160	164	179
Reliable	150	153	169
Total Responses	847	817	866

Figure 29 HH choosing PT vs. HH within 10-minute walking distance of PT

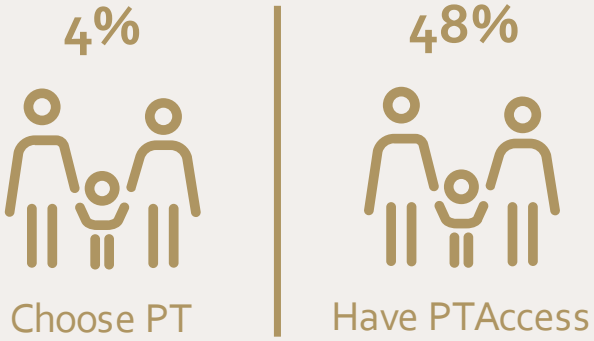
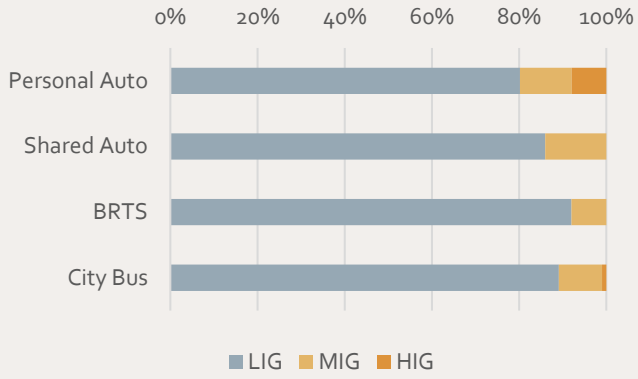


Figure 30 IPT/ PT Users by income groups



Source: Primary Data, December 2020

SDG Impacts: The various trade-offs include:

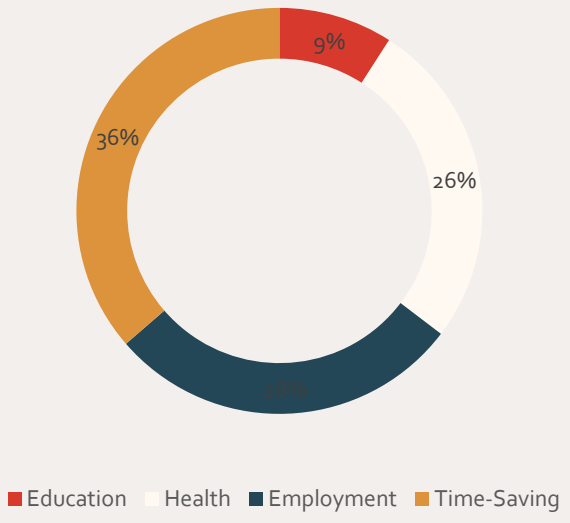
- The lack of first and last mile connectivity, preference of other public modes coupled with increasing income levels in the city has resulted in increased immobility and generates a trade-off with SDG 1 and 11.

- Apart from the improved ITS, the poor and unsafe infrastructure brings immobility and time poverty to women since their dependence on PT is far more than that of men (SDG 5).
- Even though BRT causes the lowest number of road crashes as compared to other modes, through regional bus services bypassing the city add to the high-speed traffic and congestion, which could lead to:
  - Road accidents and anxiety/ stress while travelling in the city
  - Possibility of road crash fatalities (SDG 3)
  - Increased air pollution (SDG 3 and 13).

On the other hand, it contributes to synergies like the introduction of electric buses in the existing fleet leading to lower air pollution and GHG emissions (SDG 3 and 13).

The fieldwork data indicates that a large proportion of IPT and PT users fall under the LIG or poorer income brackets, as 25% IPT users and 22% PT users surveyed make less than Rs. 60,000 annually. Also, 60% IPT users and 68% PT users make between Rs. 60,000- 3,00,000. 37% IPT users and 31% of PT users belong to religious minorities, OBC, SC or ST castes.

Figure 31 Access to opportunities if households owned their desirable vehicles



Source: Primary Data, December 2020

Figure 33 SDG Interactions with PT/IPT Network & Infrastructure in Surat

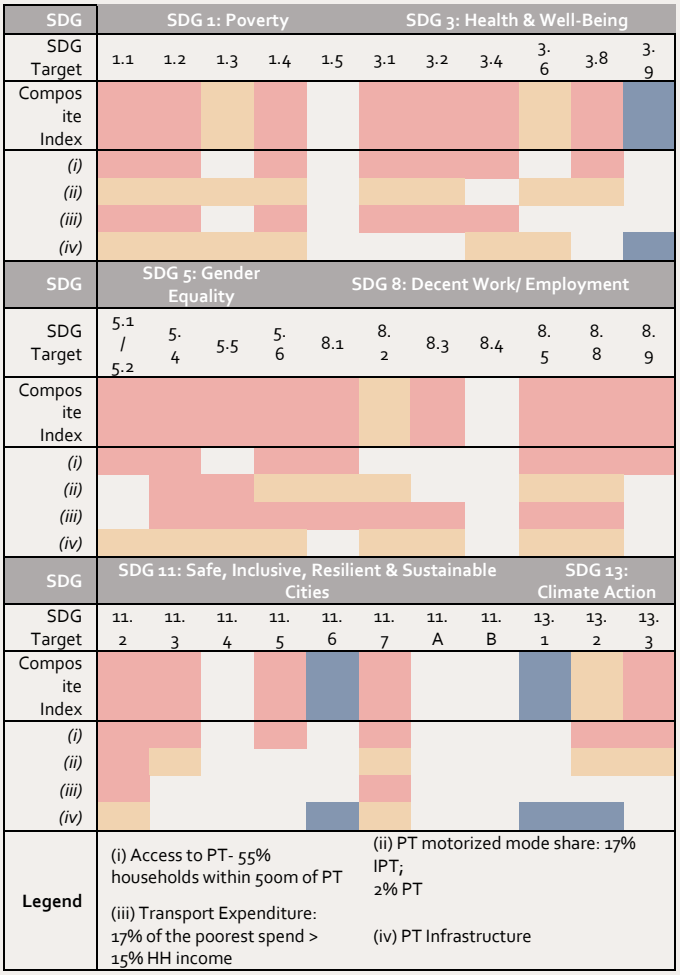


Figure 32 A woman waiting to board a city bus and BRT Station in Surat

"Autos are not as affordable as buses but due to their unreliability, there is no other mode option available. Inside the buses, women must stand as they do not get seats. Also, men crowd and are involved with pushing women." And "It does not feel very safe in autos or buses, but there is no other choice. The police imposed a strict social distancing rule since the lockdown started, where they used to catch drivers with overcrowded vehicles. But lately they do not follow it anymore. Post the lockdown, it feels safer in buses comparatively." - FGD Participants

TRANSPORT-SDG INTERACTIONS: LOW CARBON PROPOSALS BY THE CITY

Without any interventions, meaning in the Business as Usual (BAU) scenario, dependence on private vehicles will exponentially increase, adding immense pressure on transport infrastructure. NMT and public transport users would continue to face severe challenges, as neither the Master Plan or any other city development documents state NMT or PT improvement as a priority. Hence, this results in higher emission levels and a chaotic mobility scenario.

When cities have compact physical form and functional interrelationships (mixed-uses developments), trip lengths are shorter and the mode share favors PT and NMT modes. In order to facilitate a compact development in Surat, four sets of network strategies have been proposed: 1) Planned and well-managed urbanization, 2) Efficient Road network at macro and micro levels, 3) Emphasis on NMT infrastructure, especially in terms of equitable road space distribution, and 4) Investment in a robust, safe and convenient PT system. This section contains analysis of proposed low-carbon interventions in these 4 categories.

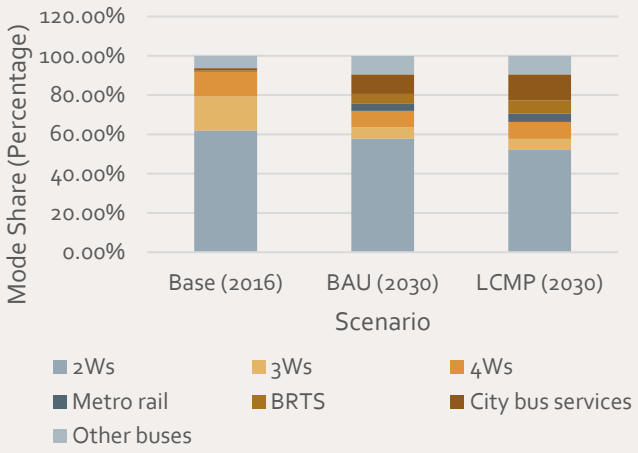
Table 4 Scenario Specification for Public Transport and Private Assignment Model

Scenarios	Demand Assigned (PCU)	Demand Assigned (Person Trips)	PT vs PVT Share (%)
Base 2046	5,746,320	2,939,466	22.6 & 77.5
BAU 2046	4,943,950	4,15,964	32.2 & 67.8
CMP 2046	4,548,400	4,811,390	37.5 & 62.5

Source: Surat CMP

Like the previous section, each aspect of the LCMP transport interventions/ proposals is tabulated across the 6 selected SDGs – 1, 3, 5, 8, 11 and 13, and their interactions are analyzed to understand the positive (green), negative (red) and both positive and negative (yellow) relationships.

Figure 34 Mode Shares as per 3 Scenario



3 scenarios namely base (2016), BAU (2030) and low carbon (2030) scenario are compared in terms of transport systems and accessibility.

Figure 35 Population within Rapid Transit System in the three scenarios

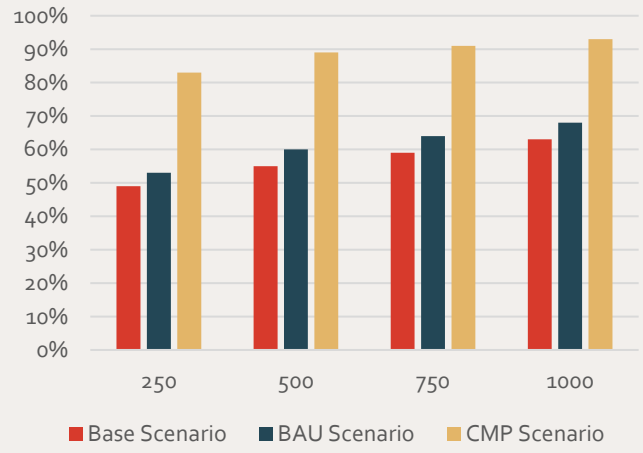
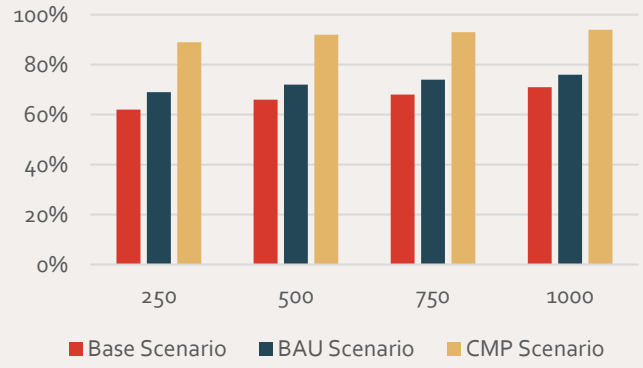


Figure 36 Employment within Rapid Transit System in the three scenarios



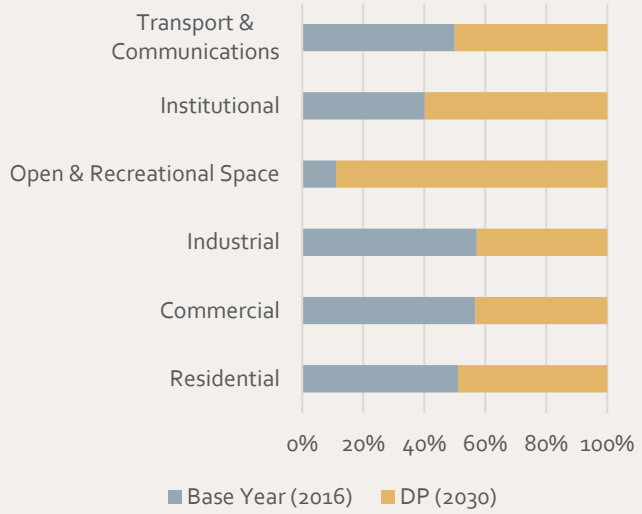
Source: Surat CMP

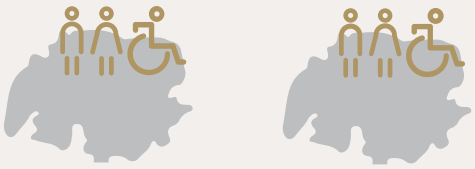
32% NMT users reported missing out on economic opportunities due to lack of transport options and 84% of the NMT users wish to switch to BRTS or Metro, if their coverage improves to access economic opportunities.

LAND-USE AND DENSITY

Interventions: To mitigate the lower ridership despite higher density (as discussed in Section 3a.), the low-carbon mobility plan aims to transform Surat into an integrated, multimodal, Transit-Oriented Development (TOD) enabled city. To achieve this, the plan proposes increasing total population density to 81 PPH and 3 levels of transit-friendly streets within the TOD; a 240 km strategic Integrated Multimodal Transit network is proposed, a 264 km long Bus-Priority Lane network is proposed for streets with width 18m or more and a large-scale Transit-Ready Streets network is proposed for streets with width 30 m or more.

Figure 37 Landuse in Base Year (2016) & Development Plan (2030)





160 PPH

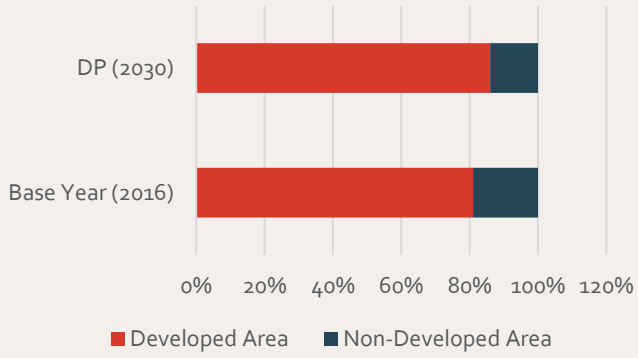
Base Year (2016)

299 PPH

DP (2030)

To mitigate the impacts of conflicting land-uses, the plan proposes to relocate heavy industries and textile industries on the periphery of the city and strengthen development in growth nodes around the core urban area. The growth nodes are expected to offer more employment opportunities and a higher quality of life. These growth nodes will in turn be linked to the core urban area through strategic links (preferably developed as rapid transit links) which will further provide efficient mobility to the core area. This will ensure a compact and managed urbanization in the core urban area, planned development in the nodes and segregation of industrial land-use from all others, especially residential. Additionally, the authorities propose a multimodal transit hub and 36 other multimodal interchanges across the city to provide safe and convenient transition between various PT/ IPT modes.

Figure 38 Developed vs Non-Developed Area (Base v DP)



SDG Impacts: Many trade-offs mentioned in the above sections are either mitigated, or transformed to synergies through land-use and density interventions like relocation of industries and fostering TOD, LAP oriented planning. While the interventions in this category largely generate synergies across most SDGs, their implementation generates many potential trade-offs, mainly with SDG 1.

Studies in the Global South indicate that creating TOD zones or other high-value capture zones poses the threat of gentrification or even evictions and displacements of the urban poor, deepening their poverty.

- The interventions in this category generate synergy with SGD 11 & 13 through improved access to PT, promotion of NMT modes for most trips and decreased VKT and emissions.
- The interventions largely generate synergies across other SDGs as well, yet, their implementation generates many potential trade-offs, mainly with SDG 1. Creating Transit-oriented Development (TOD) zones or high-value capture zones pose threats of

gentrification and eviction/ displacement of urban poor, deepening their poverty.

- If PT fails to attract projected ridership and modal shift, the increased density will exponentially increase traffic congestion, leading to loss of time, fuel, productivity, and exposure to air/ noise pollution (SDG 11 and 13).

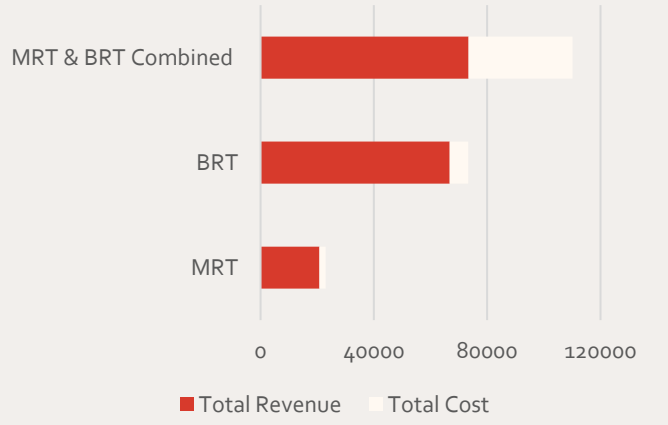
Table 5 TOD zone

Type of TOD	LAP Area	Area with Chargeable FSI	Area under Chargeable FSI
MRT	40	76.02	25.09
BRT	115	244.24	80.6
Both	141	268.69	88.67

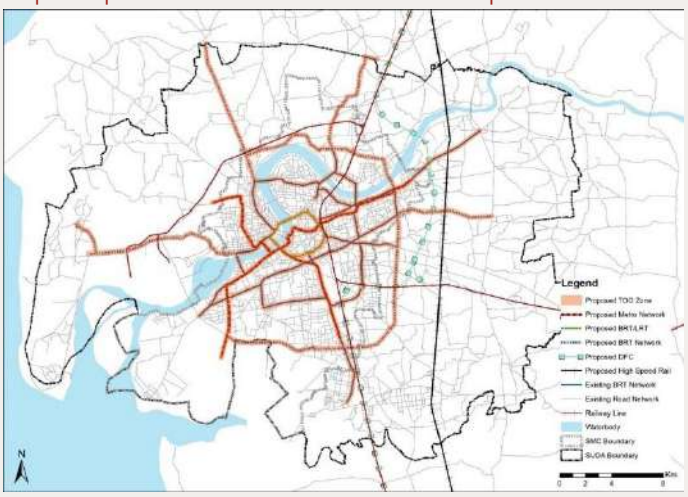
Figure 39 SDG Interactions with Land-use & Density in Surat (2030)

SDG	SDG 1: Poverty					SDG 3: Health & Well-Being					
SDG Target	1.1	1.2	1.3	1.4	1.5	3.1	3.2	3.4	3.6	3.8	3.9
Composite Index											
(i)											
(ii)											
SDG	**SDG 5: Gender Equality**					**SDG 8: Decent Work/ Employment**					
SDG Target	5.1 / 5.2	5.4	5.5	5.6	8.1	8.2	8.3	8.4	8.5	8.8	8.9
Composite Index											
(i)											
(ii)											
SDG	**SDG 11: Safe, Inclusive, Resilient & Sustainable Cities**								**SDG 13: Climate Action**		
SDG Target	11.2	11.3	11.4	11.5	11.6	11.7	11.A	11.B	13.1	13.2	13.3
Composite Index											
(i)											
(ii)											
Legend	(i) Population Density (SUDA): 81 PPH					(ii) Landuse: Transit Oriented Development (TOD)					

Figure 40 Total cost of infrastructure improvements for TOD zone and revenue potential through TOD value capture (Estimates).



Map 6 Proposed TOD Zone and Transit Route Map of SUDA



MOTORIZATION AND ROAD INFRASTRUCTURE

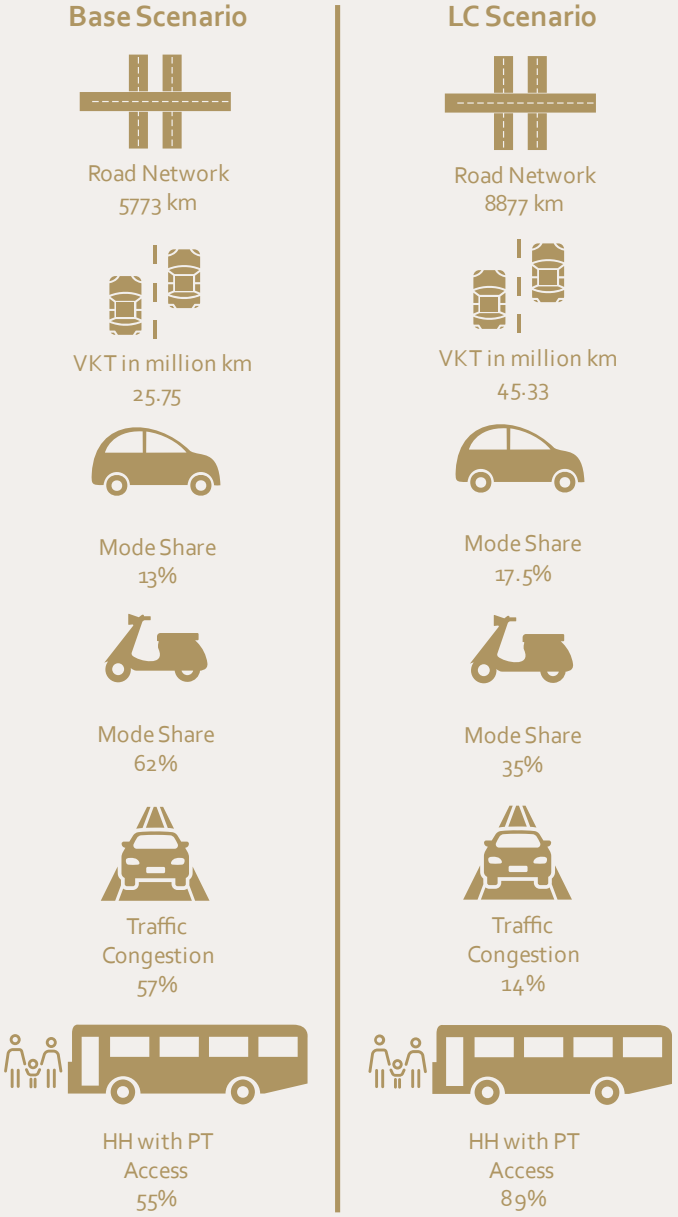
Interventions: To mitigate some of the air pollution and emission related impacts, the low-carbon mobility plan proposes a reduction in the personal vehicle mode share from 75% to 53% in 2030. The plan also aims to cap the vehicle kilometer travelled at 45 million (significantly lower growth rate than 2016). To relieve the congestion, especially the bottlenecks near the inner-city areas, the plan proposes completion and redesigning the ring-roads; the inner ring-road to have a uniform width of 90m instead of irregular width that go up to 120m at many junctions.

Map 7 Congestion due to PV

Source: Shaurya Patel

To improve connectivity between the growth centers and the core urban areas, several radials (one to each growth center) are proposed as Transit-Ready streets (refer 4a. for network details). These streets will reserve a wide median in the road cross-section for rapid transit like BRT/Metro/LRT, ensuring connectivity through PT.

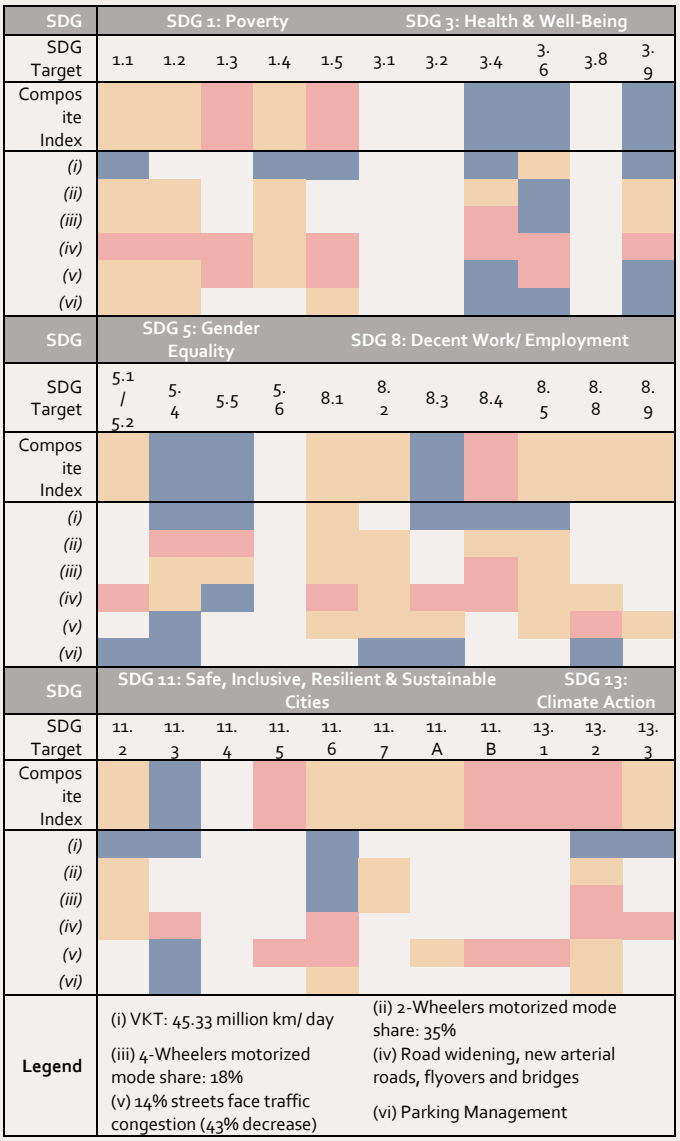
Additionally, construction of 536 km of new road network, 39 new rail over-bridges, 16 new underpasses and 6 new flyovers/ bridges is sanctioned. As a result of all the interventions, the plan projects a 43% decrease in traffic congestion.



SDG Impacts: The interventions in this category pose the greatest number of trade-offs with SDG than any other category. Among the interventions, Parking Management and VKT generate the most synergies as both are related to discouraging personal vehicle use, while building new road infrastructure and road widening largely generate trade-offs as they result in:

- Displacement, eviction, loss of employment and property for adjoining residents (SDG 1 & 8)
- Encourage the use of personal vehicles (SDG 11)

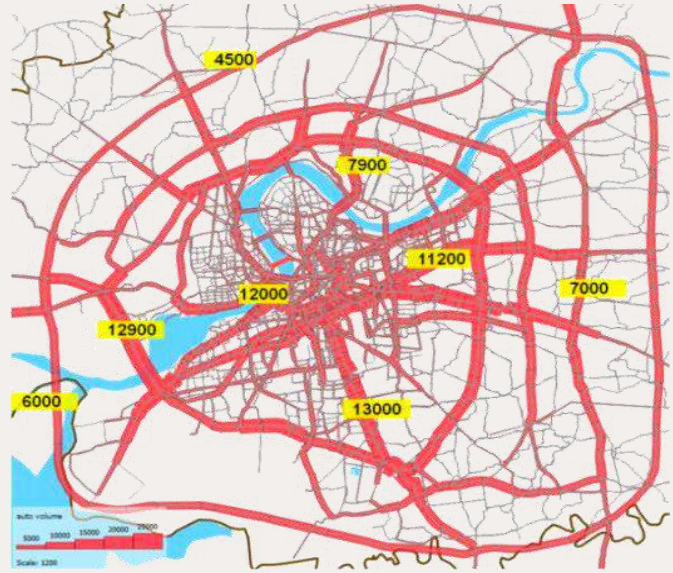
Figure 41 SDG Interactions with PT/IPT Network & Infrastructure in Surat (2030)



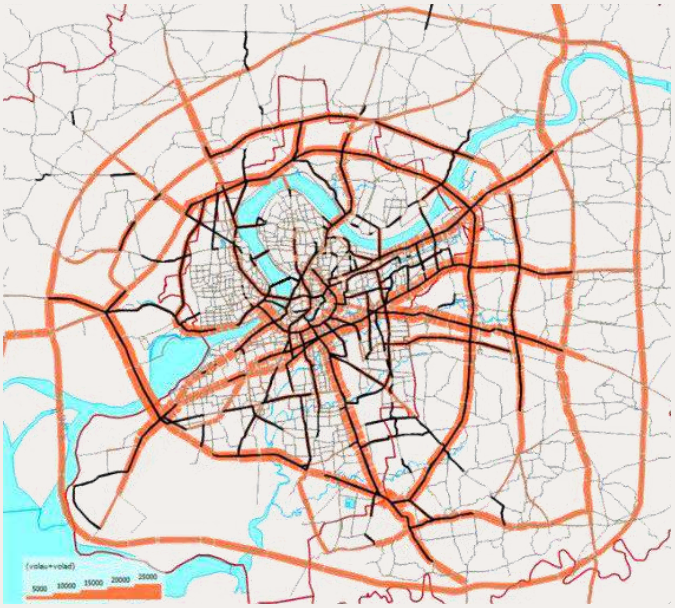
- Traffic congestion, air/ noise pollution, mental stress and anxiety (SDG 3)
- Increased emissions (SDG 13).
- The interventions regarding personal vehicle use (2- & 4-Wheelers) generates many "mixed" relationships; while personal vehicles improve access to employment opportunity, the vulnerable groups are not usually a beneficiary of this interaction, as they either can't afford personal vehicles or can't drive them (SDG 1, 11 & 5).
- Although the personal vehicle mode share (53%) reduced in 2030, it still is considerably high for an Indian city, contributing to higher traffic congestion and related physical & mental health concerns (SDG 3).
- The plan does not discuss phasing out non-renewable fuel vehicles to more sustainable

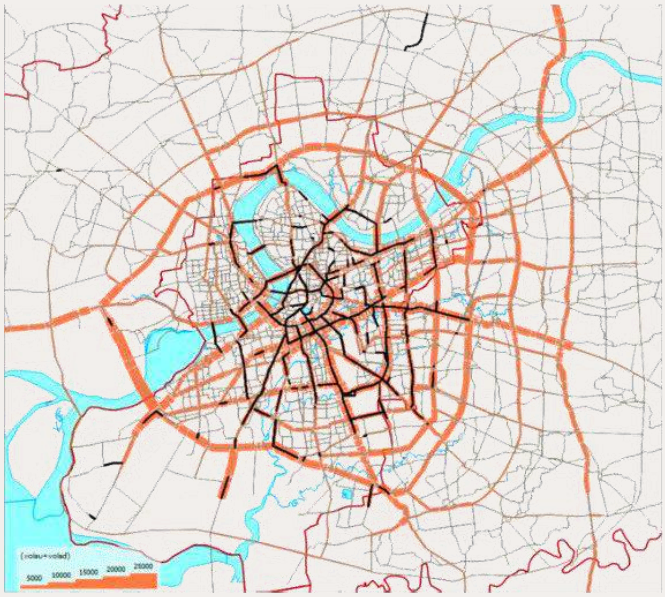
fleets like EVs, hence this intervention may not promise a decrease in emissions (SDG 13).

Map 8 Traffic Volume (PCU/hour/direction) (2046) - BAU (a) vs CMP (b)

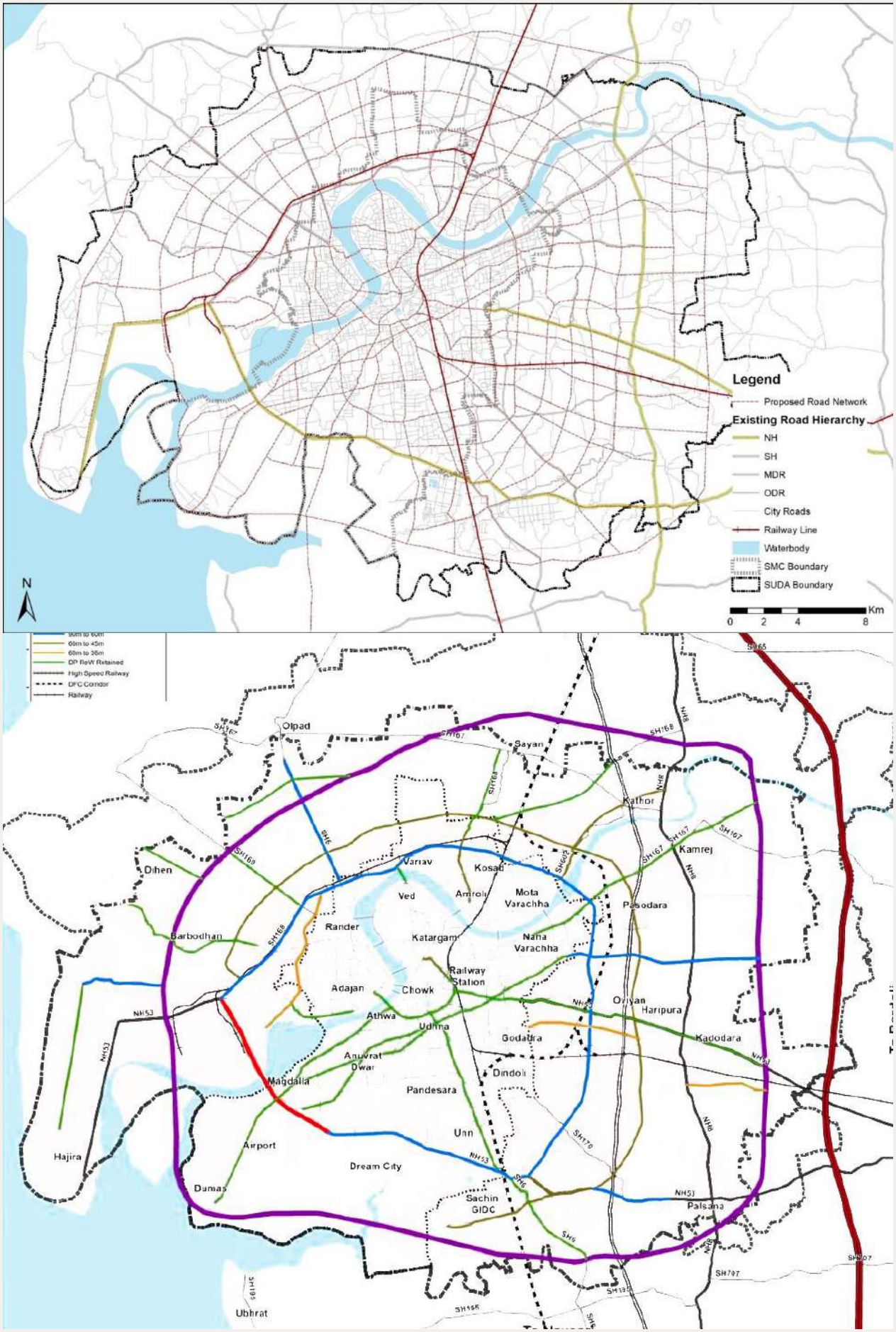


Map 9 Volume Capacity Ratio Map (V/C >1) (2046) - BAU (a) vs CMP (b)





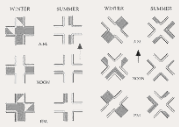
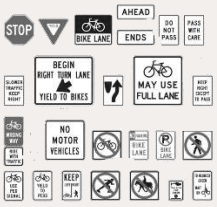
Map 10 Proposed Road Network and DP Road Modification in SUDA (2046)



NMT NETWORK AND INFRASTRUCTURE

Interventions: The plan aims to connect land uses and the public transport systems through NMT. Hence street and junction design, along with NMT network is crucial to achieve the projected modal shifts to PT and IPT. Like mentioned in previous sections, streets along transit will be designed through "Complete Streets" and Universal Street Design guidelines to ensure safe, easy and inclusive access to PT and surrounding mixed-use establishments. Along with this, street infrastructure improvement like street lights, zebra crossings, signalized junctions, and identification of mid-blocks (to reduce trip distance) will ensure safety of NMT users; especially through identifying safe movement routes that connect residential areas to work areas, schools, colleges, and PT stations.

Figure 42 NMT Street Design Principles

	**Universal Design**	Support use of streets by people of all age and ability
	**Greens**	Prioritizing existing green zones for pedestrians, bicyclist, and activity zones.
	**Sun Path: Comfort Zones**	Reserving space for NMT infrastructure based on sun path
	**Signage**	Signage that supports NMT lanes are to be encouraged and efficiently placed
	**Connected and continuous designs**	The NMT infrastructures need to be continuous to allow seamless travel.

In particular, the existing footpath network will be upgraded to have a uniform width of 1.8m. A 418 km of new footpaths of widths more than 1.8m will be added, out of these 130 km of footpath is along collector and distributor roads falling within the accident-prone areas. Similarly for bicycle infrastructure, 288 km of new bike lanes will be added. The proposal aims to popularize bike-sharing schemes and hence includes several bike-sharing interventions; 2 bike-sharing schemes with over 16,000 cycles and ITS will be introduced, 64 bike-share docking points to be installed in the walled city and SVNIT, additional docking points around major attractions and PT/IPT stand to installed. To improve road safety and foster safe, accessible, and inclusive access, especially for the TOD area the proposal has several interventions; the city will formulate an Accident Management Plan, a Junction Design and Signalization Plan and will create an Accident Monitoring Cell.

Figure 43 SDG Interactions with NMT Network & Infrastructure in Surat (2030)

SDG	SDG 1: Poverty					SDG 3: Health & Well-Being					
SDG Target	1.1	1.2	1.3	1.4	1.5	3.1	3.2	3.4	3.6	3.8	3.9
Composite Index											
(i)											
(ii)											
(iii)											
SDG	**SDG 5: Gender Equality**					**SDG 8: Decent Work/ Employment**					
SDG Target	5.1 / 5.2	5.4	5.5	5.6	8.1	8.2	8.3	8.4	8.5	8.8	8.9
Composite Index											
(i)											
(ii)											
(iii)											
SDG	**SDG 11: Safe, Inclusive, Resilient & Sustainable Cities**								**SDG 13: Climate Action**		
SDG Target	11.2	11.3	11.4	11.5	11.6	11.7	11.A	11.B	13.1	13.2	13.3
Composite Index											
(i)											
(ii)											
(iii)											
Legend	(i) Pedestrian Infrastructure Improvements (iii) Safety (as per vision): Improvement NMT users safety					(ii) Bicycle Infrastructure Improvements					

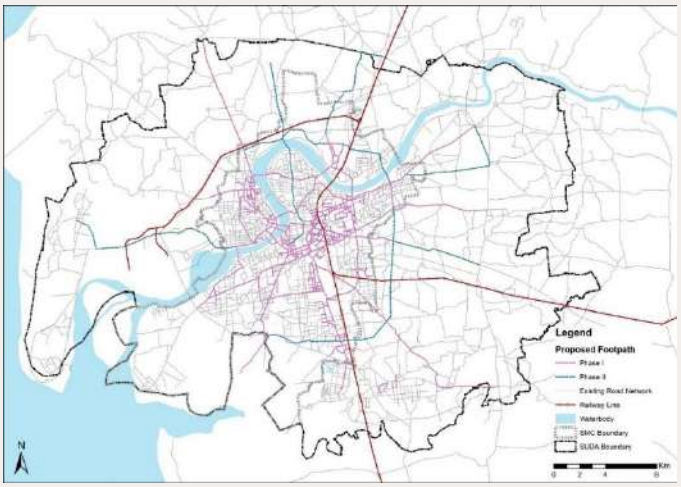
SDG Impacts: This is the only category that only fosters synergy; the interventions for improving NMT networks and infrastructure encourage the use of NMT and other low-carbon modes like PT/ IPT by serving as reliable last-mile networks. This in turn improves access to employment and civic opportunities for all (SDG 8 & 11), reduces emissions (SDG 13), air/ noise pollution and related health hazards and increases physical activity, improving physical and mental well-being (SDG 3). NMT infrastructure improvements particularly benefit the

vulnerable groups, who are often captive users of NMT, by enabling them to reach other affordable, low-carbon modes like PT/ IPT (SDG 1 & 5).

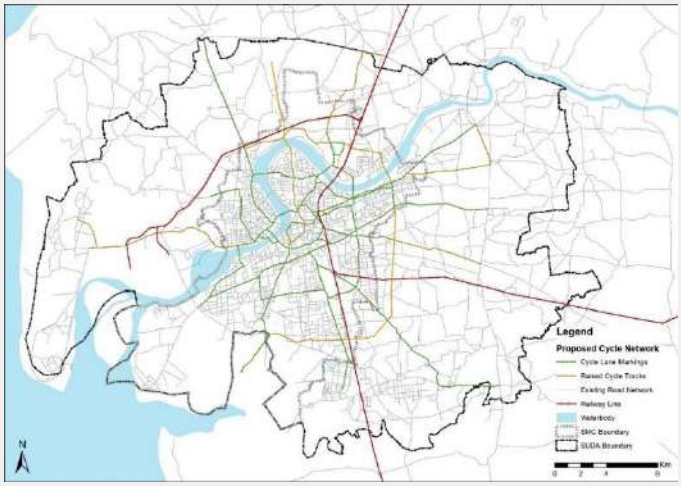
Table 6 Existing and proposed non-motorized transport infrastructure in Surat:

	Base Scenario	LC Scenario
No. of Signalised Intersections	44	178
Footpath Network Coverage	20%	44.50%
LoS of Pedestrian & Cycling Infrastructure	3	2
Cycle Network Coverage	7.60%	25.80%
No. of Public Bicycle Share Stations	0	64

Map 11 Proposed Footpath Network for SUDA



Map 12 : Proposed Bicycle Network for SUDA



PT/IPT NETWORK AND INFRASTRUCTURE

Interventions: As discussed throughout section 4, PT improvements are key to achieving Surat's low-carbon mobility vision. Apart from land-use (TOD, LAP, etc.) and street design interventions that promote the use of PT, the plan proposes extensive PT network interventions. The plan proposes expanding the city's BRTS and City Bus networks, along with developing a new metro. Once fully developed, Surat will have about 213 km of BRTS network (9 corridors) and about 73 km of metro network. Out of this, 12 km of BRT/ LRT will be along the Inner Ring-Road to relieve congestion and improve mobility.

Figure 44 PT & IPT Infrastructure Highlights

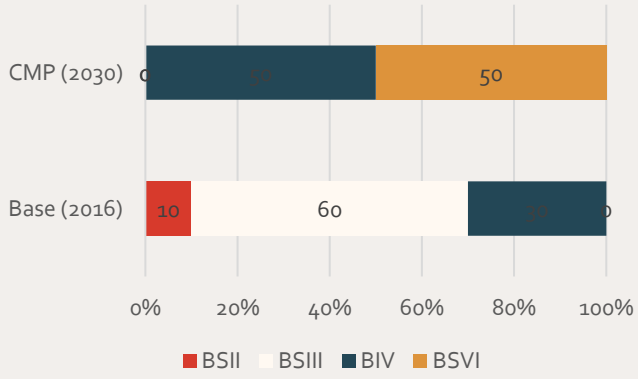
Motorized Mode Share: *5.41%*
Decrease in Motorized Mode Share: *11.59%*

7%

Motorized Mode Share: *17%*
Increase in Motorized Mode Share: *15.12%*
Network Length: *1231 km*
BRT Network Length: *213 km*
City Bus: *889 km*
Metro Network Length: *73 km*
City Bus Area Coverage: *95*

37.5%

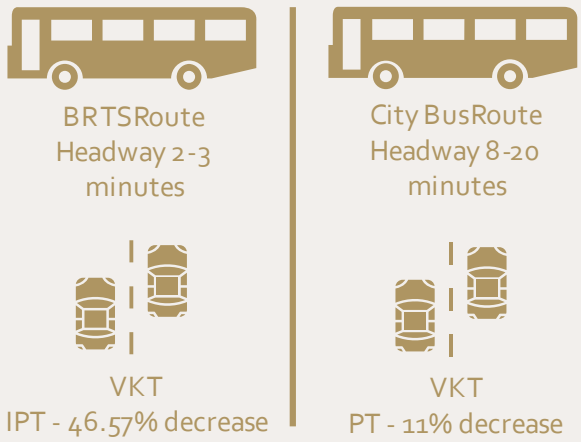
Figure 45 Fuel/Engine Mix Base vs CMP scenario



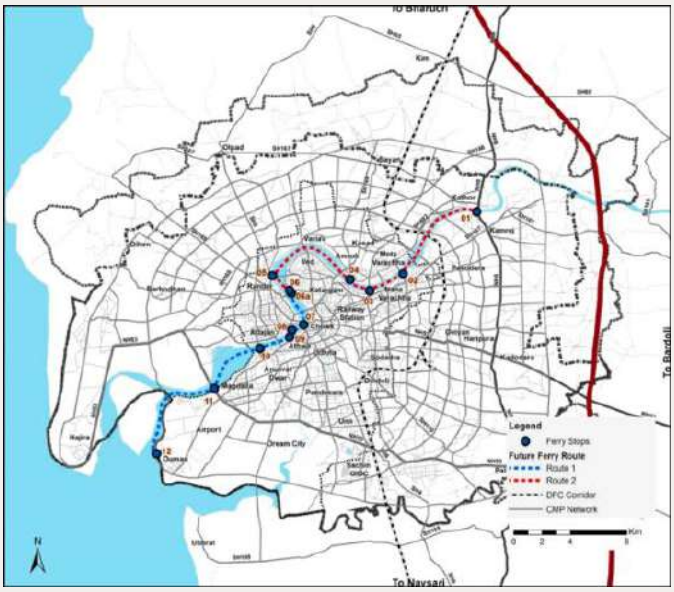
To enhance access, the entire PT network will have Bus-stops every 500m and 36 new Bus Depots across the city. 5,000 additional bus fleets will be procured and the entire bus fleet (100%) will transition to EV. The proposal also includes an ambitious Ferry System along the river Tapi; Ferry system to have a 46 km network and 12 stations. As a result of all the interventions, the proposal expects a 34% increase in accessibility, meaning 87% households will be within 500m of PT stops, out of which 83% will be within 250m of PT stops. The proposal also discusses fare integration for all PT modes and creating

MATA for better PT system management. As a result of high access, the proposal expects a 35% increase in PT mode share, making it 37.5% along with 7% IPT. In 2016, IPT services were more widely used as compared to PT. Hence, managing and integrating it is imperative for a well-planned transport system. But the proposal has missed on discussing any major proposals for IPT services addressing affordability or sustainable fleet, and has proposed a reduced share of trips.

Metro Network	BRT Network
Phase 1: 42 km	Phase 1 & 2: 102 km
Phase 2: 23 km	Phase 3: 37 km
Phase 3: 8 km	Phase 4: 74 km



Map 13 Ferry Routes and Docking Station



SDG Impacts: Although this category overall generates substantial synergies with all SDGs, a few interventions like developing the Metro cause trade-offs. As discussed above, land-acquisition processes for large-scale urban transport projects often cause displacement, evictions or loss of property and employment for adjoining residents, especially the urban poor, deepening their poverty (SDG 1 & 8). The reduced share of IPT trips may cause immobility and time poverty for women (SDG 5), and lead to issues with inclusivity (SDG 11). Additionally, the IPT sector needs more sustainable fleets to cause lower emissions and decrease health issues (SDG 3 and 13).

Figure 46 SDG Interactions with PT/IPT Network & Infrastructure in Surat (2030)

SDG	SDG 1: Poverty					SDG 3: Health & Well-Being					
SDG Target	1.1	1.2	1.3	1.4	1.5	3.1	3.2	3.4	3.6	3.8	3.9
Composite Index											
(i)											
(ii)											
(iii)											
(iv)											
(v)											

SDG	SDG 5: Gender Equality					SDG 8: Decent Work/ Employment					
SDG Target	5.1 / 5.2	5.4	5.5	5.6	8.1	8.2	8.3	8.4	8.5	8.8	8.9
Composite Index											
(i)											
(ii)											
(iii)											
(iv)											
(v)											

SDG	SDG 11: Safe, Inclusive, Resilient & Sustainable Cities								SDG 13: Climate Action		
SDG Target	11.2	11.3	11.4	11.5	11.6	11.7	11.A	11.B	13.1	13.2	13.3
Composite Index											
(i)											
(ii)											
(iii)											
(iv)											
(v)											

Legend

(i) 89% households within 500 m of PT (34% increase)
(ii) IPT/PT motorized mode share: 7% IPT; 37.5% PT
(iii) Transport Expenditure: Introducing MATA & Fare Regulation
(iv) PT Infrastructure Improvement
(v) Introducing Metrorail

Picture 9 City Bus in Surat

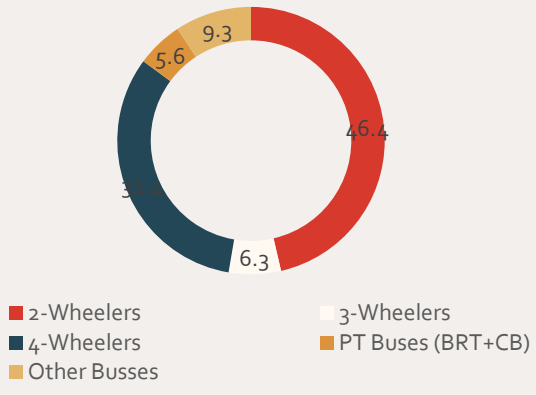
Source: Kanika Gounder

Map 14 Proposed Metro, BRT and City Bus Network in SUDA

GHG EMISSIONS INVENTORY (2030)

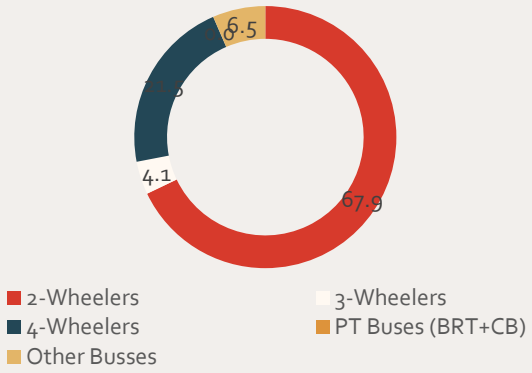
For the low-carbon scenario, the proposal aims to reduce the growth rate of motorization and recommends a higher number of NMT and PT trips. However, the GHG emissions still seem high. In terms of carbon dioxide emissions, it is observed that two-wheelers still contribute to the highest emissions (46.4%), followed by 4 wheelers that contribute to about 32.4% emissions.

Figure 47 CO_2 Emissions in 2030 in Surat



Three-wheelers/ auto-rickshaws generate about 6.3% CO_2 emissions, whereas BRT, city buses and other buses combined contribute to 14.9% emissions annually (Figure 47). Almost 89.4% of CO emissions in the city are generated by two-wheelers (67.9%) and four-wheelers (21.5%). Buses contribute to about 6.5% CO and three-wheelers generate close to 6.5% CO emissions annually (Figure 48).

Figure 48 CO Emissions in 2030 in Surat



In terms of nitrous oxides, close to 66.7% emissions are generated by other buses and 1.3% by three-wheelers. 19.9% emissions are generated by two-wheelers, followed by four-wheelers that contribute to 12.2% NOx emissions annually (Figure 49). Whereas, in case of particulate matter, 78.4% of PM emitted by the transportation sector in the city is by two-wheelers, followed by four-wheelers (12.4%), public-transport (6.6%) and three-wheelers (2.6%) (Figure 50).

Figure 49 NOx Emissions in 2030 in Surat

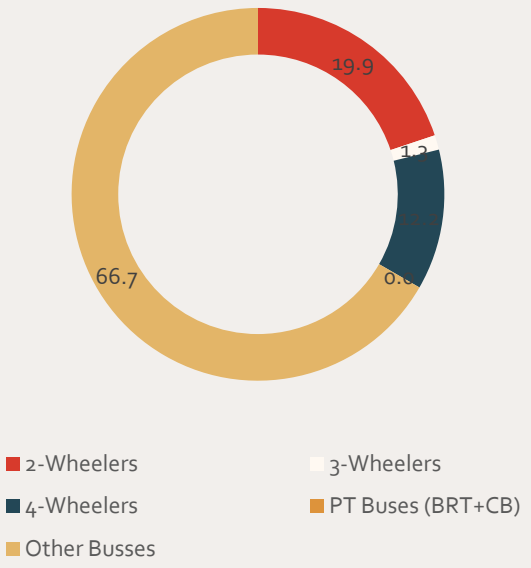


Figure 50 PM Emissions in 2030 in Surat

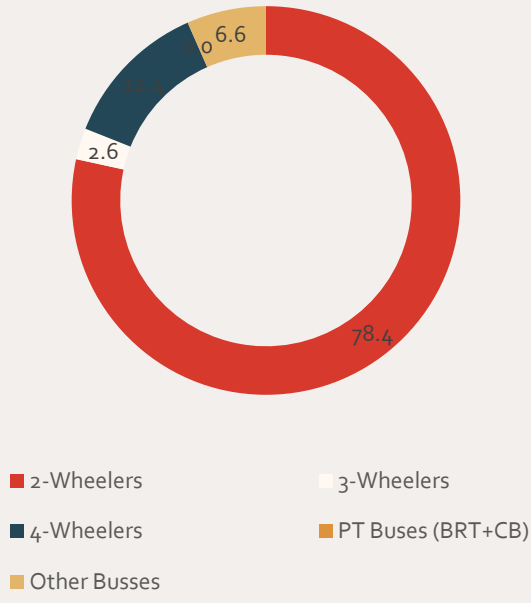


Figure 51 GHG Emissions by transportation sector in Surat (tons/year)

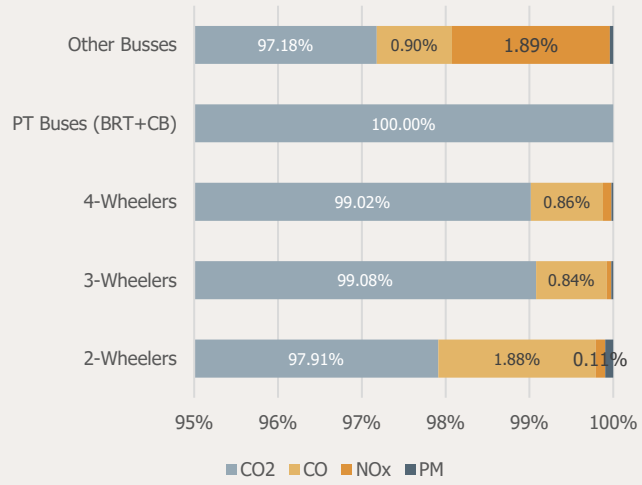


Table 7 GHG Emissions in 2030 by transportation sector in Surat (tons/year)

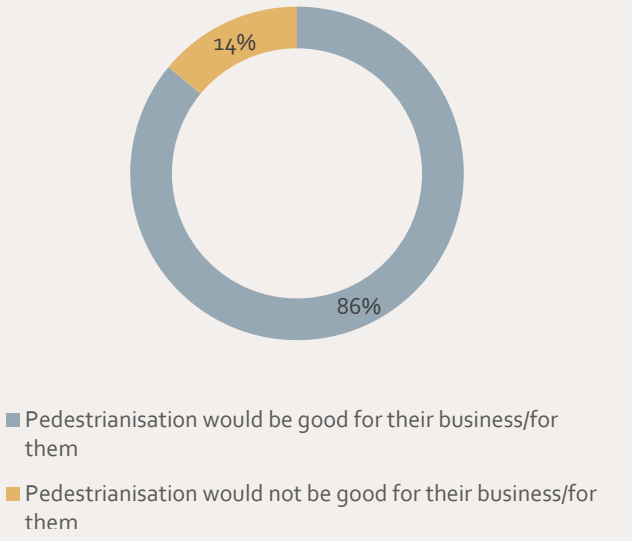
Transport Mode Type	CO2	CO	NOx	PM	Total Modal Emissions
2-W	1947350.88	3728.13	224.35	189.74	198493.1
3-W	26386.97	224.51	14.34	6.32	26632.13
4-W	135848.58	1180.62	137.57	29.94	137196.72
PT Buses (BRT+CB)	23572.04	0	0	0	23572.04
Other Busses	38792.98	357.55	752.64	15.98	39919.15
Total	418951.45	5490.81	1128.9	241.98	425813.14

Picture 10 Shared space (Parking, Vending and IPT)

STRATEGIES FOR SUSTAINABLE LOW-CARBON SCENARIO

Urban transport improves mobility of all users while improving their access to economic opportunities, leading to socio-economic upliftment, and improving their social acceptance. The CMP proposal for Surat considers a low carbon scenario focusing on developing bus-based public transport systems and developing NMT infrastructure with varied modal share. It discusses some of the initial barriers to mobility and proposes NMT infrastructure improvements and regulation and expansion of the IPT and PT network. Yet these proposals fail to address other challenges like safety, reliability, affordability, and design flaws for transport networks. In this section, we discuss how CMP's proposal can be more SDG compliant.

Figure 52 Opinion of local shop owners/ vendors on pedestrianization



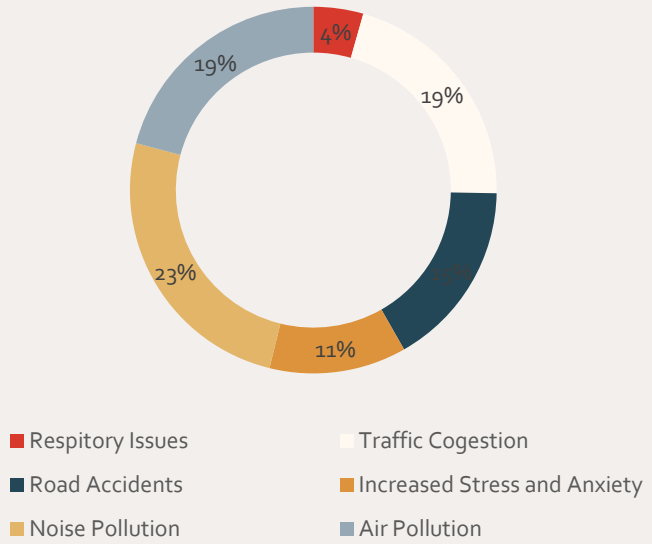
This section concludes the study by giving various interventions for each parameter in detail using recommendations from the residents from Surat as well as other urban planning experts. These interventions are also tabulated with each of the 6 studied SDGs showing their impacts and improvements comparing to the base scenario and the proposed low-carbon scenario from the CMP.

Picture 11 Vendors on the streets

MOTORIZATION & ROAD INFRASTRUCTURE

Around 70% interviewees responded that transport/ road projects impacted their daily revenue to varying degrees. Similarly, when inquired about the impact of transport/ road projects on their and their customer's safety, 48% of the total interviewees perceived impacts in varying degree. Although 93% interviewees said that they didn't think the Metrorail construction would lead to their eviction, 41% believed that a hike in property values due to Metrorail could lead to their eviction. 48% interviewees admitted the Metrorail could affect the visibility of their shops/ stalls.

Figure 53 Issues encountered by households due to proximity to flyover



- Avoid all proposed road widening project to prevent displacement and eviction of residents and businesses (SDG 1 & 8),

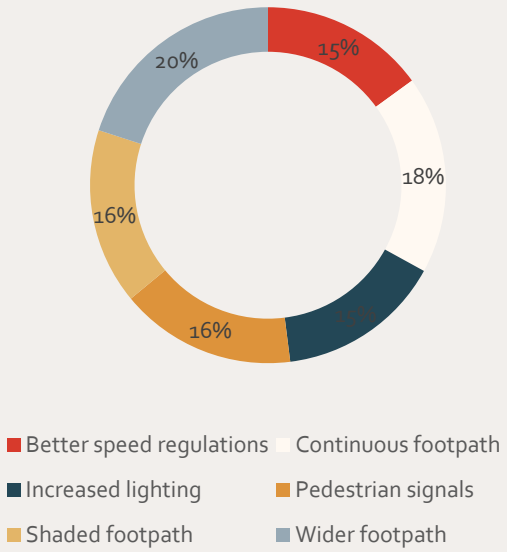
- Review the need for 536 km of new road infrastructure from urban equity approach
- Aid existing traffic management plans with a freight management to mitigate collisioxns and road safety concerns
- Introduce congestion pricing for private vehicles within inner city as decongestant measure
- Subsidize a shift to electric vehicles, especially for IPT fleet and 2-wheelers for emission & pollution reduction.

81% are willing to shift to electric bikes, whereas 63% are willing to retrofit to electric two-wheelers Confidence on Mileage (67%) and EV Charging Infrastructure (59%) were identified as the most pressing areas of improvement to enable the switch. 85% of PV users prefer public EV charging infrastructure (55% - paid, 30% - free).

NON-MOTORIZED TRANSPORT NETWORK & INFRASTRUCTURE

32% NMT users surveyed had experienced missing out on work or education opportunities due to lack of transportation options. About 84% of the NMT users surveyed are willing to shift to metro rail given the coverage and affordability. The factors affecting the users' decision to shift to metro depends majorly on the comfort (42%), followed by affordability (31%) and convenience (25%).

Figure 54 Recommendations for improved safety by non-motorized transport users in Surat



- Increase footpath width to 4m along commercial fronts and tourist spots for safe & easy pedestrian access.
- Redesign high-conflict intersections with refuge islands, smoother/ flattened turning curves, pedestrian/ cycling signals and reduced carriageway widths.
- Prioritize cycle lanes to build a robust cycling network; supplement with wide-spread bike-sharing network.
- Ensure all PT/ IPT stops are accessible by NMT and have supportive NMT infrastructure
- Strengthen NMT infrastructure along identified safe routes for daily needs.

Picture 12 A woman walking on the street

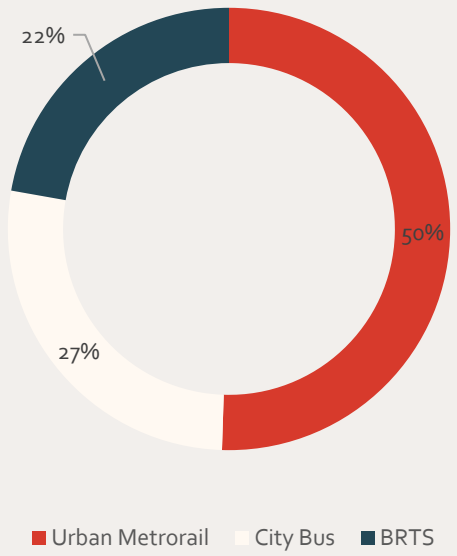
PUBLIC TRANSPORT NETWORK & INFRASTRUCTURE

The most recommended incentives to shift to PT are are, better coverage (53%), affordability (26%) and shorter Average Travel Time (17%). 47% respondents said they would travel at least 5-7 km in the 48% respondents wished for free parking on Metro Stations and another 47% wished that even if it were charged, the prices be minimal. 56% of PV users stated that they do not choose to use the bus service due to overcrowding and 26% of the users shared concern for safety.

Picture 13 BRTS Lane in Surat

- Shaded bus stops/ stands every 500m with adequate seating space, route information, signages and raised platforms for easy boarding and alighting;
- Provide cycle parking, docking stations and designated drop-off/pick-up points at all major bus-stops & stations
- Intensify development along Bus-Priority Streets, Transit-Ready Streets to enable modal switch to PT
- Enable multimodal mobility through convenient interchange designs
- Bus stations should have drinking water, public toilets, and resting facilities for bus drivers for decent working conditions.
- Promote a sustainable fleet for water transport like solar ferries
- Regularize IPT with fixed routes and fare structure that allows IPT to serve as a feeder network for PT.

Figure 55 PV users' preferences for PT services



Picture 14 Confluence of all transport modes

REFERENCES

Agarbattiwala, T., & Bhatt, B. (2016). Performance Analysis of BRT System Surat Public Bike Sharing System View project Green Building View project Performance Analysis of BRT System Surat. Article in International Journal of Engineering Research, 5, 2016. https://doi.org/10.17950/ijer/v5s6/621

Bhagatwala, J., Bhatt, U., & Desai, R. (2018). Mobility Challenges in CBD areas of Cities_ A case of Rajmarg, Surat. In International Journal of Engineering Research in Mechanical and Civil Engineering.

India, C. for S. T. (n.d.). India-Transport-Indicators.

Pandya, R. (2018). Sustainable Urban Transport Index Surat, India.

Pandya, R. J. (2018). Sustainable Urban Transport Index Surat, India.

TERI. (2011). Documenting Built Heritage - The case of Surat_UMC. Journal of the Development and Research Organisation for Nature, Arts and Heritage, 8(3).

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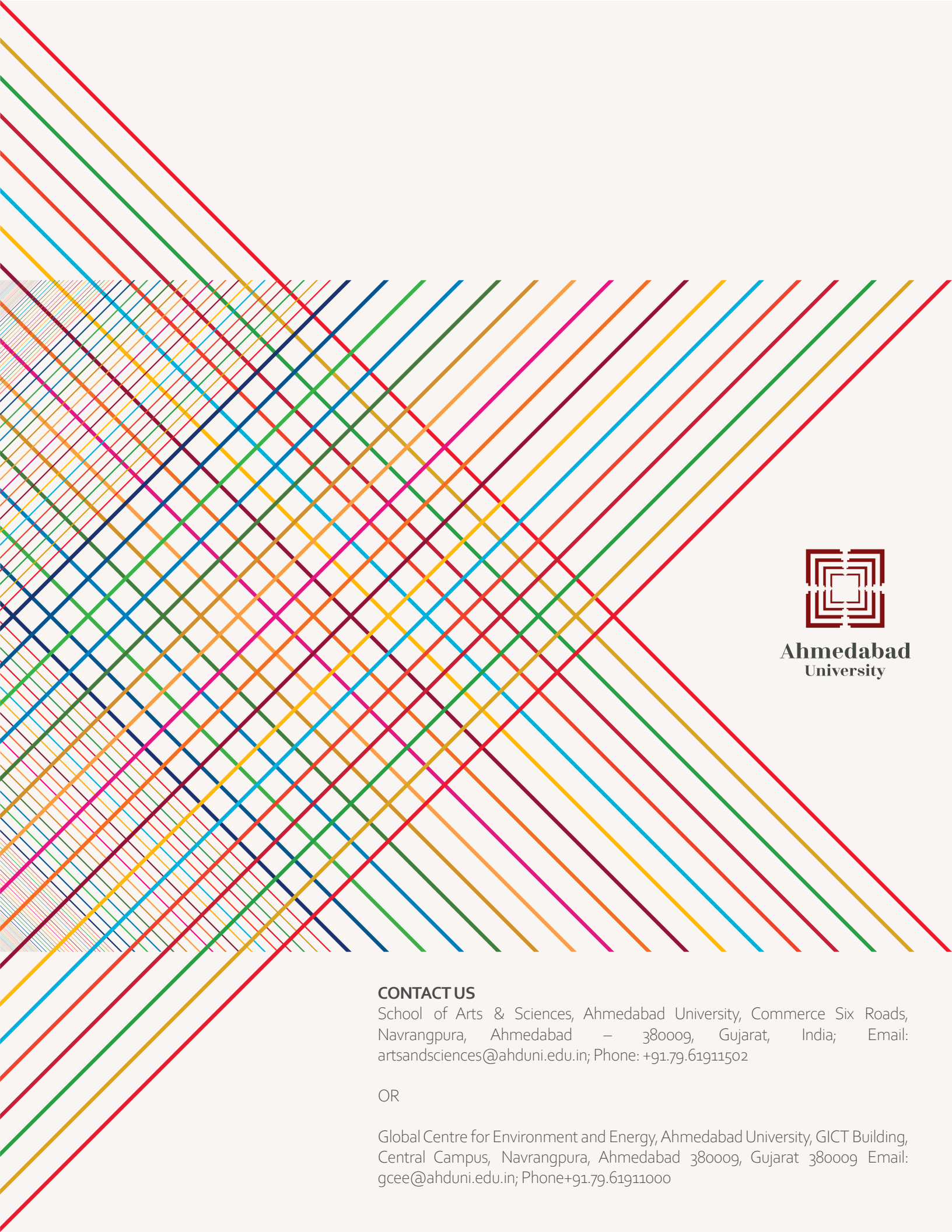

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