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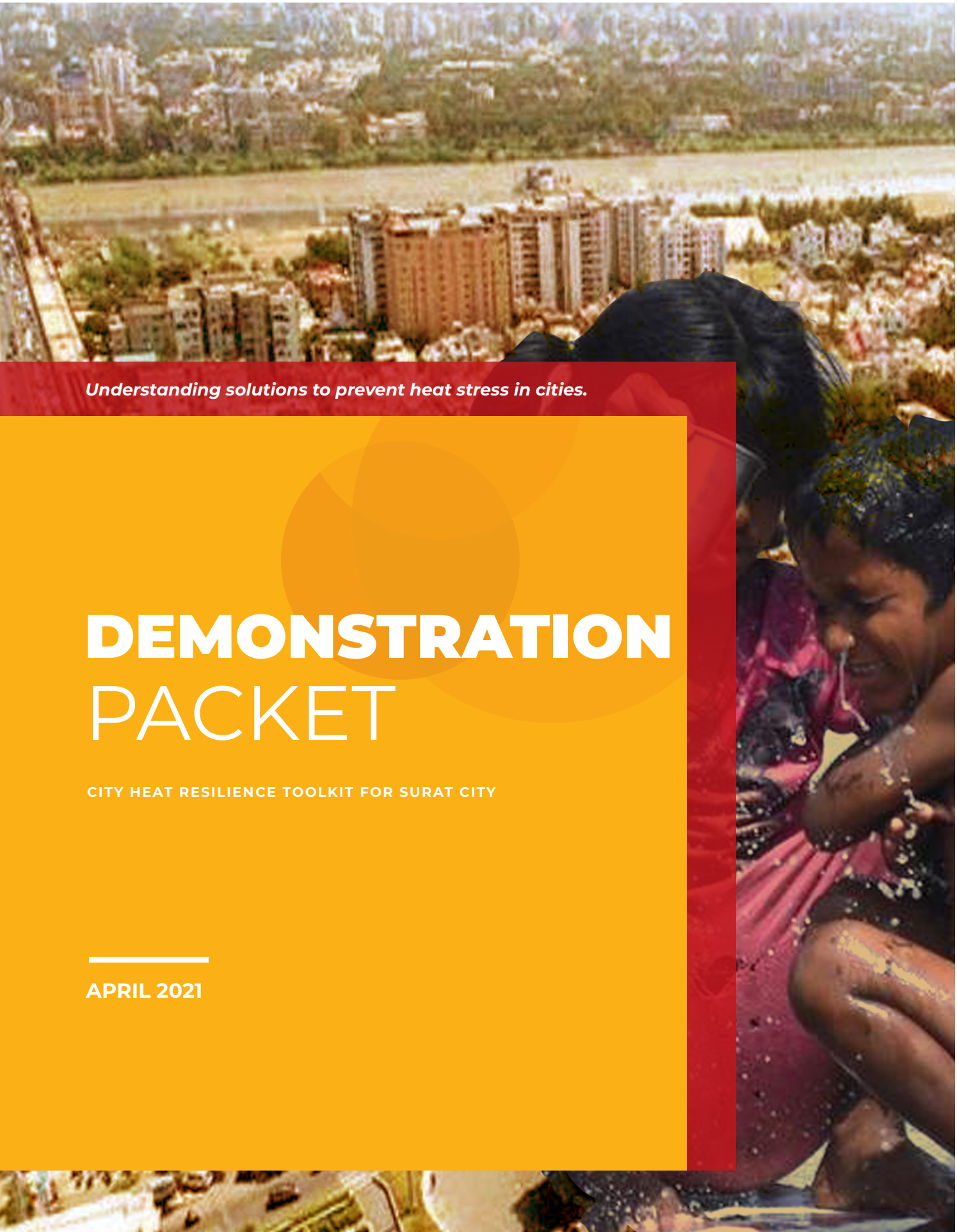

Understanding solutions to prevent heat stress in cities.

DEMONSTRATION PACKET

CITY HEAT RESILIENCE TOOLKIT FOR SURAT CITY

APRIL 2021

The report is developed with the support of Climate and Development Knowledge Network through the Knowledge Brokering Program. The report is developed through the understanding, literature review and analysis by the technical team and inputs from the contributors as well as experts.

Climate and Development Knowledge Network (CDKN)

The Climate and Development Knowledge Network (CDKN) is a programme funded by the Ministry of Foreign Affairs of the Netherlands and the International Development Research Centre (IDRC), Canada working towards enhancing the quality of life for the poorest and most vulnerable to climate change, by supporting decision-makers in designing and delivering climate compatible development. It is led by SouthSouthNorth (SSN, South Africa) and supported by ICLEI-South Asia (southasia.iclei.org/), Fundación FuturoLatinoamericano (FFLA, Quito) and Overseas Development Institute (ODI, UK). For more information, please visit: https://cdkn.org/

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Urban Health and Climate Resilience Centre

Urban Health and Climate Resilience Center (UHCRC), is a health and climate change initiative in Surat city by the Asian Cities Climate Change Resilience Network (ACCCRN) and supported by Rockefeller Foundation through the Surat City Climate Trust, in which the Surat Municipal Corporation is the main stakeholder. The project aims to include piloting assistance programmes for city authorities in India and beyond to improve urban health services.
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ABBREVIATIONS

BPMC	–	Bombay Provincial Municipal Corporation Act
CBO	–	Community Based Organisations
DP	–	Development Plan
GHG	–	Greenhouse Gases
HI	–	Heat Index
LG	–	Local Government
IPCC	–	Intergovernmental Panel on Climate Change
MNRE	–	Ministry of New and Renewable Energy
NIDM	–	National Institute of Disaster Management
NRDC	–	National Research Development Corporation
PCE	–	Passenger Car Equivalent
PCU	–	Passenger Car Unit
SDGs	–	Sustainable Development Goals
SHG	–	Self-Help Groups
SMC	–	Surat Municipal Corporation
SUDA	–	Surat Urban Development Authority
UBL	–	Urban Boundary Layer
UCL	–	Urban Canopy Layer
UHI	–	Urban Heat Island
UHCRCE	–	Urban Health and Climate Resilience Center of Excellence
ULB	–	Urban Local Body
UN	–	United Nations
UNDP	–	United Nations Development Programme
UNFCCC	–	United Nations Framework Convention for Climate Change

Image-Surat City Source-Zedge.net

01 SURAT CITY PROFILE

The process of identification of the causes of heat stress in a city, their prioritisation and the identification of relevant solutions can be done by looking at the experience of the city of Surat, one of the most affected coastal cities in India (Nital Doshi, 2018). The city has high relative humidity throughout the year and therefore, the calculation of the Heat Index is more important than the temperature threshold. The Surat Municipal Corporation (SMC) has been enthusiastic in undertaking the Heat and Health Action Plan Surat, as well as Surat City Resilience Strategies (under the 100 Resilient Cities Project).

1.1 Surat City Profile

Surat, located on the floodplains of the River Tapi on India's western coast, is currently home to five million people. Since 1950, the city's population has been almost doubling every decade, making it the fourth fastest-growing city in the world. During this period, migrant workers, attracted by the diamond and textile industries, poured into the city's slums located along the river's floodplains (NRDC, 2015), and created a complex social fabric populated by different regional, religious, linguistic and caste identities.

The SMC, established under the Bombay Provincial Municipal Act, 1949, implements obligatory and discretionary functions to build a dynamic, self-reliant, sustainable and smart city with all basic amenities. The corporation perceives itself as the principal facilitator and a provider of services that could ensure a better quality of life. It has decentralised various public services that it provides and has divided the whole city into seven zones, shown in Figure 1.

As per the 2001 Census, Surat city had the largest number of migrant population among million plus cities in India, comprising 58% of the total population (UNESCO, 2011). The city is highly vulnerable to floods and extreme heat due to climate change, because of its ecological background and geographical location.

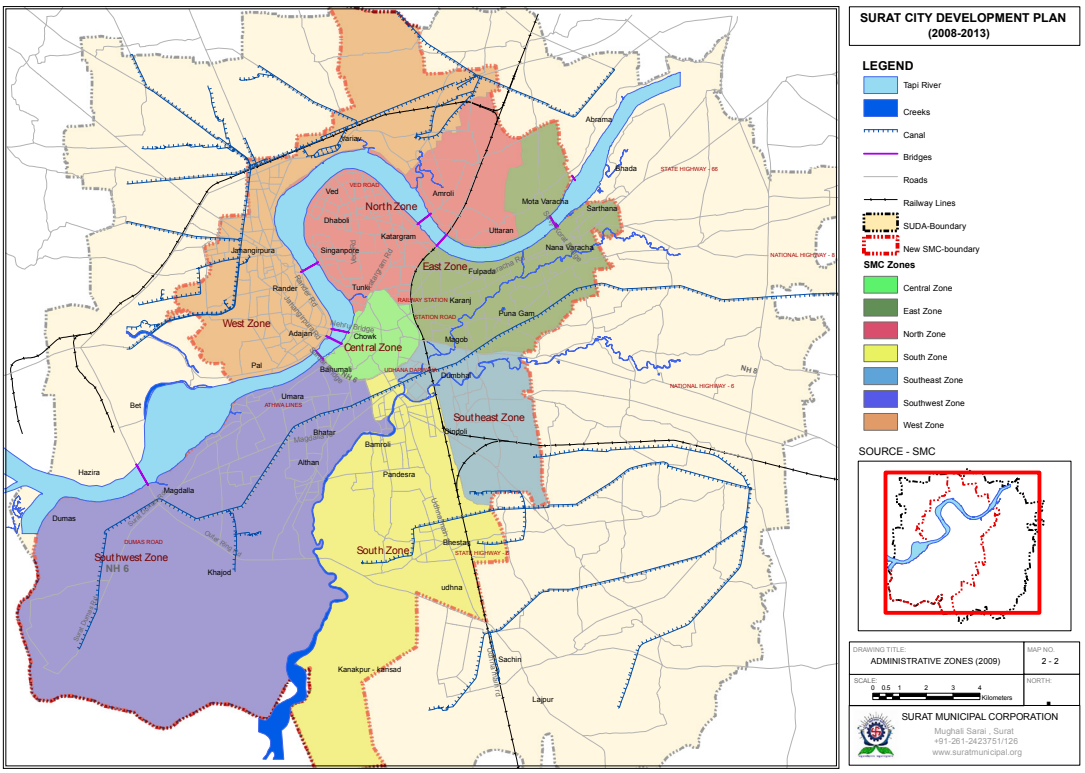


Figure 1: Administrative Zones in Surat City (Corporation, 2009)

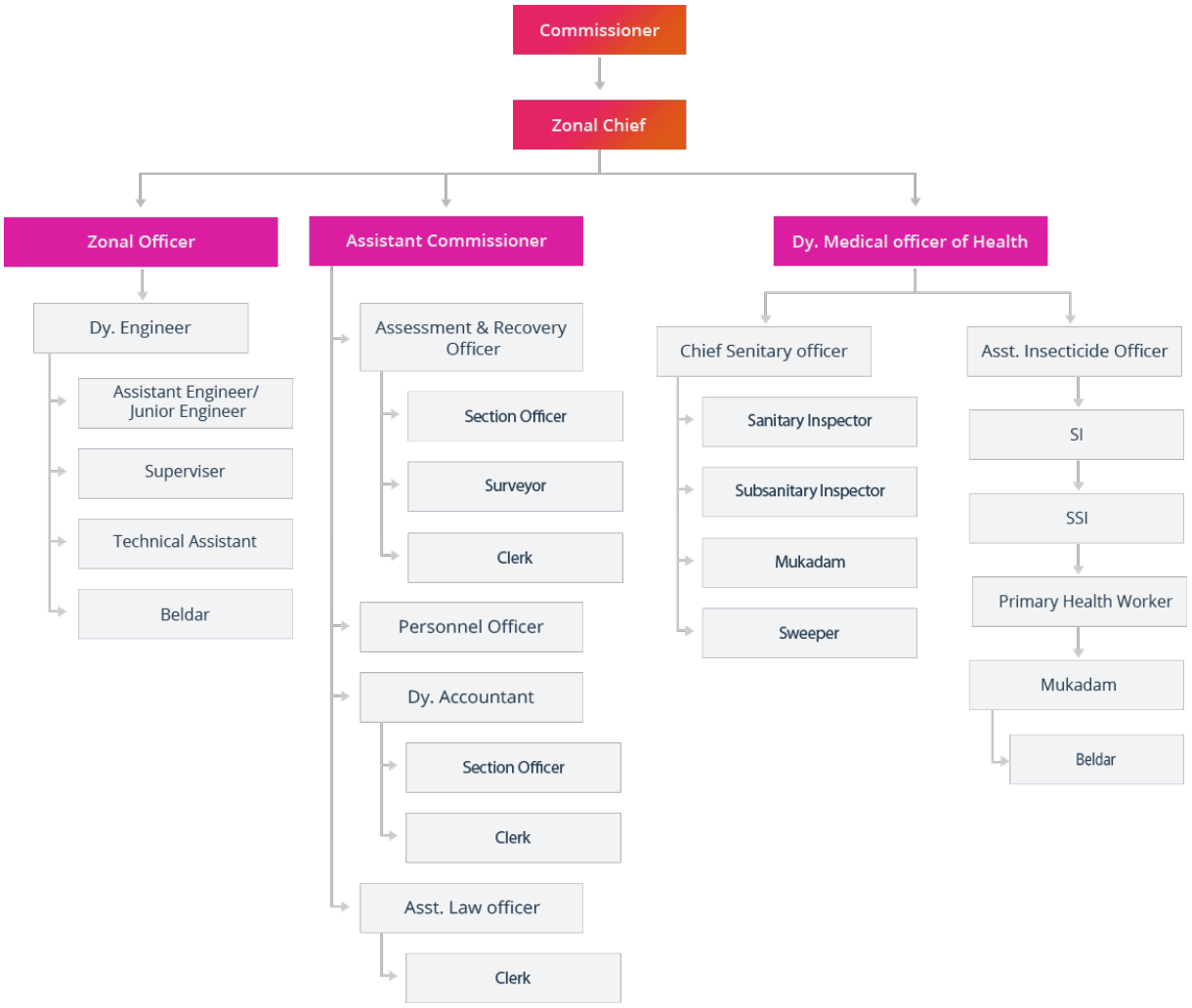


Figure 2: Organisational Chart of Surat Municipal Corporation

Source: https://www.suratmunicipal.gov.in/Corporation/Introduction

Industrial development in the city has been driven by several diamond processing factories and textiles, chemical and petrochemical industries. There are more than 41,300 small and medium-sized industries, in addition to huge industrial units in Hazira.

Most of the small-scale industries are located in Choryasi (Western Surat), Mangrol and Olpad (Northern Surat), Mandvi (Central Surat) and Palsana (Southern Surat) tehsils of the district. Further augmentation of the Surat-Hajira port linkage, the connectivity to National Highways 6 (to Kolkata) and 8 (to Mumbai and Delhi), and the Surat-Hajira rail link with a dedicated freight corridor at Vapi/ Vadodara stations have improved the infrastructural and transport situation of the district's residential, commercial and institutional areas and health facilities, and promoted industrial growth. The SMC is one of the very progressive municipal corporations in the country. It has several award-winning innovations and achievements to its credit, especially in the field of climate resilience, such as solar energy and wind energy projects, recycling of wastewater, ban on the use of plastics and methane, and establishment of weather stations and air quality monitoring stations.

1.2 SMC's Climate Reforms

With an annual budget of INR 47 crores, about 15% of which is allotted to health (2015-2016), the SMC is an example of an outstanding local government that practices good governance. It implemented the following interventions to reduce the impact of extreme temperatures in summer, prior to using the heat resilience toolkit.

- Organised health awareness campaigns and workshops to help improve tolerance of heat in summers.
- Implemented national health programmes such as the National Health Mission and the Pradhan Mantri Swasthya Suraksha Yojana
- Ran the Surat Municipal Institute of Medical Education and Research (SMIMER), which provides tertiary care services.
- Set up an Urban Health and Climate Resilience Centre, a first.

In 2009, a 'save water' campaign was conducted in Surat to sensitise the citizens and make them aware of the need to conserve water. The SMC also set up 10 weather stations all over the city. After 2011, all new establishments with a floor area of more than 300sqm were encouraged to install solar energy systems; solar lights were installed to light up advertisement hoardings, open areas, streets and public utilities. Emergency captive power generation systems became mandatory to deal with power cuts in medium and large-scale enterprises and multi-storied buildings. Waste segregation at source was promoted in the city, which helped in the segregation of reusable and recyclable waste, further reducing the load on disposal facilities and the shortage of available land. Along with these climate-resilient activities, the SMC has a unique initiative for research, training, networking and advocacy support, the Urban Health and Climate Resilience Centre of Excellence (UHCRCE).This is a trust, set up by the then municipal commissioner in 2017, following the completion of the "Urban Health and Climate Resilience Centre Project" under the ACCCRN project of Rockefeller Foundation, supported by Taru.

1. Surat Alliance for Urban Agriculture & Resilience (SAUAR)

Among the several approaches of community engagement that the UHCRCE attempted, including organising citizen's forums, city technical resource groups, and a 'peer educator' programme in schools, it also set up the Surat Alliance for Urban Agriculture & Resilience (SAUAR).

- SAUAR, a multi-stakeholder consortium, was formed by representatives from academia and non-governmental organisations in June 2015
- It aims to promote agriculture in the city to achieve health and nutrition security and climate resilience. SAUAR organises citizens' trainings, provides problem-solving and handholding support through social media, holds city events and exhibitions to promote its ideas, and forms peer groups to ensure sustained interest and documentation of experiences.
- A preliminary follow-up study of SAUAR beneficiaries (700 at present) revealed that more than 60% of them have attempted or are successfully growing vegetables at home. A majority of them are using terrace and balcony space, and are satisfied with the handholding support being provided by technical experts through social media and are involved in peer promotion too.
- SAUAR has taken baby steps for turning urban food challenges into opportunities by promoting growing of vegetables, especially local varieties, in small urban spaces, and thereby encouraging communities to contribute to health and nutrition security and climate change resilience.

2. UHCRCE's role in City Heat Action Plan

The Urban Health and Climate Resilience Centre (UHCRC), followed by the UHCRCE team, studied the trends in heat, community health, spatial variation, intra-domestic comfort, and community perceptions from 2013 to 2016 in Surat. It is still continuing these efforts to update the action plan. The UHCRCE was involved in the primary and secondary data collection for the case study. The team analysed 30- year weather data and the all-cause mortality data, which is taken as an indicator of health impact.

Image-Women using scarf to protect from summer heat Source- DNA India

02 UNDERSTAND THE ROOT CAUSES

India has a 7,516.6-km long coastline, of which 35km (0.5%) is in Surat. The city's climate is predominantly humid and hot, due to proximity to the sea, and categorized as sub-humid tropical climate. Relative humidity is the ratio of the partial pressure of water vapour in an air-water mixture to the saturated vapour pressure of water at a given temperature. Heat index is a measure of how hot it really feels, when relative humidity is factored with the actual air temperature. The seasons of Surat city are broadly summer, winter and the monsoon, with fluctuations in temperature. The summer months (March to May) are relatively hot, with temperatures ranging from 37.78°C to 44.44°C.

The maximum humidity hovers around 80%. Winters are mild, and the climate is pleasant during the monsoon season. The city's mean rainfall is 60 inches. About 90% of the rainfall occurs from June to September (Desai, Patel, Rathi, Wagle, & Desai, 2015). To understand the issues, as specified earlier, the climatic conditions and contextual challenges are considered under the three broad issues of climate, relative humidity and heat index. Firstly, a study of the climatic conditions is presented below (refer chapter- 3.2 How to understand heat stress in a city?) (Desai, Patel, Rathi, Wagle, & Desai, 2015)

2.1 Analyzing Climatic Conditions

1. **Topography of the city**

   The city is located at 21°10'N 72°50'E / 21.17°N 72.83°E / 21.17; 72.83, 13 metres above the sea level. The Surat district is surrounded by the Bharuch, Narmada and Navsari districts, with the Gulf of Cambay lying to its west. According to the Bureau of Indian Standards, the town falls under seismic zone-III, on a scale of I to V (in order of increasing vulnerability to earthquakes). The building of a dam on the River Tapi led to the closure of the original port facilities in Surat.

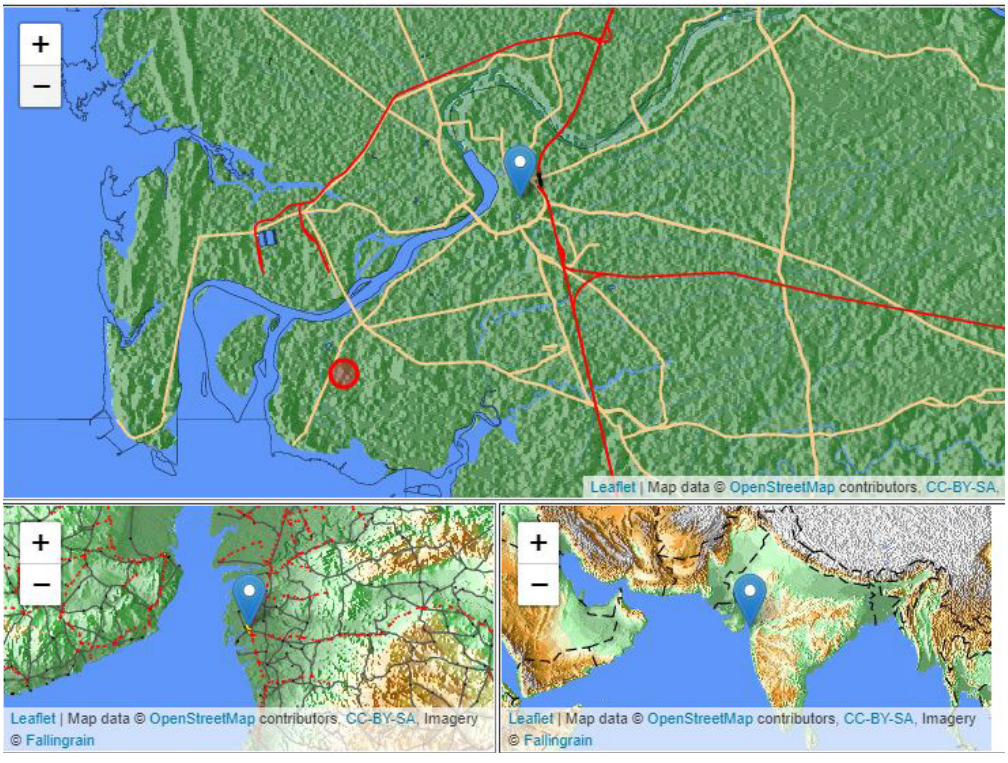


Figure 3: Topographical map of Surat City

2. Variation in air temperature and precipitation

As per the methodology explained in section 3.2, the trends in temperature changes and precipitation in the city over 30 years were analysed. It was observed that there were fluctuations in both factors, with highest temperature and highest recorded rainfall being seen in 1988. The trends also indicate that Surat experiences temperatures >40°C every summer, which qualifies as a heat stress condition as per the criteria defined by the National Disaster Management Authority of India.

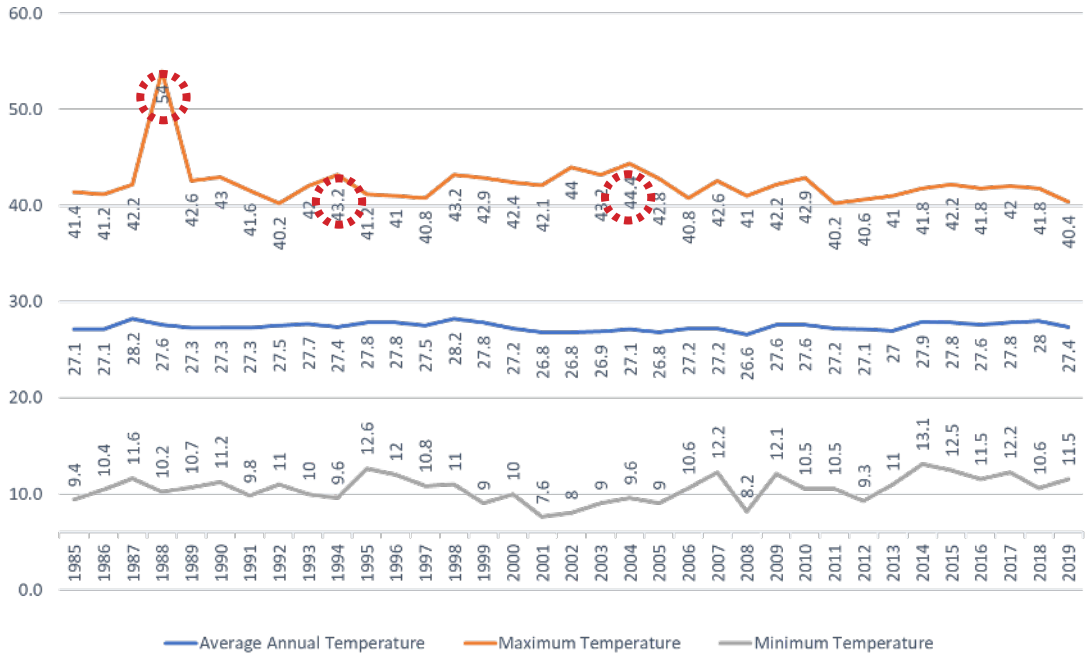
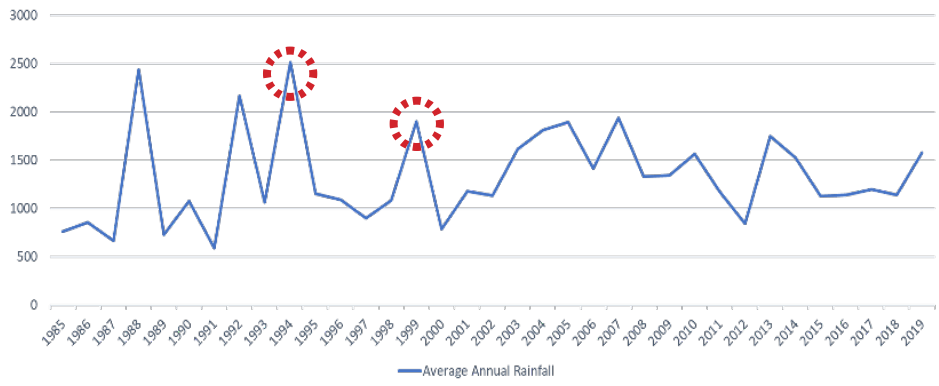


Figure 4: Trend of change in temperature in Surat (1985 - 2019)

Source: Article published in International journal of environmental sciences

The high tide from the River Tapi reaches the western part of the city, with a tidal range of five to six meters. During the rainy season, high tides often inundate the settlements located along the several tidal creeks. Flooding occurs recurrently, with records showing floods dating back to 1869. On average, the city was flooded every two and a half years between 1869 and 1884. Floods became less frequent between 1949 and 1979, occurring once every four years on average. Since then, there have been five major floods in 1979, 1990, 1994, 1998 and 2006, with last one inundating 75 per cent of the city, at a very high cost to the population, the economy and the municipal corporation (running to several hundred billion rupees). Around 150 people reportedly lost their lives, according to an official estimate.



Source: Article published in International journal of environmental sciences

Figure 5: Average annual rainfall in Surat

3. **Humidity**

The city experiences high humidity due to the Surat experiences high relative humidity throughout the year because of its proximity to the Arabian Sea, and therefore, the temperature values will not give the full picture of the extent of the heat felt in summer. Additionally, a combination of heat and high humidity can cause an extreme heat event or heat wave.

The mean humidity in summer has been rising from 54.9% to 60.4% over the last 30 years. The maximum mean humidity for the summer months is more than 70% for all five years between 2010 - 2014. A hotness risk analysis of the 2010-2014 period shows a significant rise in both temperature and relative humidity, which could be linked to global warming phenomenon responsible for the remarkable increment in extreme and mean temperatures in summer. Evidence collected from a few nations shows the negative impact of high temperatures and humidity can be mitigated with appropriate adaptation actions. Other than unfavourable climatic condition, natural contamination and conflict of precipitation brings about discernibly climbing humidity for Surat. Heat and humidity are critical factors that impact temperature, which can, in turn, affect the health and well-being of the people of Surat.

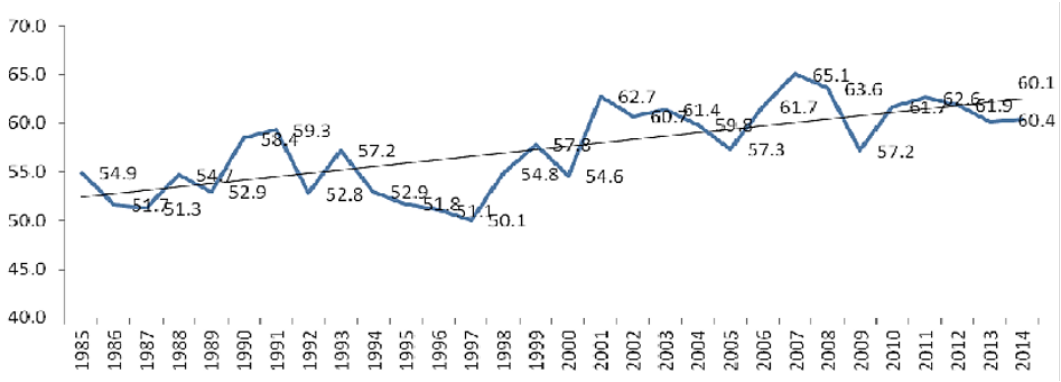


Figure 6: Average relative humidity in Surat *(Desai, V.K., 2015)*

4. **Changing patterns of the summer season**

Changes in the delay of extreme danger days/ hot days, even during the post summer months, have been observed in the city. The summer months are considered to run from February to May, while the post-summer months can vary as per the data for the selected year. In a coastal city like Surat, it is important to consider not only the temperature but also the humidity while calculating the heat days. Therefore, the number of days with temperatures above 33°C of the Heat Index is taken into consideration for plotting the trends.

Overall analysis of climatic conditions study: The impact on the all-cause mortality due to heat waves (observed because of the above-mentioned climatic conditions) has been explored and documented by public health experts and climatologists. Generally, the linkages between the heat and the all-cause mortality are studied at broader scales that are less likely to be relevant at the local level. Within the city, the geography of the zone (sector), its location near a river or sea, the number of industrial units, population density and slum population might redistribute the temporo-spatial pattern of the all-cause mortality in relation to the high temperature. However, the spatial variation of the all-cause mortality with the summer temperature has not been the focus of attention.

Understanding mortality in the city due to the heat morbidity: In Surat, 36,167 deaths were reported in 961 summer days from 2001 to 2012. The mean daily mortality rate was 37.6±9.4 in this period. When the maximum temperature crossed 40°C, a 11% rise in the all-cause mortality was recorded, while all-cause deaths increased by 3 (9%) per day when the Heat Index reached 'Danger' levels and increased by 6 (18%) per day when the Heat Index reached 'Extreme Danger' levels. The effect of extreme heat on mortality was at peak on Day 2 of the maximum temperature.

The increase in mortality in relation to rise in temperature leads to the conclusion that temperature is an important factor that affects the all-cause mortality for Surat.

CLIMATE INDICATORS AND MORTALITY STATISTICS OF SURAT CITY			
Indicator	No. of Deaths	No. of Days	Mean no. of Deaths per Day
Maximum Temperature (°C)			
25-30	228	6	38
30-35	17299	472	36.6
35-40	15721	413	38
40-45	2919	70	41.7
Heat Index (Category °C)			
(27 to 31) Caution	68	2	34
(32 to 40) Extreme Caution	3427	96	35.6
(41 to 54) Danger	25098	674	37.2
(> 54) Extreme Danger	7574	189	40.0
Total	**36167**	**961**	

Table 1: Mortality statistics and relation to the heat indicators for Surat

This also augments the previous findings and is consistent with the results obtained from other areas of Surat (S.K. Rathi, 2017). The all-cause mortality is also correlated with the heat index, as stated by various studies. The fact that high humidity (≥ 50%) for 147 summer days, temperature ≥ 40ºC for 14 days and HI > 54ºC for 38 days can pose a risk of excess all-cause mortality is consistent with previous results (Vikas Desai U. P., 2015).

The East zone of Surat shows a high rate of all-cause mortality in summer, as compared to the total zonal deaths. This can be explained by: 1) high population density; 2) greater distance from the sea as the wind flows from the South-West direction, having a cooling effect,
3) more heat wave days (42 out of 184 summer days) with temperatures ≥ 40°C, and 4) greater numbers of settled migrants (Vikas Desai S. R., 2015). The all-cause mortality is high in the southwest and central zones, where there is a combination of high density of population, industries and slums with migrants with low availability of healthcare, disaster and urban services. As a result, these zones are most vulnerable to the risks posed by extreme temperatures (refer ANNEXURE 5: HEAT STRESS VULNERABLE ZONES IN SURAT).

2.2 Analyzing the causes (with the data available for the city)

Understanding the impervious areas and green spaces:

Figure 7: Development Plan 2015 for SUDA

To analyze the percentage of per capita green cover and water bodies, the relevant data from development plans is considered. The comparison of these development plans (2015 and 2035) provides an understanding of the focus on green cover/ water bodies by the town planning department.

Annexure 6 (ANNEXURE 6: PROPOSED LAND USE FOR SUDA DEVELOPMENT PLAN 2035) provides a detailed comparison of the area reserved for recreational purposes, which is proposed to be increased from 1% to 5.80% in the Urban Development Authority region. However, the space for agricultural areas, water bodies and other non- urbanised areas would be reduced from 730sq.km to 304sq.km (approximately equal to 41% decrease).

Further, Annexure 2 (ANNEXURE 2: CHANGING PATTERN OF BUILT DENSITY AND GREEN COVER) explains the increase in urbanisation over the years from 1985 to 2012. The percentage of per capita green cover was recorded as 0.63%.
The tree cover study by the Gujarat Forest Department (Annexure 3) provides an overview of tree cover and number of trees per 100 persons in major cities of Gujarat State. The tree density per hectare in Surat is 8.4 and the number of trees per 100 persons is only 7.48, which is the lowest among the enlisted cities, of which Gandhinagar is observed to be the greenest city.

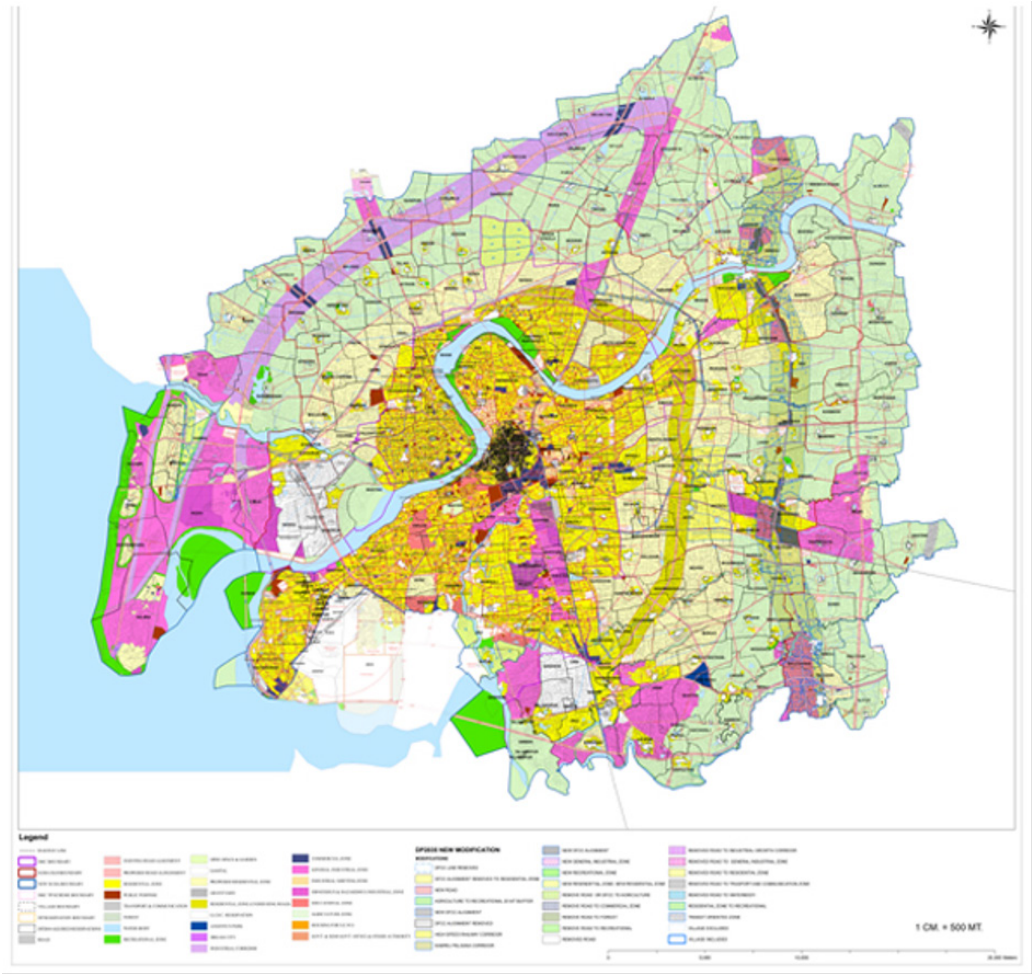


Figure 8: Development Plan 2035 for SUDA

Understanding the waste heat and energy:

The details for analyzing the waste heat and energy for the city of Surat are as follows:

1. **Calculating the passenger car unit** – As listed in the ANNEXURE 4: REGISTERED VEHICLES IN TOP 10 CITIES, the number of cars per sq.km is 0.34, while that of all other vehicles is 2.67. The data shows that although the number is quite low as compared to Delhi and Bengaluru, it is similar to that of the cities of Pune, Hyderabad and Kolkata. These cities have larger populations (being Tier 1 cities) and are larger in area, which implies that, in comparison, the per sq.km density of vehicles is quite high in Surat.

For the road transport emissions inventory, besides the total number of vehicles and their usage information, the vehicle speed information to spatially and temporally allocate the estimated emissions to the respective grids is also important. This information was gained from Google Maps services. For Surat, the speed information for representative routes across the city should be collected for multiple days.

2. **Calculating trend analysis** - An emissions inventory for the Surat region revealed the following pollutants – Sulfur Dioxide (SO2), Nitrogen Oxides (NOx), Carbon Monoxide (CO), Non-Methane Volatile Organic Compounds (NMVOCs), Carbon Dioxide (CO2); and Particulate Matter (PM) in four bins (a) coarse PM with size fraction between 2.5 and 10 µm was conducted for the year 2015 and projected till 2030.[3]

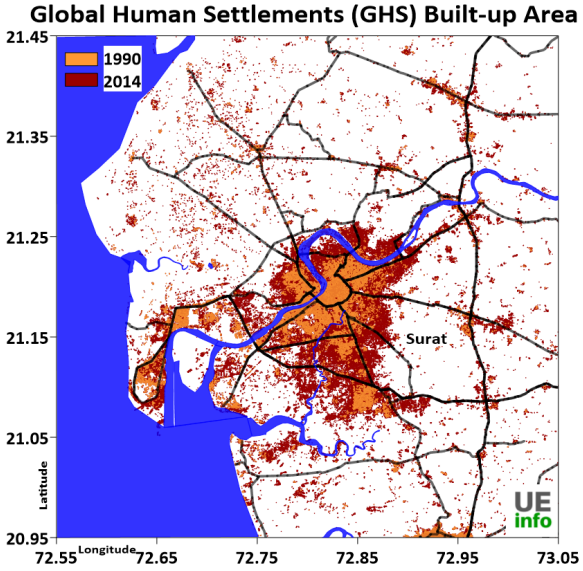


Figure 9: Emissions through built up areas

Apart from the official reports, the resource materials included GIS databases of land use, land cover, roads and rail lines, water bodies, and built-up area (as shown in Figure 9), besides commercial activities (such as hotels, hospitals, kiosks, restaurants, malls, cinema complexes, traffic intersections, worship points, industrial hubs and telecom towers), population density and meteorology at the finest spatial resolution possible (1-km).

This emission inventory is based on the available local activity and fuel consumption estimates for the selected urban airshed (represented in the grid). This information is collated from multiple agencies such as the Central Pollution Control Board, State Pollution Control Boards, Census Bureau and National Sample Survey Office. The results of the satellite data derived concentrations are useful for evaluating annual trends in pollution levels and are not a proxy for on-ground monitoring networks. This data is estimated using satellite feeds and global chemical transport models. Satellites are not measuring one location all the time; instead, a combination of satellites provide a cache of measurements that are interpreted using global chemical transport models (GEOS-Chem) to represent the vertical mix of pollution.

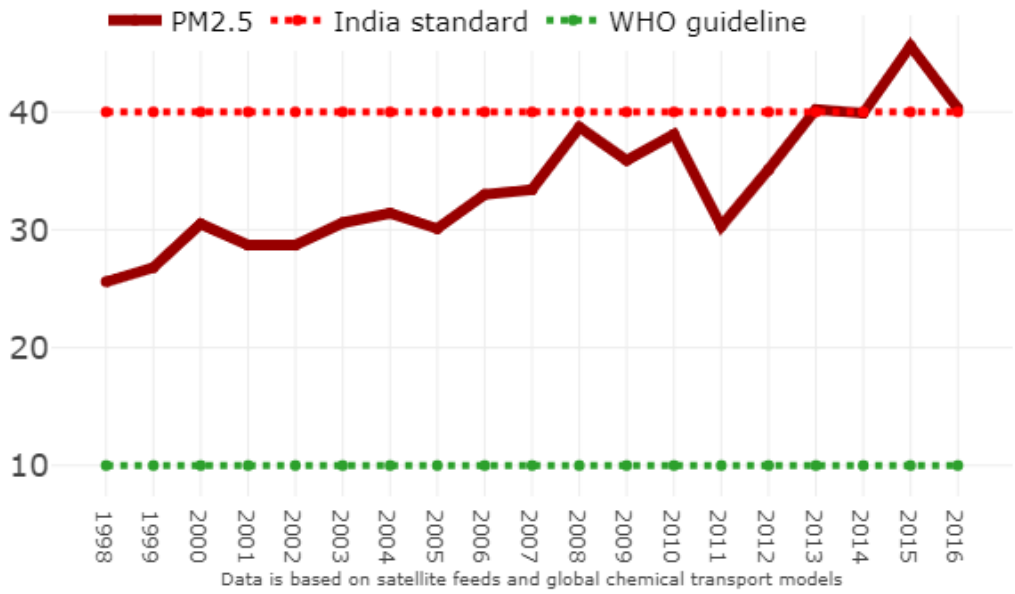


Figure 10: Trend of emissions for Surat

2.3 Contextual challenges (with the use of stakeholder engagement tool)

To understand the experiences and issues regarding heat stress from stakeholders and decision makers, a multi-stakeholder engagement workshop was conducted in Surat. The participants included the local government officials, public health researchers and officers, climate researchers, urban planning practitioners and NGO representatives.

As per the discussions, it was observed that the sections of population most vulnerable to heat waves in Surat are migrant workers and their families due to higher exposure, as they are primarily working as construction labourers and vegetable sellers, in addition to traffic police, sales people, delivery persons and school children. The effects of a rise in temperature are different in Surat due to the presence of humidity along with heat. A special approach is needed to ensure comfortable housing, workplaces and healthcare services for the major vulnerable groups. The contextual challenges explained by the key stakeholders were

- The presence of humidity and its combination with high temperatures reduces the rate of perspiration and increases heat inside buildings
- Concrete buildings absorb heat and humidity gets trapped inside during the daytime; it gets released at night when the outside temperature drops.
- Higher rate of evaporation causes drying of lakes and water bodies
- Presence of industries, with Surat being a port city, also leads to a higher amount of industrial emissions

2.4 Identifying the root causes of heat stress[5] for Surat

Following the analysis of the climatic conditions and the feedback from the discussions, the causes of heat stress in Surat city have been identified as follows:

- High humidity – Due to topography and geographical conditions.
- Trapping of heat inside buildings (day-time) – As explained through the intra-domestic discomfort data (Nital Doshi, 2018), higher levels of humidity outside lead to the trapping of heat inside buildings during daytime.

2. **Increase in thermal reflectance (night-time):** When the outdoor temperature falls at night, the heat trapped inside buildings is released through the concrete and tin surfaces and leads to increase in the outdoor temperature as well.

3. **Increase in waste heat and external energy inputs:**

- Vehicular and Industrial emissions – The rise in the number of industries and of emission of harmful air pollutants are among important causes of heat stress in Surat.
- Increase in the use of artificial cooling – Higher humidity on the outside leads to trapping if heat within the buildings. This increases and results in the delayed use of artificial cooling systems.
- Increase in electricity usage – As a result of increased use of artificial cooling systems, there is an increase in the electricity demand for the entire city, which eventually increases the waste energy output for the city.

4. **Lack of green spaces and water bodies:**

- Limited green spaces – It refers to the shortage of parks and green spaces in the city to reduce the heat island effect.
- Degradation of water bodies – The river and lakes in the city are important for reducing the surface temperature. These water bodies are currently contaminated due to lack of maintenance and dumping of solid waste, besides other factors

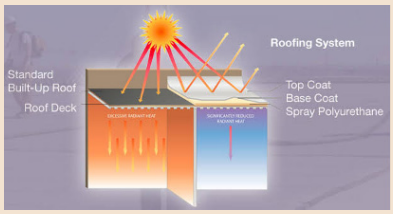
Image-Surat Clock tower Source-Twitter

03 IDENTIFICATION OF CONTEXTUAL SOLUTIONS

The following matrix has detailed descriptions of the solutions to combat heat stress in Surat, and the process of identifying them:

Cause 1: Increase in impervious surfaces:

NEIGHBORHOOD LEVELI TECHNOLOGICAL SOLUTION FOR EXISTING, NEW AND PERIPHERAL DEVELOPMENT	COOL ROOFING SYSTEM
What?	Over the past few decades, rooftops have become a large contributor to excessive heat issues. As many as 90% of the roofs in the city are poorly designed and built with dark, non-reflective, heat-absorbing materials. Because of this, rooftop temperatures can rise to 32°C above the prevailing air temperature. The cool roofing system, therefore, considers solar reflectance and thermal emittance. There are different types of cool roofs that can be used in Surat.
How?	**Coated Roofs** involve a coating the roof with a paint-like finish to help enhance its adhesion, durability and longevity, while simultaneously reducing bacterial growth. Cool coatings are best applied on flat roofs of existing buildings, and can be used on a multitude of surfaces, including asphalt cap sheet, gravel, metal and other materials. **Foam Roofs** are topped with a foam-like material for insulation purposes. Foam roofing has been recognized as a dependable, long-lasting and affordable cool-roofing technique. The foam is generally made from two liquid chemicals that combine to form a solid, flexible, and lightweight material that attaches seamlessly and has proven itself to be sustainable by requiring minimal maintenance and creating minimal waste. **Built-Up Roofing Systems, or BUR systems**, are roofs made of multiple layers of various materials. These various layers, when put together, help prevent solar heat from entering the building. Common BUR layers include: a base sheet, fabric reinforcement layers, and a protective surface layer.
Where?	This programme can be conducted at any government or private school of the city; involving 2-3 teachers per 50 students from grades 8th to 10th. The sensors can be installed at the schools and the data can be recorded online by linking all the sensors through a website.
Who?	Private organisations or funding agencies (e.g., Climate and Development Knowledge Network) the local government can initiate and execute the programme. The cost of execution only includes only the procurement and installation of the sensors (which is approximately INR 38,000 per sensor kit).



Cause 2: Increase waste heat/ energy for which the solution can be:

CITY/ REGION LEVELI AWARENESS BUILDING PROGRAM FOR EXISTING DEVELOPMENT	EARTH LEADER'S PROGRAM
What?	This component recognises children as Earth Leaders, who will raise awareness on environmental challenges. They will learn designing and development of sensor kits, monitoring of its performance and management of the sensors for continuous data generation on air quality (CO_2, PM2.5, PM10), ambient temperature and relative humidity. The children will also be trained in water quality testing (of bottled water carried from home), soil quality testing and primary healthcare in case of extreme heat and in checking the nutritional quality of food.
How?	The trends observed from this study will help them understand the seasonal variations , bacterial infections and effects of rising temperature, and to take relevant measures. • Children will learn to make monitoring kits using sensors, microprocessors, GSM Boards, LCD display, Photovoltaic Cells, rechargeable batteries and the basic programming language for running microprocessors. • They would be trained in preparing the sensor kits/devices and to use them in their schools to get live data and send it to a dedicated website. • A 'maker space' will be created in each school for the children to learn and use the above–mentioned technology. • Children will be also be taught about air pollution, urban heat island effect, heat waves, smog, and disaster risk mitigation, besides climate change during the training sessions. • They would be given training to interpret the data to understand the air/ water/ soil quality in their school premises. At the end, the students will be certified as "Earth Leaders" for their contribution and participation in the training programme.
Where?	This program can be conducted at any government or private school of the city; involving 2-3 teachers per 50 students from grades 8th to 10th. The sensors can be installed at the schools and the data can be recorded online by linking all the sensors through a website.
Who?	Private organisations or funding agencies (e.g., Climate and Development Knowledge Network) or the local government can initiate and execute the programme. The cost of execution only includes the procurement and installation of the sensors (approximately INR 38,000 per sensor kit).

Cause 3: Lack of green spaces for which the solution can be:

CITY LEVEL I TECHNOLOGICAL SOLUTION FOR EXISTING, NEW AND PERIPHERAL DEVELOPMENT	URBAN MICRO FORESTS	
What?	SAUR Urban forestry is defined as a planned, integrated and systematic approach to the management of trees in urban and peri-urban areas. Urban micro-forests promote and encourage creating a tiny dense forest on any land parcel owned by the municipal corporation or an individual owner. They contribute to the environmental, physical, social and economic well-being of the urban society	
How?	The existing parks require retrofitting, whereas new plantations can be considered on unused government-owned or individual plots. The following steps can be considered for executing the concept: • Selecting an existing park to be restored. • Understanding the ownership of the area. • Understanding the existing ecosystem. • Studying the existing biodiversity and vegetation. • Studying the quality of water and soil. • Understanding the required maintenance infrastructure. • Treatment and processing of the soil to prepare it for plantation. • Selecting plants as per native plant varieties, context, soil condition, weather and availability of resources. • Avoid large-scale plantation and adapt plantation in batches to nurture and monitor the growth of plants over a time period. • Undertake sustainable practices with regard to the compost and fertilisers used (rather than spraying chemicals). • Once densification takes place, the seating areas, play areas, shops and nurseries can be added to the strategically designated areas as per the design.	
Where?	• The planning and designing of these micro-forests can be explored through existing parks or unutilised areas. It can be created on any government land, land reserved for green spaces, vacant areas of institutions and individual vacant plots • Converting an existing park into a micro-forest - Creation of a micro forest on a land having remnants of native plants is one of the most sustainable ways of planning a forest. These forests are created by selecting species that can survive alongside existing plants and provide environmental benefits. Further, the existing micro-forest, after densification, can be designed as an inclusive public space to incur user charges. • Converting unutilised areas into a micro-forest –The development of an urban forest will consider several actions, such as whether it is a living forest, an individual ecosystem, a provider of ecosystem services or a landscape project. These are a few broad ways of selecting vegetation for creating a micro-forest.	
Who?	An individual plot owner and the local government can develop a micro-forest with the help of private organisations/ NGOs that can provide the material and execution guidelines.	

Solution for engaging and creating awareness among the community:

Community education is an important tool to reduce the impact of heat on public health. Three partners - SMC, organisations that are involved in creating awareness and the community that is benefitting from by the campaign - have to work in synergy to achieve the goal of "Healthy Surtis in Healthy Surat". The community need to be informed, educated and skilled to empower itself and become an effective partner in the heat and health action plan.

The community information and education process can be done through mass media by conveying appropriate messages with the help of audio visual media and social media, besides other platforms.

Community skill building is more of a participatory process. Thus, NGOs volunteers should be engaged to reach a larger group effectively in schools, women's organisations, youth organisations, occupational groups and senior citizens' groups. The peer education model may be adopted by which student-to-student, student-to-family, woman-to-woman, woman-to-family, youth-to-youth, youth-to-family, youth-to-society, NGO- to-society impact can be achieved. A snowball effect shall multiply the reach. While preparing the educational materials, simple principles of community education such as clear messages, simple language, and effective presentation need to be adhered to.

Community Education:

Community awareness campaigns that are conducted with the approval of the SMC are given below:

1. **Community group interactions (Surat Arogya Samvad).**
   - A forum of community members to learn, share and care.
   - Opportunity to get updates, add community understanding and practices and identify doable and adoptable practices.
   - Convert the core group members as PEER educators for wider and extended networking.

2. **School awareness campaigns (Hamsafar)**
   - Vulnerable and active group.
   - Innovative participatory information, caution and action sharing.
   - A sensitive messenger for the family.
   - An effective and active PEER educator for students of their and other schools.

3. **Circulars**

4. **Handbills, Stickers, Posters etc.,**

5. **Mass media (simple and clear advertisement should be circulated)**
   - News paper
   - TV scrolls/TV panel discussions
   - List of videos compiled for community awareness

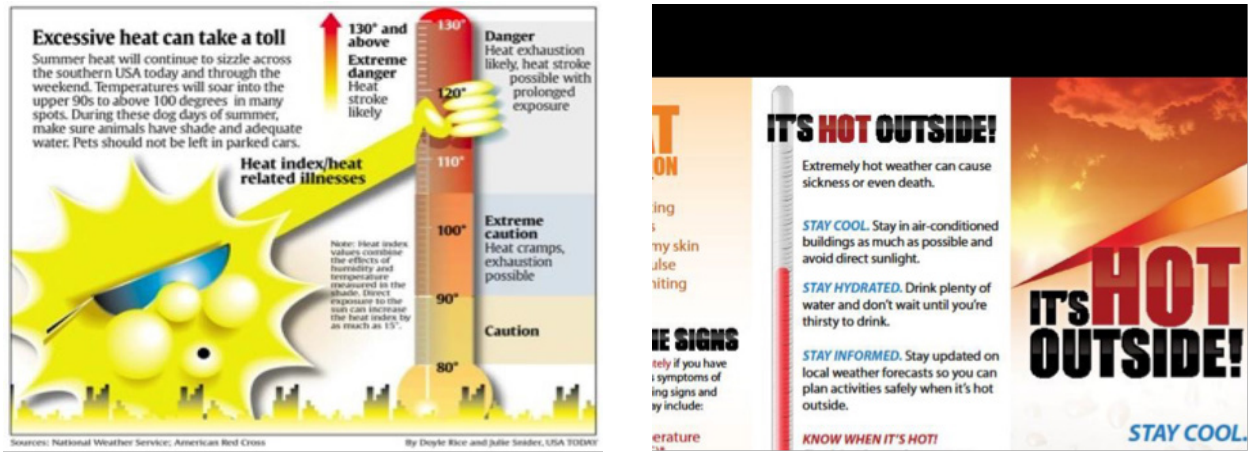


Figure 11: Examples of posters and leaflets

Image- Migrant workers returning home duing COVID-19 Source-TheEconomicTimes

04 PRIORITISE THE SOLUTIONS

A demonstration of how to prioritise the solutions, listed in Chapter 4, by following the criteria for prioritisation (as per the City Heat Resilience Toolkit), is described below:

ACTIONS/ SOLUTIONS	IMPACT	TIME SPAN	COST	REFORMS	TOTAL SCORE	PRIORITY
Cool roofing system	Health & environment	20 days	Only the material cost	-		IV
	35	18	27	0	80	
Solar Parks	Environment	6 Months	Material and installation	Installation of solar panels promoted by MNRE		X
	17	13	20	15	65	
Cool/ Permeable pavements	Environment	3 months	Material and installation	Roads and footpath projects		VIII
	17	16	20	15	68	
Urban micro forest	Health & environment	10 years	Cost of seeds/ saplings	-		VII
	35	10	28	0	73	
Earth Leader's programme	Environment	5 days/ school	Cost of sensor kits	-		XI
	17	19	25	0	61	
Material and design specifications for affordable housing schemes within DCRs	Health & environment	Immediate	-	DCRs		I
	35	20	30	15	100	
Early warning systems and community awareness programme	Health & environment	Immediate	Cost of the systems	-		IV
	35	20	25	0	80	
Teacher's Awareness Program	Environment	Immediate	-	-		IX
	17	20	30	0	67	
Urban Agriculture (SAUAR)	Health & environment	3 months	Cost of training areas	Citizens online training, exhibition		VI
	25	16	25	10	76	
Community / Citizens groups	Health & environment	Immediate	Cost of awareness charts and stationery			II
	35	20	25	10	90	
Continuing Medical education	Health	1 week	Cost of awareness charts, doctor and medical adviser team	Medical camp arrangement		IX
	17	20	20	10	67	
Heat and health action plan	Environment	6 months -1 year	Cost of experts, surveys, research etc.	-		XII
	17	10	28	0	55	
Yuva climate resilience group	Environment	Immediate	Cost of experiment material	Arrangement of group discussion		V
	17	20	30	10	77	
Street education events (U Turn at Surat)	Health & environment	Immediate	Only material cost	-		III
	35	20	30	0	85	
Future urban practitioners joint trainings	Health & environment	30 days	Material and space cost	-		IV
		18	27	0	80	

ANNEXURE 1 HEAT STRESS VULNERABLE ZONES IN SURAT

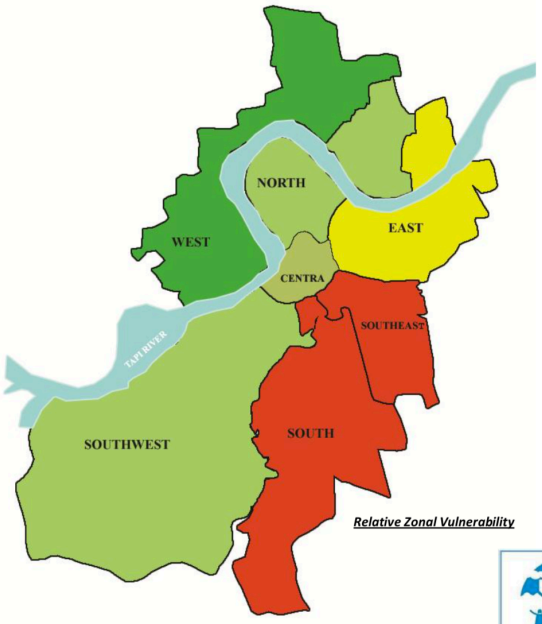
"RELATIVE ZONAL PUBLIC HEALTH VULNERBALITY" ASSESSMENT

INDICATOR WISE RELATIVE SCORING

Zones	Health	Disaster	Socio Demography	Urban Service	Total Score	Percentage W.R.T Max. score
West	27	12	20	25	84	78
South West	27	12	18	22	79	73
Central	25	11	18	24	78	72
North	24	10	18	22	74	69
East	21	11	21	20	73	68
South	24	10	16	15	65	60
South East	21	10	9	21	61	56

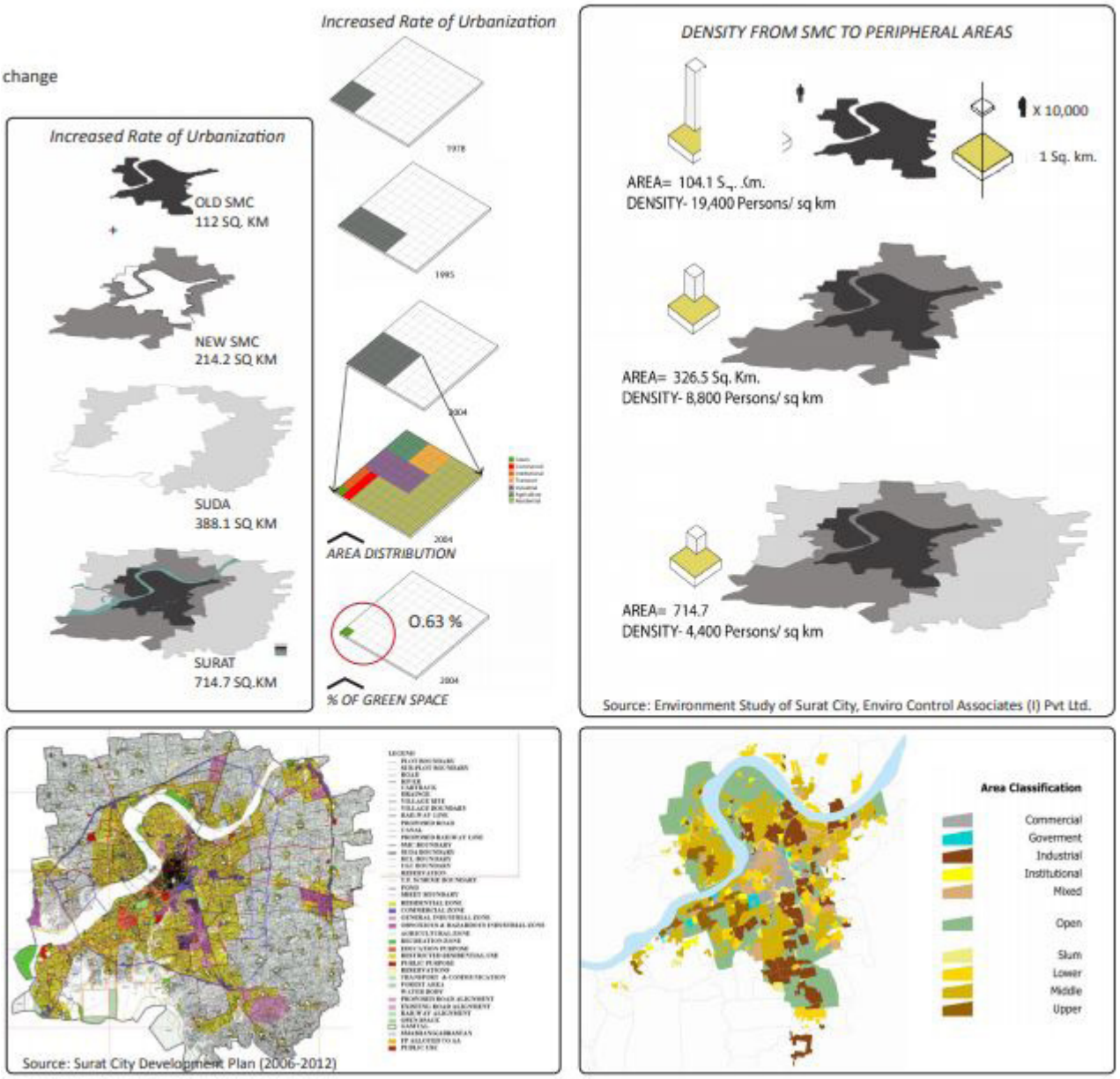
RELATIVE COLOUR CODING FOR ZONE

ZONE		RELATIVE VULNERABILITY
WEST	78	LESS
SOUTH WEST	73	MODERATE
CENTRAL	72	
NORTH	69	
EAST	68	HIGH
SOUTH	60	VERY HIGH
SOUTH EAST	56	



Source – Surat City Public Health Adaptation – Spatial Vulnerability study report (2016), Urban Health & Climate Resilience Center of Excellence (UHCRCE)

ANNEXURE 2 CHANGING PATTERN OF BUILT DENSITY AND GREEN COVER



Reference: http://www.asiapacificadapt.net/sites/default/files/resource/attach/Surat_City%20Resilience%20Strategy TARU-SMC.pdf

ANNEXURE 3 VARIATION IN TREE COVER FOR MAJOR CITIES IN GUJARAT

Status of tree cover in Municipal Corporation Areas

Tree counting data reveal that Gandhinagar is the greenest city in the terms of tree density as well as the area under tree cover. Over all, Gandhinagar, Bhavnagar and Vadodara may be called as green cities having tree densities higher
than the average density in the eight municipal corporations. Other municipal corporations- Surat, Ahmedabad, Rajkot, Junagadh and Jamnagar have tree densities below the state average.

Table 2: Tree population in Municipal Corporation Areas - Eight major cities in Gujarat

MAHANAGAR PALIKA	HUMAN POPULATION	GEOGRAPHICAL AREA IN HA	NUMBER OF TREES ABOVE 10 CM GBH	TREE DENSITY PER HECTARE	TREE COVER % OF GEOGRAPHICAL AREA
Ahmedabad	5,570,590	46,985	618,048	13.2	4.66
Surat	4,462,000	39,549	333,990	8.4	3.00
Vadodara	1,666,700	16,264	747,193	45.9	16.29
Gandhinagar	208,300	5,700	866,672	152.0	53.9
Rajkot	1,287,000	10,400	137,522	13.2	4.69
Bhavnagar + Victoria Park	593,770	5,320	475,953	89.46	21.35
Junagadh	320,250	5,670	76,694	13.5	4.80
Jamnagar	529,310	3,434	45,877	13.4	4.74
Total	**14,637,920**	**133,322**	**3,301,949**	**24.8**	**9.65**

Note: (i) Victoria Park (202 ha.), a forest area, is within Bhavnagar Municipal Area and a total of 212,521 trees of Victoria Pak are included in the above figures. Similarly, trees in about 450ha of Indroda Park (forest area) are included in the tree population in Gandhinagar

Table 3: The tree cover and tree cover per inhabitant

MAHANAGAR PALIKA (MUNICIPAL CORPORATION)	GEOGRAPHICAL AREA (IN HA)	TREE COVER (IN HA)	TREE AND FOREST COVER PER HABITANT	TREES PER 100 PERSONS	NUMBER OF TREES TO MEET A MINIMUM STANDARD OF 10M2 TREE COVER/ INHABITANT (LAKH)
Ahmedabad	46,985	2,188	3.9 m^2	11.08	15.82
Surat	39,549	1,184	2.7 m^2	7.48	12.37
Vadodara	16,264	2,650	15.9 m^2	44.83	7.47
Gandhinagar	5,700	3,075	147.6 m^2	416.07	8.67
Rajkot	10,400	488	3.8 m^2	10.69	3.63
Bhavnagar + Victoria Park	5,320	1,136	19.1 m^2	88.16	4.76
Junagadh	5,670	272	8.5 m^2	23.4	0.90
Jamnagar	3,434	1,877	3.1 m^2	8.66	1.48
Total	**133,322**	**12,870**	**3,301,949**	**22.55**	**55.10**

Note: On an average, trees in Gujarat are large. In Table 3, one hectare of tree cover is equivalent to 282 trees, having GBH above 10 cm. It is expected that about half of this number may be in medium to large trees. Saplings, shrubs, woody flowering plants and bushes below the dimension of tree size (10 cm GBH), which are not accounted as trees, fill some space to cover the gap.

Reference: https://forests.gujarat.gov.in/writereaddata/images/pdf/Status-of-Tree-Cover-in-Urban-Areas-of-Gujarat.pdf.

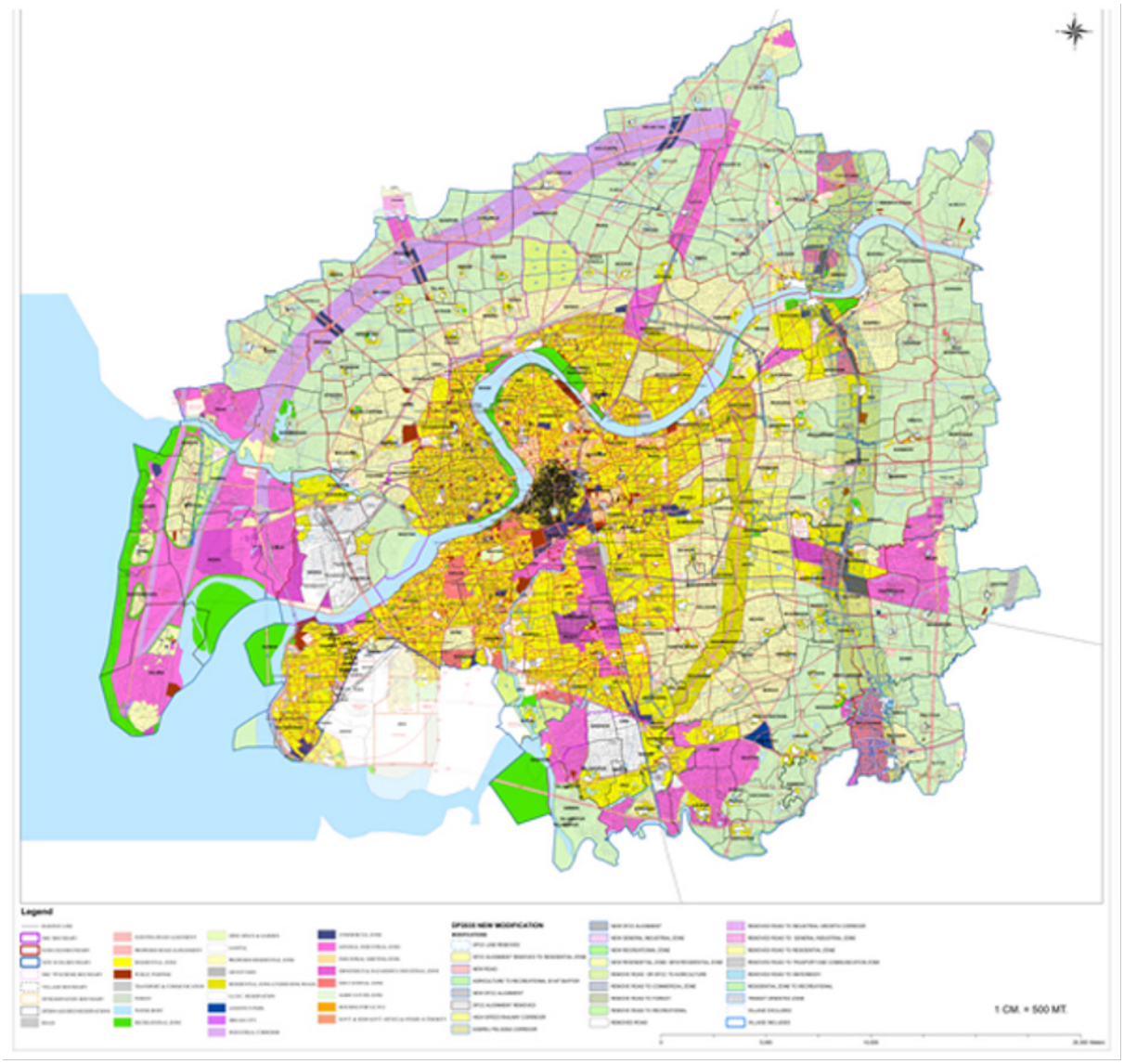
ANNEXURE 4 PROPOSED LAND USE FOR SUDA DEVELOPMENT PLAN 2035

LANDUSE		EXISTING - 2015		PROPOSED – 2035 (U/S 16)	
		Area Km^2	%age of Urbanised Land	Area Km^2	%age of Urbanised Land
1 Residential		**123**	**48**	**346.73**	**50.93**
	Residential Zone DP - 2004			166.54	
	Proposed Residential Zone DP - 2035			144.63	
	Residential Zone 90 m ORR			20.06	
	Gamtal			11.15	
	Industrial Shift Zone			4.35	
2 Commercial		**5**	**2**	**10.48**	**1.53**
3 Industrial		**67**	**26**	**112.96**	**16.59**
	General Industrial Zone			100.89	
	Obnoxious and Hazardous Industrial Zone			12.07	
4 Public Purpose		**14**	**6**	**47.87**	**7.02**
	Public Purpose Zone			10.41	
	Educational Zone			5.57	
	Reservations			31.89	
	DREAM City Zone			-	
6 Recreational		**2**	**1**	**39.48**	**5.80**
7 Traffic and Transportation		**44**	**17**	**95.26**	**13.99**
	Transportation Zone			94.46	
	Logistics Park			0.80	
8 Surat Industrial Growth Region		**-**	**-**	**28.14**	**4.13**

ANNEXURE 5
VULNERABLE POPULATION

VULNERABLE POPULATION	RISK FACTORS
Adults over 65	Less aware and adaptable to extreme heat
Individuals with chronic medical conditions	These medical conditions include heart disease, lung and kidney conditions and mental illness. Those taking medications that can worsen the impact of extreme heat are especially vulnerable.
Children under five years old	Sensitive to the effects of extreme heat and must rely on others to keep them cool and hydrated
Women and girls	May not have access to a variety of media, sleep in ill ventilated rooms, lack private bathing space, especially during menstruation
Pregnant and lactating women	Pregnant women are more likely to go into early labour in the week following a heatwave. This risk goes up with more consecutive days of extreme heat. *Lactating women require more drinking water as breastfeeding is extremely dehydrating
Outdoor workers (including traffic police and security guards)	Often engaged in strenuous labour while directly exposed to sunlight as well as heat and air pollution. More likely to become dehydrated and suffer from heat-related illness
People living alone	May not access help quickly
Individuals with disabilities	May not be able to access help quickly
Overweight and obese individuals	May be more sensitive to extreme heat and have difficulty thermoregulating
Individuals of low socio-economic status	May not have access to clean drinking water and other cooling measures. May not be able to access information about heatwaves and cooling centres
Migrants and refugees	May not have access to current information about heat advisories and health risks, or may experience heat conditions that are different from their place of origin
Homeless people	May not receive warning messages, may be unaware of cooling centres and may have limited access to other cooling measures (e.g. cool showers or baths)
Individuals unable to read and non-native language speakers	Cannot read current information about heat advisories and health risks. Non-native language speakers also may not be able to understand advisories broadcast on TV and radio
Tourists	May not be able to understand advisories in local languages. May not know how to access cooling centres, green spaces or other resources, including emergency management systems. May be from cooler climates and less adapted to the heat.
Animals/ pets	Dependent on owner for adequate protection from heat.

ANNEXURE 6 DEVELOPMENT PLAN 2015 FOR SUDA



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Climate & Development Knowledge Network

DEMONSTRATION PACKET

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