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The role of urban transport in delivering Sustainable Development Goal 11: Learning from two Indian cities

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A B S T R A C T

The next wave of unprecedented urbanisation is expected to occur in South Asia and Africa, with India being the most populous country. India's urbanisation choices will influence the success of the three global agendas: New Urban Agenda, Sustainable Development Goals, and the Paris Agreement. Sustainable urban transport is vital in delivering United Nations Sustainable Development Goal 11 (SDG11) on inclusive and sustainable urbanisation. SDG11 includes dimensions such as equity, gender equality, health, employment, and climate change. Through a mixed-methods approach, the paper develops an assessment framework to investigate: 'What are the roles of existing urban transport interventions in delivering SDG11?' in two Indian cities: Surat (an industrial city of 5.9 million) and Udaipur (a tourist city of 0.8 million) across three interrelated transport roles: providing Inclusive Access, delivering Climate-Resilient Development, and delivering Context-Sensitive Planning. Each urban transport interaction is assigned synergy (+1), trade-off (−1) or mixed impacts (−/+1). The paper finds that current transport interventions in Surat & Udaipur largely result in trade-offs across all three themes Inclusive Access (−1 for Surat & Udaipur), Climate Vulnerability (−1 for Surat & Udaipur), and Context-Sensitive Planning (−1 for Surat & +1 for Udaipur).

1. Introduction

The Sustainable Development Goal (SDG) 11, 'making cities inclusive, safe, resilient and sustainable' subsumes and links the New Urban Agenda (NUA) with emphasis on inclusiveness and the Nationally Determined Contributions (NDCs) committed by the countries after the Paris Agreement on climate change mitigation actions in 2015. Urban scholars have termed the NUA and the SDGs as progressive [1,2] but acknowledge the work needed to achieve a sustainable and equitable future of cities particularly of those in the Global South, which is expecting high levels of urbanisation.

Today, more than half the world's population lives in cities, and by 2050, about two-thirds of the global population is estimated to inhabit cities (Daniel, 2015); India alone will add about 400 million new urban dwellers, doubling its urban population by 2050 (UN, 2019). Cities account for 60–80% of energy consumption [3], 70% of resource consumption [4], and contributes to about 75% of global greenhouse gas emissions 5. The transport sector contributes to about one-third of the greenhouse gas emissions in urban areas and is rising faster than in any other sector; global emissions from road transport alone increased by 77% between 1990 and 2016 [6]. An accelerated decoupling of emissions from the transport sector is crucial to advance climate action in cities (IPCC, 2022; Iacobuţă, 2017); limiting warming to the Paris Agreement target of 1.5 °C requires a 40%–70% reduction in transport emissions by 2050.

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Locating climate change mitigation actions within the SDG11 requires assessing the synergies and trade-offs between the two suggested in the two reports from the Intergovernmental Panel on Climate Change (IPCC) [7] (Lwasa et al., 2022). For the SDGs and climate change mitigation actions to not remain as lip service, these agendas must be assessed for their coherence with each other. An informal connection between the SDGs and NUA exists [8]. Scholars have commented on policy coherence between the seventeen SDGs and questioned whether such coherence can be achieved [9] and if so, what tools or framework [10] could be used for the same. The SDGs have multiple internal contradictions, as all agendas at the global scale do. SDG11 marks important compromises and contradictions [11] when assessed against location-specific development concerns. Thus, these global agendas have to work within the real situation that is increasingly becoming unequal [12] amidst slowing down of economic growth, increasing global temperatures on account of global warming and ongoing war as well as conflicts within the cities. These agendas have to be localised within the local conditions and governance system [8] and require a monitoring and evaluation framework, which they lack [13].

Even at a low level of urbanisation [34.03% [14]], India's urban landscape is highly unequal. It is characterised by chronic poverty, gender inequality, and high levels of informalities in employment, housing, transportation, and service provisioning [15]. This often manifests as low levels of education, work participation rates, and low physical, social, and economic mobility among women, urban poor, and other vulnerable groups [16]. India is expected to have the highest urban population growth in the World [17], and to have an urbanisation level of 53% by 2050, adding about 400 million new urban dwellers [16].

Increased urbanisation also increases passenger transport demand, in turn increasing emissions. When rapid urbanisation is not accompanied by a robust public transport network, it leads to rapid motorization, and lack of investments in public transport translates, pushing people to rely on private vehicles (Ola Mobility Institute, 2021; Dalkmann, 2019). India and ASEAN countries' increasing dependency on 2 & 3-wheelers has increased their CO_2 emissions by 260% [18] (MoUD, 2014). Thus, urban transport's role in decarbonising cities is significant. Several low-carbon strategies tested across the globe include long-term strategies of changes in land-use and urban form to promote compact development and net-zero urban economic activity (Jaramillo et al., 2022; Macmillan et al., 2020) [19] short- & medium-term strategies such as decreasing travel demand (Taylor, 2021), a shift towards non-motorised transport (NMT) and public transport (PT) (Woodcock et al., 2021) [20], increasing vehicle occupancy (Hassold & Cedar, 2014), and increasing the share of cleaner fleet such as electric- and hydrogen-based vehicles (Logan et al., 2019).

India's transport sector is globally the fourth largest GHG emitter [21]. This makes it a priority area with regard to India's Nationally Determined Contribution (NDC) and its subnational policies. 'Sustainable mobility' in India is conceptualised as low-carbon transport modes and built-forms, which support land-use transport integration [19], the modal shift from private vehicles to public transport (PT) systems [20], promoting alternative fuel vehicles, promoting energy-efficient vehicles, stringent emission norms, promoting Intermediate Public Transport (IPT) and non-motorised transport (NMT), and the electrification of urban transport. At the same time, sustainable transport also includes increasing mobility of those who are mobility-poor, such as women, low-income populations, etc. [22]. Thus, the low-carbon transport agenda has to be in sync with the SDGs, which assessment is undertaken in this paper.

Against this backdrop, the paper assesses the interactions between urban transport and Sustainable Development Goal 11: Sustainable Cities and Communities-chosen for its urban focus and strong relevance with urban transport. Urban transport has a robust and multifaceted relationship with eight of the seventeen SDGs (Partnership on Sustainable Low Carbon Transport (SloCat), 2018) [23]. Based on an extensive systematic literature review, the study discusses the role of urban transport interventions in delivering SDG11 by identifying three broad themes emerging from this SDG's targets. These are (i) Inclusive Access (SDG11.1, 11.2), (ii) Climate Resilience (SDG11.5, 11.6, 11. B), and (iii) Context-sensitive planning (SDG11.3, 11.4).

The paper is grounded in two Indian cities, Surat (an industrial city of 5.9 million) and Udaipur (a tourist city of 0.8 million). Through a mixed-methods approach, the paper develops an assessment framework to investigate: 'What is the role of existing urban transport interventions in delivering SDG11?' in these two cities. The methodology for on-ground assessment of transport-SDG interactions involves two stages: (i) the first stage is an in-depth critical assessment of available transport- and city-development plans of the two cities based on which an inventory of urban passenger transport use and its GHG emissions use was prepared. This helped us identify transport modes for conducting users' surveys. At this stage we also undertook assessment of transport-SDG interactions focused around three themes listed earlier. These interactions were given tentative scores, explained later in the paper. (ii) The second stage involved field survey in each city which included transport users' survey. 75 questions across nine transport modes were administered to capture current travel patterns, mode preferences, mobility challenges, willingness to shift, user perception of the existing transport systems, accessibility during extreme weather events, and user recommendations to improve mobility for all. The responses from the transport users were triangulated with the assessment of transport-SDG interactions undertaken in stage 1 to obtain the final scores of these interactions. The sample drawn was using stratified random sampling, wherein the strata used were transport mode and geographic location. Further details related to the methodology are stated in section 3.

The next section discusses the findings from the literature review, followed by a section on methods. Section 4 discusses the transport landscapes of the case-study cities, followed by a detailed account of their transport-SDG interactions. Section 5 discusses the way forward for cities of the Global South and Section 6 concludes the paper.

2. Mapping urban transport's relation with sustainability

2.1. Inclusive Access

The first role, identified as providing Inclusive Access, is discussed in two aspects: (i) providing access to employment, affordable housing, and basic services (SDG11.1) and (ii) ensuring the inclusive design of transport systems to make them safe, affordable and universally accessible (SDG11.2). Inclusive access is measured against four parameters deemed vital for inclusivity: the network coverage of public transport and intermediate public transport, the network coverage of non-motorised transport, the affordability of public and intermediate public transport, and the quality of service.

The recent trend for the peripheralisation of the urban poor in cities of the global South makes affordable and accessible transport key to achieving housing for all [24,25]. The peripheralisation of affordable housing leads to longer travel distances, increased travel costs, and time poverty (King et al., 2017) [26]. SDG11.1 promotes access to affordable housing and basic services through public transport [27], which is vital for low-income communities, as improved access reduces instances of poverty and social exclusion regarding time, power, and space [28]. Designing transport systems for the most vulnerable benefits all user groups [29]. A range of initiatives around inclusive transport, such as age-friendly transport [30,31], pro-poor transport, and women-centric transport, have gained momentum over the past two decades [32–34]. Although transport systems that respond to special needs lead to higher operational costs [35], they generate positive impacts such as improved accessibility to education [36], reduced fatalities and injuries to school-going pupils [37], the improved well-being of the elderly [38,39], and further enhance the participation of women in economic and civic spheres [16].

2.2. *Climate resilient transport*

Urban sprawl, inadequate network coverage, and inefficient (i.e., unaffordable and low quality of service) public transport have increased dependence on private vehicles. All else being equal, this has led to various sustainability concerns. Longer trip lengths in terms of time and severe traffic congestion due to increased dependence on private vehicles have contributed to higher GHG emissions from urban transport [40,41]. At the same time, exposure to poor air quality affects individuals' cardiovascular, nervous, and respiratory systems [42,43], causing 4.2 million premature deaths globally (2016). SDG11.6 deals with mitigating the adverse environmental impact of cities, primarily through reducing air pollution and GHG emissions [44].

Resilient transport systems have the potential to mitigate various extreme weather events [45] and to form lifelines for rescue and relief work pre- and post-disasters [46]. In such scenarios, climate-resilient transports are crucial for vulnerable groups who are often disproportionately affected by extreme weather events and captive users of public and non-motorised transport [47,48]. These transport networks are often more susceptible to the damage caused by such events; erratic and heavy floods damage urban transport networks through prolonged waterlogging, while heat waves and droughts damage road networks. Cumulatively, such impacts reduce the ease with which people can access transport, which, in turn, curbs their access to economic activities [49–51]. Streets with green infrastructure are identified as providing effective strategies for enhancing urban resilience in India [52,53]. Streets provide a bundle of ecological services and generate co-benefits with sustainable transport [54]. Co-benefits include improved air quality, moderate micro-climates, and comfort during hot summer days through shaded streets, reduced risk of urban flooding during heavy monsoons by catching and filtering storm-water, and reduced risk of severe droughts by improving ground-water recharge. SDG11.5 and 11.B discuss the significance of resilient transport planning that focuses on reducing disaster risk and fatalities, including vulnerable groups.

It follows that the role of urban transport system towards delivering climate-resilient development includes two broad aspects: (i) accessibility during extreme weather events (SDG target 11.5 & 11.B) and (ii) contributing to improved (urban transport) air quality (SDG target 11.6). The latter is measured against three parameters: dependence on personal motorised vehicles, GHG emissions from urban transport, and streets with green infrastructure.

2.3. *Context-sensitive planning*

SDG11.3 and 11.4 highlight the importance of context-sensitive transport planning (e.g., the selection of bus services over rail services) in preserving natural and cultural heritage and supporting vital links between urban areas [55]. Additionally, context-sensitive transport projects mitigate mobility conflicts between locals and tourists in heritage-rich cities and tourism-based economies [56]. Intangible and tangible cultural heritage are impacted to a great extent by air pollution, noise pollution, and instances where there is a higher dependence on private motorised vehicles. Many low-carbon transport interventions (such as mass transit projects), when routed through eco-sensitive zones or historic cores, result in the loss of flora, fauna, canopy cover, built heritage, and public spaces [57]. Conceptually, higher urban densities are linked to better public transport access, improving economic outcomes. However, urban densification plans, which prioritize the financial viability of mass-transit projects, also adversely affect heritage [58]. The extent of regulation on informal activities and encroachment (e.g., by street vendors) influences context-sensitive planning. For example, formalising water taxis exponentially improved tourism and economic activities in Xochimilco, Mexico [59], while the partial regulation of informal mode E-rickshaw in Delhi indicated reduced dependency on private vehicles [60].

Thus, the roles of urban transport in delivering context-specific planning include (i) Inclusive Urbanisation (SDG11.3) and (ii) Natural & Cultural Heritage Preservation (SDG11.3 & 11.4). The latter is measured against three parameters: large-scale transport projects in the vicinity of eco-sensitive and heritage zones; streets with multi-utility zones which incorporate activities such as vending and parking; and conducive land use (mixed-use developments) and density.

3. Method and materials

This paper investigates the roles of intra-city urban passenger transport in delivering seven relevant targets (SDG11.1, 11.2, 11.3, 11.4, 11.5, 11.6, 11.B). Relevant SDG11 targets are identified using a mapping exercise through the Global South-based literature review, tested on two study cities using primary data, Surat and Udaipur, which were selected due to the availability of well-developed mobility plans. The transport plan (Comprehensive Mobility Plan[1]) [61] for Surat is for its Urban Development Area (SUDA), while Udaipur's (Low Carbon Mobility Plan[2]) (UMTC, 2015) focuses on the Udaipur Urban Control Area (UUCA). The study illustrates the need to analyse urban transport interventions against the likeliness of delivering SDG11 at a target level. A schematic representation of the project methodology is shown in Fig. 1. Key steps from Fig. 1 are elaborated below.

The critical steps noted in Figure 1 are elaborated upon as follows.

- Desktop assessment of city-level mobility plans: This includes a critical assessment of both cities' current mobility status using data from their city-level mobility plans and transport data in twelve other city-level planning and policy documents. A dataset of 77 data-points was created for both cities, including socio-demography, travelled demand, transport infrastructure, transport interventions, finance and governance details. Based on the dataset, each transport mode (NMT, PT, etc.) was compared against national benchmarks (refer to Supplemental Material- A) to analyse the adequacy and efficiency of each transport system element, and supplemented with the findings from the fieldwork, to assess whether the transport intervention generates a trade-off (−1), synergy (+1) or a mixed effect (±1).
- GHG Emission Inventory: Two GHG inventories were generated, one each, for Surat's and Udaipur's 2016 GHG emissions using ASIF[3] methodology, a bottom-up, model-based approach. The input data was borrowed from the mobility plans. Based on the activity level, the equation for calculating emissions was equivalent to the product of the number of vehicles, vehicle kilometres travelled (km), and the Automotive Research Association of India's (ARAI) emission factor (gm/km).
- Online Focus Group Discussions: Initially planned as an immersive workshop (pre-pandemic), the focus-group discussions were intended to capture experts' opinions on urban transport interventions and their impacts within and on two selected case study cities. Experts included renowned academics and professionals working on transport in Indian cities, government officials, non-government organisations (NGOs), civil society organisations, and other technical stakeholders. Three focus groups were conducted:

A. Mobility in Rapidly Urbanising Megacities (August 31, 2020): Experts from various backgrounds discussed transportation trends and needs in rapidly urbanising cities like Surat. Planning and Mobility experts shed light on urban planning's relationship with transport demand in Surat. Municipal officers discussed transport planning interventions catering to rapid urbanisation and motorization in their cities. The non-profit organisations and civil society representatives highlighted the challenges of various disadvantaged users like children, older adults, women, and the urban poor.

B. Mobility in Low-Income Neighbourhoods (September 2, 2020): In collaboration with the Mahila Housing SEWA Trust, 25 women community representatives from Surat's disadvantaged neighbourhoods engaged with the OPTIMISM team on travel patterns and needs of the disadvantaged community members, with a focus on women's mobility and mobility (neighbourhood-level) during extreme weather events like extreme heat and monsoon.

C. Mobility in Heritage Towns and Cities (September 9, 2020): Experts from different backgrounds with a working knowledge of mobility in Heritage Towns and Cities engaged with the OPTIMISM team on the unique mobility needs and challenges of Heritage Towns, transport infrastructure provision in the context of Cultural and Built Heritage Preservation, the impact of transport planning on heritage tourism, and innovative transport planning solutions tailored for heritage towns like Udaipur.

- In-person fieldwork: Initially, the project aimed to capture trip diaries of approximately 0.05% of the total population in both cities through in-person surveys. Capturing detailed trip diaries (generally containing trip details via various modes for a fortnight) through in-person surveys for such a large sample size was challenging especially given the ongoing pandemic. In keeping with the approaches used by researchers across the globe, mixed methods were deployed to overcome the hurdles of fieldwork during the COVID-19 pandemic. As a result, instead of detailed trip diaries, three types of surveys were conducted from October to December 2020: detailed transport users' surveys, household surveys, and a stakeholder's survey (refer to Table 1 for sampling details). Transport user surveys for nine different transport modes, contained over 75 questions prompting the respondents to reflect on travel patterns, mode choices, user satisfaction, mobility challenges, safety while using transport, affordability of transport, resilience during extreme weather events, impacts of transport projects on their mobility and livelihoods, and recommendations to enable sustainable, low-carbon mobility in their cities. Similarly, the household surveys captured demand-side trends, including travel patterns, mobility challenges, safety, affordability, resilience by mode, and the impacts of transport projects [62]. The stakeholder surveys with street vendors, local businesses, and other stakeholders located in the vicinity of large-scale transport projects, capture the socio-economic and health impacts of being located close to large-scale transport projects and infrastructure, opinions on common transport interventions like road widening, one-way streets, pedestrianization of historic urban cores, and recommendations for enabling sustainable mobility for all. In addition, supply-side data was captured through transport operators' surveys.

[1] Comprehensive Mobility Plan (CMP) presents a strategy for short-, medium-, and long-term investments to improve accessibility and mobility for its residents. Accessible at https://www.itdp.in/resource/tor-for-preparation-of-a-comprehensive-mobility-plan/.

[2] Low Carbon Mobility Plan provides a vision for urban transport in the city encompassing an approach that addresses both climate change and development benefits through an integrated transport and land-use planning process. Accessible at https://www.unep.org/resources/report/toolkit-preparation-low-carbon-mobility-plan.

[3] $A \times S \times I \times F$, where A is total transport activity (in pkm); S is share of pkm by mode; I is fuel efficiency by mode; F is emissions per unit of fuel by mode and type of fuel (UNFCCC, 2018).

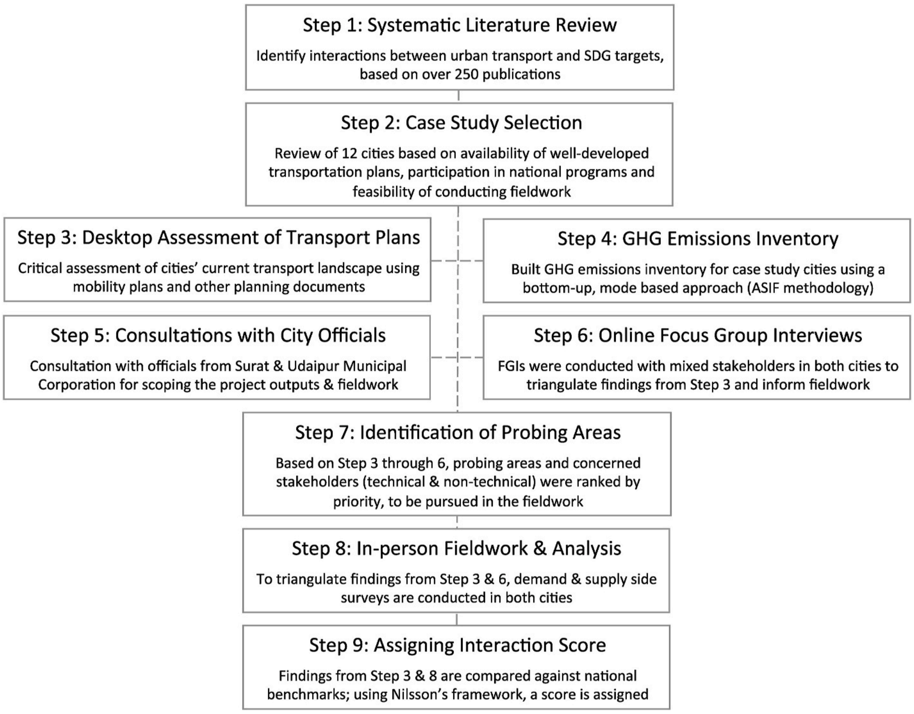

Fig. 1. A schematic representation of project methodology.
Source: Authors

Table 1
Survey sampling by Disaggregated Actors.

Survey Type	Disaggregated Actors	(#) Samples in Surat	(#) Samples in Udaipur
User Surveys	NMT Users	553	204
	PT Users	259	15
	IPT Users	135	30
	Private Vehicle Users	273	145
	Taxi Users	40	11
	Sub-Total	**1260**	**405**
Household Surveys	All Households	100	44
	Low-income Households	100	–
	Households within Vicinity of Proposed Metro	46	–
	Sub-Total	**246**	**44**
Operator Surveys	IPT Operators	45	25
	PT Operators	20	5
	Taxi Operators	20	10
	Sub-Total	**85**	**40**
Stakeholder Surveys	Shop owner & Street Vendor	30	20
	Tourist	–	51
	Sub-Total	**30**	**71**

Survey Administration: Random, stratified sampling was adopted for each survey type to ensure equitable representation of each neighbourhood. The sample size for each transport mode was proportionate to its mode share. Since strict inter-state travel restrictions persisted during the pandemic, the authors partnered with municipal corporations to draft a survey plan and deployed a team of local researchers. The authors followed stringent Quality Control (QC) and Quality Assurance (QA) protocols. Before the fieldwork, the authors hosted training sessions to ensure local teams in both cities were well-versed with survey content, QA/QC protocols, and survey administrative methodology. The team of local researchers recorded responses via tablets or mobile devices onto the Google Forms. The authors had real-time access to those Google Forms, enabling effective tracking of QA/QC protocols (refer to Table 1 for sampling details).

- Assigning Interaction Scores: Based on the desktop assessment, as discussed above, and assessment of the primary data collected through the online Focus Group Discussions (FGDs) and the in-person field surveys, the authors assigned interaction scores[4] to each urban transport-SDG11 target interaction. For each broad theme, the sub-themes (a total of six sub-themes) and parameters (a total of ten) were derived from the literature. The sub-themes pertained to specific SDG11 targets, while the parameters pertained to urban transport characteristics. Each parameter was based on universal transportation data points; for example, transport affordability was quantified through monthly household transport expenditure. This approach ensured the explicability of assessment scores for similar studies across different geo-political contexts. Each interaction was assessed into synergy (+1), trade-off (−1), or mixed impacts (±1). If both stages indicated a clear synergy or trade-off, then the respective scores were assigned, but if either stage indicated the opposite impact, a composite score was assigned (±1). A value of 0 indicates no impact. Assigning interactions scores, adopted from Ref. [10] are subjective as they are assigned by the authors, who are field experts. We acknowledge that results may vary with different groups of people, a common limitation of any exercise involving the assignment of assessment scores [10,28].

3.1. Transport - SDG interactions assessment in Surat and Udaipur

Surat Urban Development Area (SUDA) is over 1351 km^2 in size and has a population of 5.9 million (2016). Its primary industries are synthetic textiles, diamond polishing, and petrochemical; the latter is located close to the port [61]. The city is polycentric, with an incomplete ring-radial network expanding on its southern sides (Figure-2), and it had a population density of 6,190 persons per km^2 in 2011. Increased urbanisation has led to a steep increase in motor vehicles and 2.5 times increase in traffic. Private vehicles (2Ws, and 4Ws) make up most of the traffic and account for most of the trips made in the area. Despite hosting India's one of the longest Bus Rapid Transit System (BRTS) network, the lack of a robust and affordable public transport network results in low ridership in Surat. This has led to reliance on intermediate public transport and non-motorised transport; both of these forms of transport exhibit longer than average trip lengths - especially for vulnerable groups. A metro rail project is under construction in Surat.

The Udaipur Urban Control Area (UUCA) has a population of 0.8 million (2016) and envelops an area of 348 km^2; tourism forms the economic base of Udaipur, a city with rich cultural and built heritage. In 2019, 1.2 million tourists visited Udaipur, according to the Rajasthan Tourism Board. Udaipur is traditionally a compact city with a dense, ring-radial road network. The latter is, however, now rapidly expanding along two highways, which has created high travel demand (Figure-3). Udaipur has a small urban centre; 75% of the population resides within 18% of the total area. The traffic composition of Udaipur is predominantly comprised of 2Ws; such transport also serves high-income groups. Despite their poor quality, there is reliance on intermediate public transport and non-motorised transport. Overarching transport trends for both cities are listed in Table 2.

3.2. Inclusive Access

Table 3 shows the interaction score for the first theme, providing inclusive access. The authors decided on the scores assigned in Table 3 after comparing the primary data with the standard benchmark.[5]

a. Public transport and Intermediate Public Transport Network Coverage:

Udaipur's public transport comprises a limited city bus network and inter-city minibus services. With fixed routes and fares, intermediate public transport functions as an extended public transport, even though it is more expensive than formal public transport. The desktop assessment undertaken for this research evidenced that while Udaipur has a dense network of roads and highways (Figure-3), it also has inadequate public transport network coverage (20%). This restricts Udaipur's bus service modal share to 2%, against an average of 9% for Indian cities with populations of between 0.5 and 1 million persons [68]. Minibuses have a higher mode share (10%) than city buses due to the former's inclusive coverage of peri-urban areas. There are 27 fixed intermediate public transport routes in Udaipur, which provide coverage of about 50% within the UMC area (the core of the UUCA). However, this network thins as the distance from the centre increases towards the hinterlands. Except for heritage structures, public places lack universal access. UMC is working towards delivering toddler- and caregiver-friendly transport based on the Urban95 kit.[6]

The public transport network in Surat spreads across 376 km, with a 48% coverage (Table 1). Despite this, the public transport modal share is only 3%, compared to an average of 21% for Indian cities with a population of 4–8 million [63]. A potential reason for the meagre modal share of public transport is the lack of last-mile connectivity and poor network coverage in low-income neighbourhoods. Surat has a wider intermediate public transport network coverage, a mode share of 10.3%. Civil societies working on universal access have agreements with local and state authorities to deliver age-friendly and disable-friendly public transport infrastructure (FGD-01).

Surat's and Udaipur's limited public and intermediate public transport network coverage generate clear trade-offs (−1); both sub-

[4] Borrowed from [10].

[5] Level of Service standards stem from the Ministry of Housing and Urban Affairs' Service Level Benchmark Manual [69].

[6] Urban95: Urban95 kit prepares the built environment for early career development, for the age group of 0–3 years and their caregivers. Accessed at https://bernardvanleer.org/ecm-article/2018/urban95-creating-cities-for-the-youngest-people/on 26th December 2022.

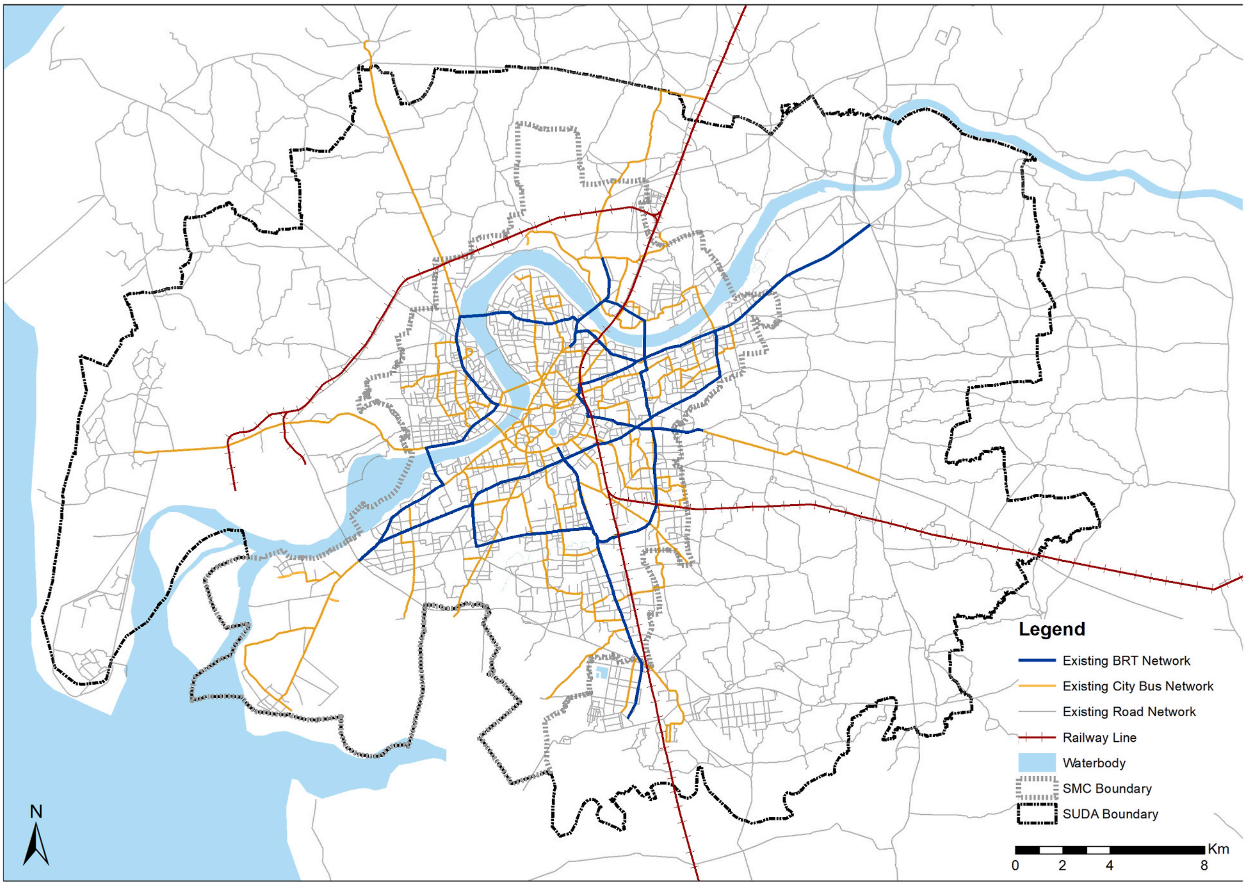

Fig. 2. Surat Urban Development Area (2016).
Source: Authors based on Comprehensive Mobility Plan (2016)

themes validate the desktop assessment. 74% of private vehicle users in Udaipur feel that public transport is non-existent, and only 4% of respondents chose public transport for work commutes. Intermediate public transport modes are preferred over buses due to flexibility in route and wider coverage (FGD-03).

b. NMT Network Coverage:

Non-motorised transport is a zero-emission mode primarily serving as a last-mile connector to public transport. However, owing to lower public transport coverage in both cities, it needs to be assessed as the sole mode of transport for average trips of up to 2.5 km (Centre for Science and Environment (CSE), 2019).

Non-motorised transport networks in both cities fare poorly against national standards, which is 75% coverage as per MoUHA (2013). This generates a trade-off (−1) with inclusive access, especially for the most vulnerable. With an average daily pedestrian footfall of 53,338, and 80% intra-zonal trips on foot, walking is the most preferred mode of travel across all socio-economic groups for shorter trips in Udaipur. Additionally, 54% of pedestrian trips and 89% of cycling trips in Udaipur are undertaken to access economic opportunities. Despite this, only 1%–4% of Udaipur's road network has any form of pedestrian or cycling infrastructure.

In Surat, 85% of non-work-purpose trips are undertaken on foot. Despite this, the city has inadequate coverage of non-motorised transport infrastructure; 20% and 7.6% of the total road network (302 km) have footpaths and cycle tracks, respectively. Footpaths are predominantly found in the historic core of Surat, while cycle tracks are fragmented and only found along a few arterial streets. The non-motorised transport networks exclude low-income neighbourhoods in Surat, creating a dire need for accessible transport infrastructure (FGD-02, Household Survey).

Regarding last-mile connectivity, 69% of households in Udaipur are within 10 min (700 m radius) walking distance to public/intermediate public transport stops, compared to a national average of 500 m [70]. The increased distance for a majority of households discourages the use of public transport in Udaipur. Similarly, in Surat, only about 59% of the total SMC area enjoys a 500 m public transport catchment area, with 74% of the area living at a distance above 700 m. Residents from poor neighbourhoods are forced to travel further and to wait longer to access public transport. This generates a trade-off (−1) with inclusive access (FGD-03; Transport user survey).

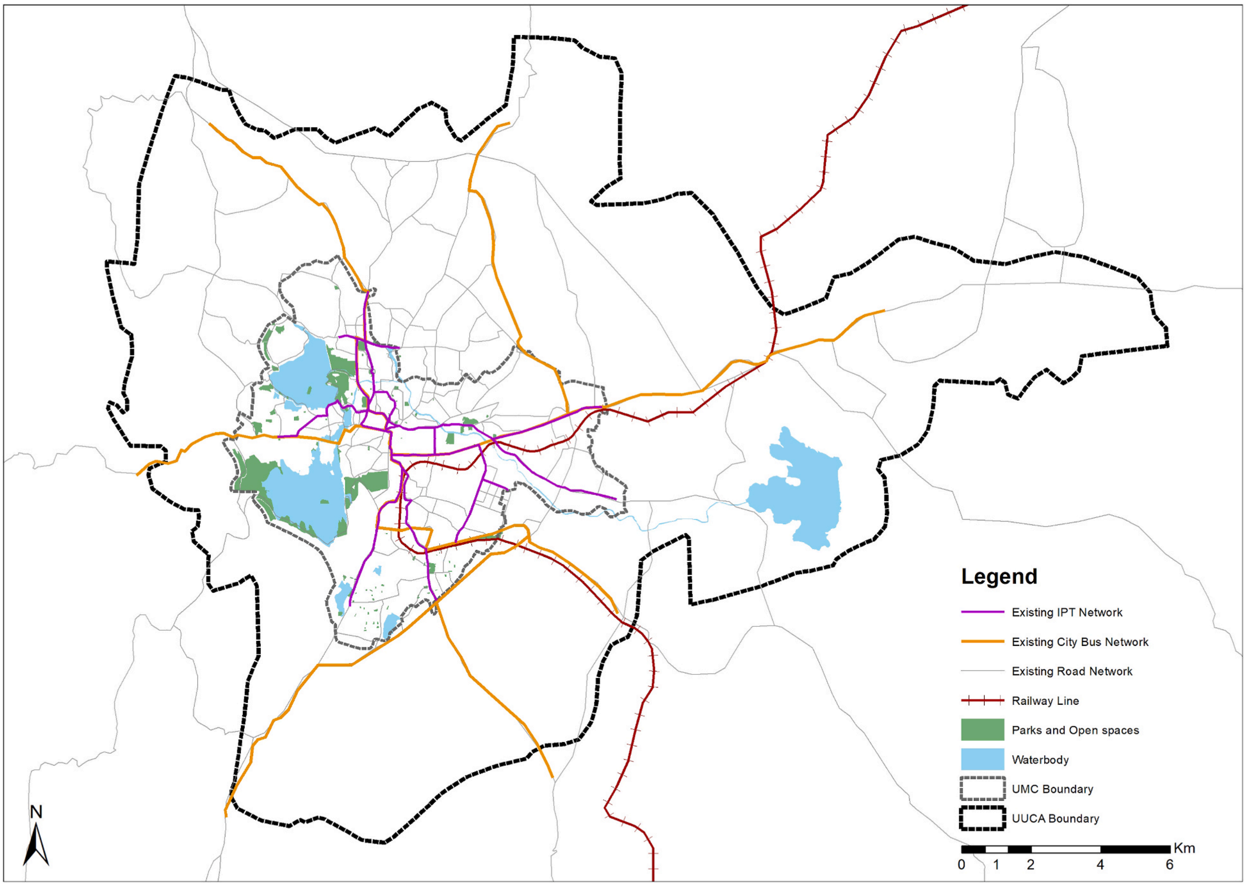

Fig. 3. Udaipur Urban Control Area.
Source: Authors based on Low Carbon Mobility Plan

Table 2
City Profile of Surat and Udaipur (2016).

	SUDA	UUCA
Demography		
Population (2016)	5,929,821	702,001
Area (in km^2)	958	348
Density (people per km^2) (2016)	6190	2017
Transport Characteristics		
Per capita trip rate	1.6	1.1
Trip length (in km)	5.01	5.09
Modal share (as per 2016)	Walk: 40.3% Cycle: 2.0% 2Ws: 35.6% 4Ws: 2% PT (BRTS & City buses): 1.4% IPT/3Ws: 10.3% Other: 8.0%	Walk: 48% Cycle: 2% 2Ws: 34% 4Ws: 3% PT (City buses): 2% IPT/3Ws: 11%

Sources: Udaipur Low-Carbon Mobility Plan [71], Surat Comprehensive Mobility Plan [60].

Most participants of three focus group discussions reported that non-motorised transport in both cities was inconsistent and inadequate. According to the household survey, only 7% of all households in Surat and 14% in Udaipur willingly walked or cycled to work (Household survey). 42% of non-motorised transport users in Udaipur and 63% in Surat mentioned that the lack of availability of motorised transport forced them to cycle/walk on carriageways (Transport users' survey). Additionally, 27% of all private vehicle users in Surat and 10% in Udaipur reported a dire need for last-mile connectivity to public transport (users' survey). These findings reinforce the desktop assessment.

Table 3
Assessing inclusive access in Surat and Udaipur for SDG targets 11.1 and 11.2

Assessing Inclusive Access in Surat and Udaipur		Access to Affordable Housing & Basic Services (SDG Target 11.1)	Universal Access (SDG Target 11.2)
SURAT	*PT/IPT Network Coverage a. PT Network Coverage: 48%; b. IPT Network Coverage: 9.5%*	(-1)	(-1)
	NMT Network Coverage a. Pedestrian Network Coverage: 20%; b. Cyclist Network Coverage: 7.5%	(-1)	(-1)
	Affordability of PT/IPT a. Monthly Household Expenditure Share: 8%	(-1)	(-1)
	Quality of Transport Infrastructure a. LOS of NMT: 4.0; b. LOS of IPT: 3.0; c. LOS of PT: 3.0	(-1)	(-1)
UDAIPUR	***PT/IPT Network Coverage** a. PT Network Coverage: 20%; b. IPT Network Coverage: 10%*	(-1)	(-1)
	***NMT Network Coverage** a. Pedestrian Network Coverage: 4%; b. Cyclist Network Coverage: <1%*	(-1)	(-1)
	***Affordability of PT/IPT** a. Monthly Household Expenditure Share: 12.5%*	(-1)	(-1)
	***Quality of Transport Infrastructure** a. LOS of NMT: 4.0; b. LOS of IPT: 4.0; c. LOS of PT: 4.0*	(-1)	(-1)

c. Affordability of public/intermediate public transport:

Transport affordability is crucial for inclusive access, especially for vulnerable groups. Generally, 15% of the income is considered the upper-most cap of transport affordability (CSE 2019).

In Udaipur, despite the low cost of public transport (USD 0.066 per trip in 2016), 60% of households spend 26.5% of their household incomes [71], 1.77 times the national average (CSE, 2019) on public transport. At the same time, inaccessible and unreliable public transport service in Udaipur forces low-income inhabitants to use non-motorised transport, which curbs the mobility of low-income individuals and forces middle-income earners to use private vehicles, which increases their expenditure on transport. In both scenarios, inclusive access is compromised (−1). In Surat, 17% of households earning less than 200 USD per month spend more than 15% of their monthly income on public transport [61]. Due to on-demand services and better last-mile connectivity, low-income households prefer intermediate public transport even though it comes at a higher cost. This makes the affordability of public/intermediate public transport a significant challenge (FGD-03). With the increasing peripheralisation of formal affordable housing in Surat, connectivity to the city centre is neither adequate nor affordable, generating a trade-off (−1) with inclusive access.

46% of low-income households in Udaipur and 63% in Surat spend more than 15% of their monthly household incomes on transportation (transport users' survey and household survey). 26% of low-income households reported missing out on economic opportunities due to a lack of affordable transport in Surat (household survey). 47% of in-person survey respondents from low-income neighbourhoods of Surat's neighbourhoods reported they could not afford public or intermediate public transport. The assessment of the above components indicates trade-offs (−1) in both Udaipur and Surat.

d. Quality of Service:

The quality of service of transport is measured by the Level of Service (LOS) and includes levels of comfort, fleet, average waiting time, average speeds, street light, intersection delay, and encroachment. As per the Ministry of Housing and Urban Affairs's (MoHUA) Service Level Benchmark (SLB) Handbook (2013), the level of service (LOS) is measured on a scale of 1–4; from highest to lowest Quality of Service (QoS).

Overall, the QoS of transport infrastructure in Surat generates a trade-off (−1) with SDG targets 11.1 and 11.2. A large share of the pedestrian network has inconsistent widths and is narrower than 1.5 m. Only 38% of road intersections have signage, and 25% of cycle tracks are encroached by vehicular parking. Pedestrian and cycling infrastructures in Surat have a LOS of 3 and 4, respectively. About 56% of users reported non-motorised transport infrastructure as being discontinuous and needing drastic improvement (Transport users' survey).

A fleet of 352 buses in Surat carried about 162,000 passengers per day (as of February 2018 [61], with a headway of 8–20 min, longer than the SLB standard of $\leq$ 8 min .48% of public transport users reported dissatisfaction over the frequency and routing of buses. The average wait time in Surat was 9.59 min (11.68 min for women), which far exceeds the '6 min or less' standard (Urban Bus Specification Guidelines). 44% of users reported dissatisfaction over the time taken to travel and waiting times (Transport users' survey). Although a large fleet of 38,000 intermediate public transport vehicles functions on 56 fixed routes, there is a lack of fare integration with public transport, and unregulated route and fare structures have resulted in a low LOS of 3.

QoS of public transport & non-motorised transport infrastructure in Udaipur generates a trade-off (−1) with SDG targets 11.1 & 11.2. 60% of streets in Udaipur lack street lighting, and over 38% of footpaths are encroached on by vehicular parking. The non-existent cycling infrastructure results in 54% of users (compared to 12% in Surat) reporting the carriageway as being "unusable" and "discouraging." Over 60% of users rate the non-motorised transport infrastructure as poor (Non-motorised transport users' survey). The overall LOS for pedestrian and cycling infrastructure is four.

In Udaipur, a slim fleet of 13 buses operates on five routes. Due to the lack of dedicated public transport stops/stands, raised platforms for onboarding, signage, lighting, route, and fare information, and failure to incorporate universal design guidelines, the LOS fairs at four. The 8950 intermediate public transport vehicles function on 26 routes. 40% fleet is older than ten years and fails to comply with fuel and engine efficiency standards. Despite the abundant availability of intermediate vehicles, it remains a polluting and expensive mode choice, leading to LOS 4. The desktop assessment and fieldwork indicated a dire need for non-motorised transport infrastructure improvement in both cities, especially Udaipur, as it has a tourism-based economy that benefits from walkable and bikeable streets.

3.3. Climate Resilience

Table 4 shows to what extent the second role of delivering climate resilience of urban transport is met in the two cities using three parameters.

a. Dependence on Personal Motorised Vehicles

Udaipur's rapid expansion has resulted in a steep increase in private vehicles. In the absence of reliable public transport, there is a high dependency on private vehicles, especially 2Ws, as they can easily navigate the narrow alleys; Udaipur has 287 registered vehicles per 1000 population, with a compound annual growth rate (CAGR) of 11.3% [71]. Registered vehicles have increased by 52% within the last decade, with 2-wheelers accounting for the largest share (78%) of vehicle composition, followed by cars (13%). When traffic often reaches 9495 Passenger Car Units (PCUs) during peak hours, on-street parking reduces the carrying capacity along approximately 39% of the road network, resulting in critical bottlenecks. This, in turn, has caused more frequent and more prolonged traffic congestion and has also contributed to a degradation of air quality. Increased dependence on personal motorised vehicles eases accessibility during extreme weather and generates a synergy (+1), but it also contributes to degraded air quality, a trade-off (−1).

High average household incomes in Surat, coupled with poor public transport connectivity, have resulted in a drastic, seven-fold increase in vehicle ownership, with 79% of motorised vehicles being personally owned. Without a reliable public transport system, vehicle ownership improves access to economic opportunities. 36% of households, who do not own a vehicle, reported that vehicle ownership would significantly improve their access to economic opportunities (household survey).

66% of households in Surat and 50% in Udaipur reported exposure to air pollution as a significant concern for personal health (household survey). When asked about the use of sustainable modes of transport (non-motorised/public transport) over private motorised transport, all users in Udaipur and 89% in Surat reported a willingness to shift to non-motorised transport for shorter trips provided that infrastructure is improved (transport users survey).

b. GHG Emissions from Urban Transport:

[7]Udaipur's total motorised vehicle kilometres travelled were 1011.69 million in 2016 (1.49% annual growth rate, 71). Rapid motorization has increased CO_2 emissions, with higher respirable suspended particulate matter and suspended particulate matter percentages than the standard norms set by the Central Pollution Control Board (CPCB). Udaipur's GHG inventory for urban passenger transport illustrates that the city experiences about 4500 tons of PM10 and 17 million tons of CO_2 annually. 2-wheelers account for more than 80% of annual vehicle kilometres travelled (VKT) in the city and 55% of the total GHG emissions in Udaipur.

In Surat, 2-wheelers contribute to more than 2/3rd of the annual VKT, 43% of GHG emissions, and cause the highest air pollution[8] (Table 5). Surat has a high share of vehicles with higher emissions standards.,[9][10] Although Udaipur has a large share of BS-I & II vehicles, and hence a more polluting fleet, Surat's motorised travel demand (3,095,365 trips/day) is much higher than Udaipur. This leads to much higher per capita emission levels. In turn, GHG emissions contribute to local air pollution and more frequent extreme weather events at a global scale, causing severe climate vulnerability (−1).

Conforming to the desktop assessment, the focus group discussions highlighted that, as a result of both cities sitting amidst a dense network of highways/flyovers and having high dependence on private motorised transport, vulnerable groups (such as the urban poor) are often disproportionally subjected to, and are more susceptible to, negative externalities. Most non-motorised transport users, 69% of public and 73% of intermediate transport users reported falling victim to air pollution and related health issues in Surat (transport users survey). Reducing air pollution is a significant co-benefit of reductions to GHG emissions, advanced by the electrification of mobility and the shift to sustainable modes such as public and non-motorised transport. As an intervention, SMC is creating new electric buses under the Panchamrit initiative,[11] while UMC introduced E-rickshaws in 2017 under the CapaCITIES[12] project.

[7] Only urban passenger transport for SUDA and UUCA.

[8] Additional 43% of GHG is emitted from freight transport, which isn't accounted for in the scope of the study.

[9] Bharat Standard (BS) I to IV defines the upper limit of the percentages of carbon compounds a particular vehicle can emit. Besides the engine, BS defines limits of pollutants that can come out of the exhaust for each vehicle class. BS-I emits the most severe pollutant, while BS-IV emits least severe pollutants.

[10] BS-III makes the largest share for private transport and BS-IV for public transport.

[11] Panchmrit: Prime Minister Modi announced five essential commitments, including a step-plan for a greener India. Accessed at https://www.roedl.com/insights/india-modi-panchamrit-cop26-implication-industrial-perspective on 26th December 2022.

[12] CapaCITIES: Capacity building for Low-carbon and climate-resilient city development. Accessed at https://www.capacitiesindia.org/on 26th December 2022.

Table 4
Assessing climate vulnerability in Surat and Udaipur for SDG targets 11.5, 11.6 and 11.B

Assessing Climate Vulnerability in Surat and Udaipur		Accessibility during Extreme Weather Events (SDG Target 11.5 & 11.B)	Contribution of urban transport towards Air Quality (SDG Target 11.6)
SURAT	***Dependence on Personal Motorised Vehicles*** *a. Annual vehicle registrations growth rate: 9%; b. Motorised mode share: 75% PV*	(±1)	(-1)
	GHG Emission from Urban Transport *a. CO2 emissions from PV: 80%; b. CO2 emissions from PT & IPT: 16%*	(-1)	(-1)
	Streets with Green Infrastructure *a. Share of Street Network with Tree Cover: 80%; b. Share of Street Network with Permeable Surfaces & Bio-swales: Negligible*	(-1)	(±1)
UDAIPUR	***Dependence on Personal Motorised Vehicles*** *a. Annual vehicle registrations growth rate: 11.3%; b. Motorised mode share: 74% PV*	(+1)	(-1)
	GHG Emission from Urban Transport *a. CO2 emissions from PV: 79.5%; b. CO2 emissions from PT & IPT: 17.3%*	(-1)	(-1)
	Streets with Green Infrastructure *a. Share of Street Network with Tree Cover: <15%; b. Share of Street Network with Permeable Surfaces & Bio-swales: Negligible*	(-1)	(-1)

Table 5
Motorised Mode Shares and Mode-wise GHG emissions for SUDA and UUCA (2016).

	SUDA (2016)		UUCA (2016)	
	Motorised Mode Share	GHG emission	Motorised Modal share	GHG emission
2W	62.0%	43.6%	31.7%	55.07%
3W	17.2%	14.5%	15.9%	5.08%
4W	12.5%	36.9%	1.6%	18.9%
Public Transport	1.8%	0.9%	50.8%	1.5%
Other buses	6.4%	4.1%		19.4%

c. Streets with Green Infrastructure

The desktop assessment of Surat indicated a trade-off (−1) with both sub-themes. Unlike Udaipur, heavy monsoons and frequent flooding in Surat hamper access for personal vehicle owners, as triangulated during online focus group discussions. Surat was selected for the Rockefeller Foundation's 100 Resilient Cities Network in 2013 due to its history of severe urban floods. Regarding green infrastructure, about 80% of Surat's major streets have tree cover, but the city lacks a robust network of permeable pavements, vegetated swales, and curb extensions (Surat Urban Development Authority (SUDA), 2017). Extreme weather events often severely affect the mobility of Surat's vulnerable groups (FGD-03), as the urban poor often live either in informal housing located on undevelopable land disproportionately affected by calamities [64], or are solely dependent on public transport (FGD-03). This generates a trade-off (−1) with easy transport use during extreme weather events.

Their mobility is compromised during extreme weather events; this deepens their economic insecurity. 47% of private vehicle users, 39% of public transport users, and 44% of intermediate public transport users were uncomfortable using transport during hot summer days in Surat (transport user survey). 79% of users reported discomfort or inability to use transport during heavy monsoons. The mobility of low-income communities was exceptionally constrained due to waterlogging; this led to a loss of livelihoods (FGD-03). 68% of respondents recommended green streets-related improvements to enhance mobility during extreme weather events, especially floods.

In contrast, although fewer streets in Udaipur have green infrastructure, the city's well-maintained water body network helps regulate the microclimate during hot summer days, reducing discomfort in accessing public and intermediate public transport. Udaipur's natural heritage and environmentally conscious planning generate synergy (+1) with resilience during extreme weather conditions.

3.4. Context-sensitive planning

Surat has a magnificent heritage value as one of India's oldest port cities and strong business links with over 84 countries. However, it also has limited formally designated heritage structures. Identified as the fastest-growing city globally [61,65], Surat also experiences issues concerning spaces, which are integral to the cultural and civic life of the city. There has been a general decline in Udaipur's natural heritage due to population increases, a lack of natural resource management, and the indiscriminate destruction of water bodies due to untreated wastewater disposal. Car parking around gardens, parks, and water bodies is used for solid waste disposal, and vehicles washed on the banks of lakes by locals have added to degradation (Crisil & MoUD, 2014). Table 6 uses three standard transport parameters for assessment against each theme.

Table 6
Assessing context sensitive planning in Surat and Udaipur for SDG targets 11.3 and 11.4

Assessing Context Sensitive Planning in Surat and Udaipur		Inclusive Urbanisation (SDG Target 11.3)	Natural & Cultural Heritage Preservation (SDG Target 11.3 & 11.4)
SURAT	***Large scale transport projects in vicinity of special zones (eco-sensitive & heritage zone)*** *a. No. of highways and flyovers/Million people: 20.7; b. No. of highways/flyovers passing along old city: 10*	(-1)	(-1)
	Streets with Multi-Utility Zones *a. % streets with vending zones: 0%; b. % streets with vending encroachment: 5.4%*	(-1)	(-1)
	Conducive Land Use & Density *a. Share of Mixed-use development: 62%; b. Population Density in SMC: 137 PPH; c. Built Density in SMC: 335 PPH*	(±1)	(-1)
UDAIPUR	***Large scale transport projects in vicinity of special zones (eco-sensitive & heritage zone)*** *a. No. of highways and flyovers/Million people: 15.6; b. No. of highways/flyovers passing along old city: 2*	(±1)	(+1)
	Streets with Multi-Utility Zones *a. % streets with vending zones: 14; b. % streets with vending encroachment: 39%**	(+1)	(±1)
	Conducive Land Use & Density *a. Share of Mixed-use development: 47%; b. Population Density in UMC: 75 PPH; c. Built Density in UMC: 59 PPH*	(-1)	(-1)

a. Large-scale transport projects in the vicinity of special zones (eco-sensitive & heritage zone)

Surat has a densely built core with mixed land use. The metro-rail project proposed six underground stations to avoid demolishing the built environment, which has heritage value. However, underground metro stations emit GHGs much higher than street-level or elevated metro stations. Due to project construction, there have been evictions and displacement of, as well as protests by, low-income communities. Shop owners and vendors have protested as the project curbs their visibility and may gradually result in gentrification. Many preferred upgrading the BRTS project (effective in mitigating GHG emission) instead of mega construction projects such as Metrorail. In contrast, Udaipur's urban local body has adopted a minimal intervention approach to preserve its natural and cultural heritage, forming the base of the city's economy. This has generated a clear synergy (+1). In the Focussed Group Interview, the professionals and NGOs recommended carefully routing public transport (especially smaller EV buses) at the cost of compromising private vehicles around the walled city and other sensitive areas. A context-sensitive network of one-way routes and pedestrianised streets should complement the public transport network to minimize mobility challenges vulnerable groups face (FGD-02; Communication with city commissioner).

b. Streets with Multi-Utility Zones[13]

As per the desktop assessment, encroachments along streets (average width of 12–30 m) are a prime cause of congestion in both cities. Over parking and traffic management mechanisms, Surat Municipal Corporation (SMC) prioritizes the removal of street vendors to decongest roads. Street vendors are integral to Surat's informal economy; removing 'encroachments' to ensure smooth traffic flow generates a trade-off (−1) with inclusive development. 86% of local shops and street vendors reported that vehicular traffic congestion hampered their businesses (stakeholder survey). Due to heavy traffic volume, parking management in Surat was the most recommended (55% of local shop owners and vendors) intervention (stakeholder survey).

In contrast, UMC's pro-heritage approach has allotted 14 new vending zones across the city.[14] The cultural performances and festivals hosted in Udaipur's public spaces are embraced as an integral part of its intangible heritage. However, unsustainable mobility patterns, such as a conflict between vehicular traffic and cultural performances on the road, and poor infrastructure have led to congestion and pollution, adversely affecting the public sphere and generating a mixed impact on heritage preservation (±1). 100% of local shops and street vendors reported that vehicular traffic congestion (the average width of a street being 12–30 m) affected their businesses, and they also stated that they believed that pedestrianisation would be a positive intervention (stakeholder survey). Being a heritage-rich city, non-motorised transport infrastructure improvement in the walled city of Udaipur was the most recommended (65% of local shop owners and vendors) intervention (stakeholder survey).

c. Conducive Land-Use and Density

The walled city area is the commercial hub in Surat, and it has a high share of mixed-use development. This enhances walkability while also reducing trip lengths/Vehicle Kms (VKT) Travelled. However, the walled city's high built density, narrow streets, and unmanaged activity generation have led to congestion. High built density has also put the walled city at a higher risk of fire accidents, while emergency vehicle movement is also restricted. Additionally, Surat's placement of incompatible land uses (such as residential

[13] Defined as a buffer between footpath and carriageway that has dedicated space for street vending, street furniture, landscape, busstops, and property access ramps. (ITDP, 2020).
[14] Source: *UdaipurTimes*, 9 August 2017.

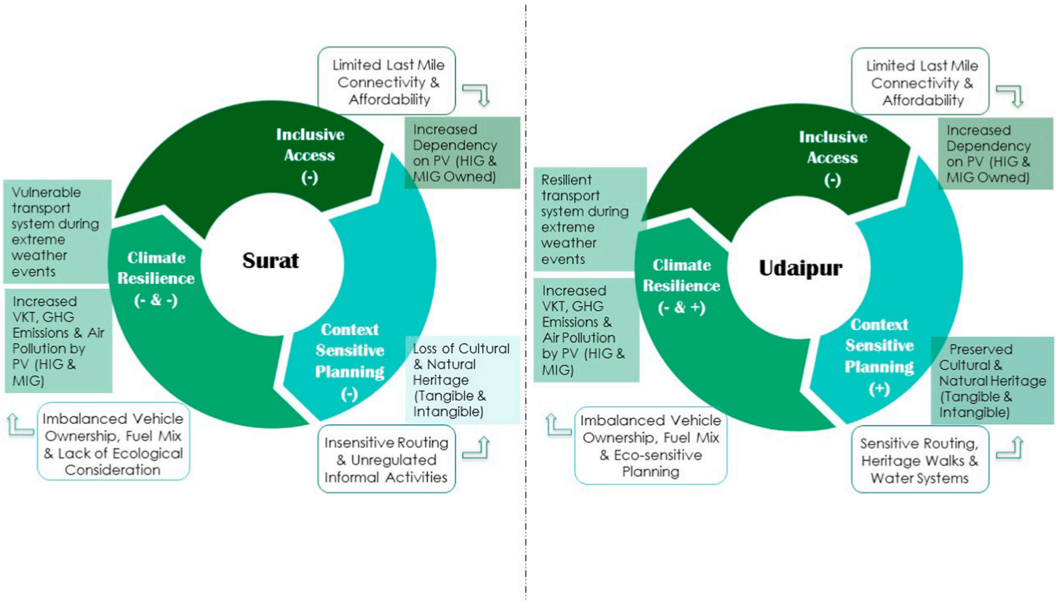

Fig. 4. A schematic diagram comparing the findings from the two cities under the three themes.
Source: Authors

and industrial concerns in the same vicinity) has resulted in a high level of unrestricted freight traffic, leading to conflict between passenger and freight movements. Out of 257 road fatalities per year, nearly 47% are attributed to non-motorised transport, where 27% of fatalities are caused by personal vehicles (2- & 4-wheelers), followed by 25% caused by freight trucks [61]. Density and land use have created a trade-off (−1) with heritage preservation in Surat. It has generated a mixed impact (±1) in Surat.

The walled city of Udaipur possesses mixed-use development and acts as a commercial and tourism hotspot. It is highly contested by heterogeneous road users: motorised vehicle users, pedestrians, cyclists, street vendors and their clientele, private bus operators and their clientele, pavement dwellers, locals, and tourists. The narrow streets and high traffic volume has led to bottlenecks, with an average speed as low as 10 km/h. Fig. 4 compares the findings from the two cities under the three themes: Inclusive Access, Climate Resilience and Context-sensitive Planning.

4. Discussion

Surat was assigned the scores (−1), (−1), and (−1) for inclusive access, climate vulnerability, and context-sensitive planning, respectively. Udaipur was assigned the scores (−1), (−1), and (±1). In regions with high inequalities and poverty, assessing future transport projects through a similar framework has the potential to mitigate negative externalities and maximize synergies for all. This paper is focused on two cities in western India: Surat and Udaipur. Limited network coverage, unaffordability, and low QoS of existing public, intermediate, and non-motorised transport modes in Surat cause a trade-off with Inclusive Access (including Access to Housing & Services and Inclusive Design). While Surat has the longest BRT network in India, last-mile connectivity could be improved. Introducing electric buses would ensure improved access for the vulnerable group and affordability of the service over time. Surat's high dependence on private vehicles and its exposure to frequent floods make it difficult for the city to deliver climate-resilient transport projects and development. Surat's transport network must be designed for resilience and incorporate an extensive drainage system and green infrastructure. Due to its preserved natural environment, Udaipur's transport projects synergize with climate-resilient development, though severe air pollution remains a challenge in both cities. The use of cleaner fuel and a modal shift to low-carbon modes such as public and non-motorised transport would help reduce pollution; such a policy is recommended in both cities.

The trade-offs caused by network coverage and QoS can be mitigated by expanding public transport networks in low-income neighbourhoods, infrastructure improvements, enabling last-mile connectivity, and improving the frequency of buses to reduce travel and wait times. Fare integration and discounts for vulnerable groups (elderly, differently-abled) can mitigate trade-offs caused by transport unaffordability. Infrastructure improvements will likely encourage a modal shift to public transport, which may reduce dependence on personal vehicles. Additionally, incentivizing higher emission standard vehicles and subsidizing electric vehicles (especially 2Ws and 3Ws) would reduce GHG emissions substantially [66]. National and subnational level interventions such as

Urban95, AMRUT,[15] and Cycle4Change[16] promote a transition towards sustainable mobility. Street redesigns enabling green infrastructure and multi-utility zones along trunk routes and significant collector streets would maximize co-benefits with heritage preservation, resilience, and sustainability. Lastly, land-use and density measures such as mixed-use and transit orient development would reduce motorised travel demand and promote shorter trips. However, these cannot be implemented by 2030 because land use change takes at least 20 years.

The paper recommends that urban transport systems, particularly in the context of inadequate infrastructure and high levels of inequality, need to be assessed against their interactions with the SDGs. In addition, there is a need for future research to assess transport plans with regard to how they address SDGs. Transport plans are expected to improve mobility and overall quality of life, whilst creating resilient cities and reducing inequalities; these ambitions are included in SDG11. As the IPCC's 1.5 °C report has flagged that not necessarily all mitigation actions would have a synergistic relationship with the SDGs, there may be a need to negotiate conflicts through policy measures.

5. Conclusion

Amidst a deepening climate emergency, cities are more vulnerable to climate change owing to the high concentration of people and activity intensity, yet hold the potential to forward sustainable development and resilience. The success of the three global agendas i.e., The New Urban Agenda (NUA) adopted in the Habitat III, the 2030 Agenda of Sustainable Development Goals (SDGs) and the Paris Agreement (2015) on GHG emission mitigation depends on India's urbanisation choices, making sustainable and low-carbon development crucial for India. All global agendas highlight the significance of urban transport's role in decarbonising cities, owing to its rapidly growing demand and related emissions. This paper investigates the roles of intra-city urban passenger transport in delivering seven relevant targets (SDG11.1, 11.2, 11.3, 11.4, 11.5, 11.6, 11.B). The paper finds that current transport interventions in Surat & Udaipur largely result in trade-offs across all three themes Inclusive Access (−1 for Surat & Udaipur), Climate Vulnerability (−1 for Surat & Udaipur), and Context-Sensitive Planning (−1 for Surat & +1 for Udaipur). Expansion of public transport networks in low-income neighbourhoods and increased level of service, large-scale non-motorised transport infrastructure improvements, and enhanced last-mile connectivity hold the potential to mitigate the majority of the trade-offs in both cities. Future research must investigate transport's role in forwarding SDGs.

Author contribution statement

1 - Conceived and designed the experiments: Darshini Mahadevia, Chandrima Mukhopadhyay, Saumya Lathia, Kanika Gounder
2 - Performed the experiments: Darshini Mahadevia, Chandrima Mukhopadhyay, Saumya Lathia, Kanika Gounder
3 - Analyzed and interpreted the data: Darshini Mahadevia, Chandrima Mukhopadhyay, Saumya Lathia, Kanika Gounder
4 - Contributed reagents, materials, analysis tools or data: Darshini Mahadevia, Chandrima Mukhopadhyay, Saumya Lathia, Kanika Gounder
5 - Wrote the paper: Darshini Mahadevia, Chandrima Mukhopadhyay, Saumya Lathia, Kanika Gounder

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Data included in article/supplementary material/referenced in article.

Declaration of competing interest

Additional information:
Supplementary content related to this article has been published online at [URL].

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[15] AMRUT: Atal Mission Rejuvenation and Urban Transformation by Ministry of Housing and Urban Affairs, accessed at http://amrut.gov.in/content/on 27th December 2022.

[16] Cycle4Change: Bike sharing program promoted by the Ministry of Housing and Urban Affairs, Govt of India, under Smart City Mission during Covid-19 lockdown. Accessed at https://smartnet.niua.org/indiacyclechallenge/on 27th December 2022 [67]. discusses integration of public transport with bike-sharing.

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Appendix A. Supplementary data

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