



Assessment of Urban Mobility in Jaipur using the Sustainable Urban Transport Index (SUTI)

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2019

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1. Introduction

Located around Arawali hills, Jaipur is the capital city of the state of Rajasthan, India. Its geographical coordinates are 26.5° N and 75.5° E. It is the 10th largest city of India spread over 467 sq km, housing a population of 3.4 million (Census 2011) and is one of the fastest growing cities in India. The greater metropolitan area of Jaipur spreads over an area of 2940 square km with a population of 4.45 million and incorporates 15 satellite towns. Jaipur city is subdivided into eight geographical zones, 91 wards, and 61 localities¹. Education, commerce and tourism are the main drivers of economic growth of the city. Due to its historical significance and defining architecture it is one of the most popular tourist attractions in India, also popularly known as the ‘Pink City’. Walled city houses most of the traditional economic activities such as jewellery and other trade. Industries are mostly located in the surrounding areas, especially in the southern and western parts of the city. Due to high concentration of the economic activities, the walled city has very high density of population, exceeding 75,000 inhabitants per square km. The Jaipur city is shown in figure 1.

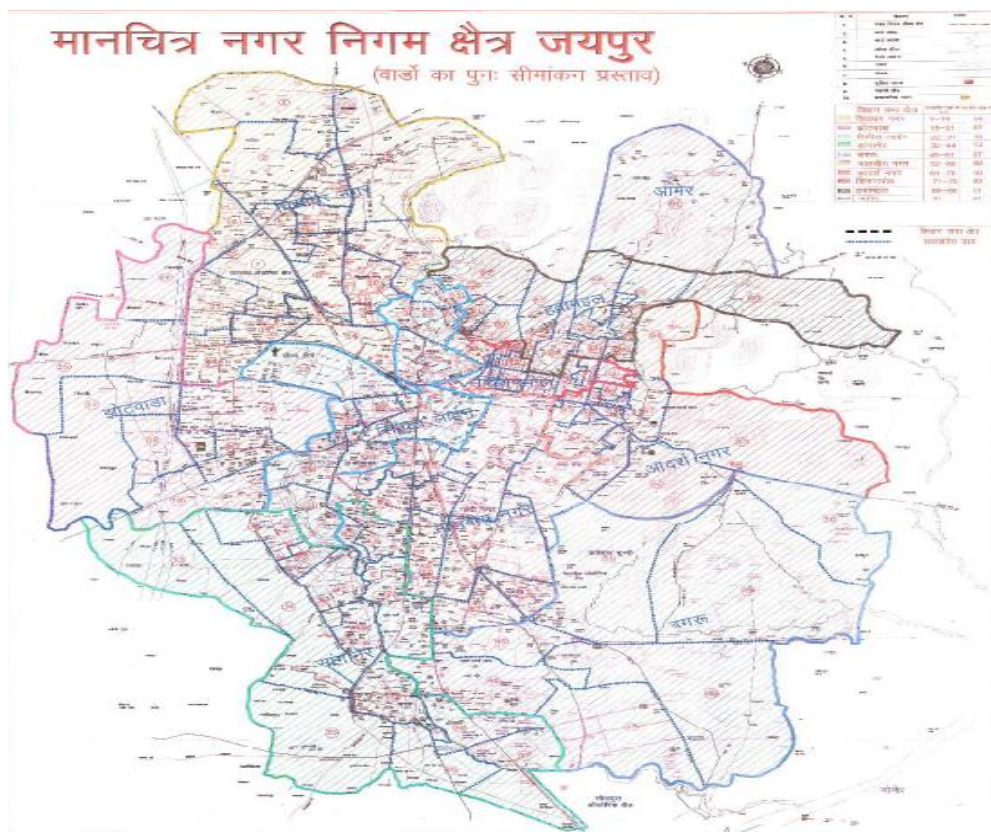


Figure 1: Map of Jaipur city

¹ Locality means a geographical neighborhood in a city.

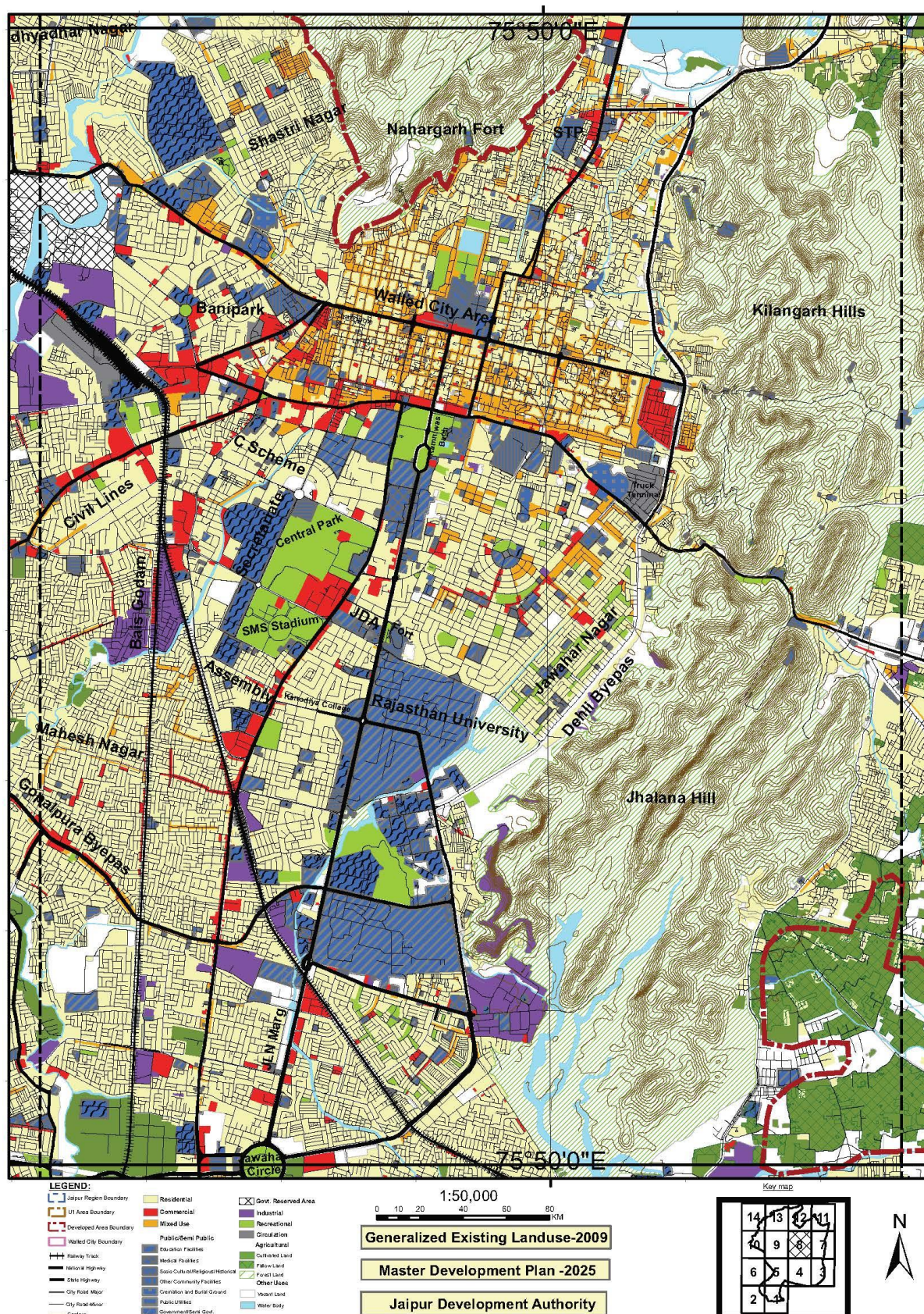


Figure 2: Jaipur city and land use map

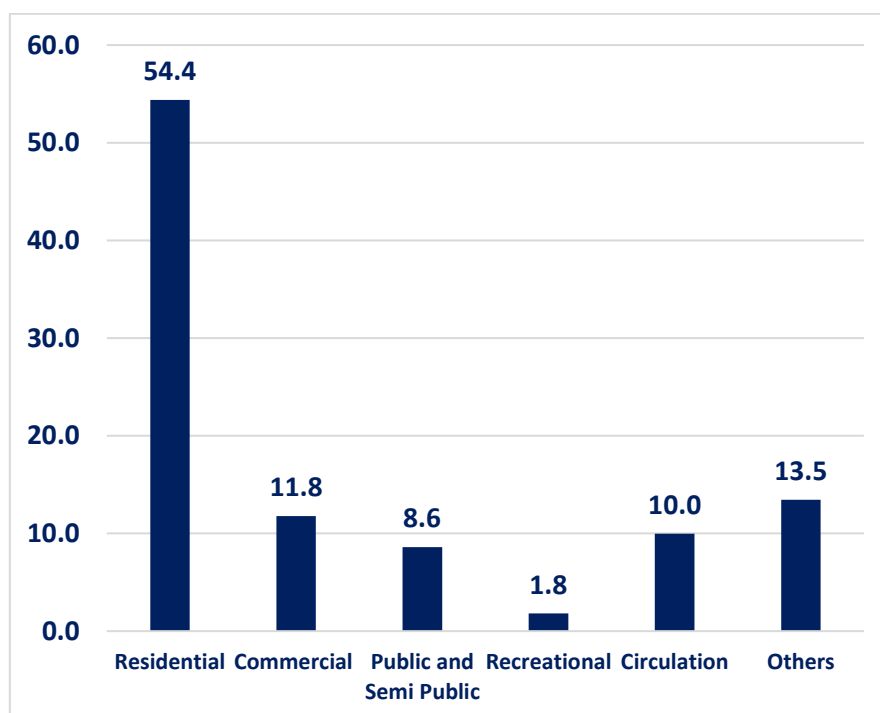
Source: Jaipur Nagar Nigam (Jaipur City Corporation)

2. Land Use Pattern in Jaipur

Topography of Jaipur is diverse with narrow plains surrounded by Aravalli hills in the East and Nahargarh in the North. The city has expanded along the Plains on the Southern and western part of the city. Due to urban sprawl, the agricultural land and wastelands have been converted into built-up areas.

Jaipur strategic plan 2011 defines twelve land use categories for the city. Residential category constitutes 54.4 per cent commercial 11.8 per cent, while 10 per cent of the land was used to support transport (circulation) system. It is important to note that the ideal share of transport in the land use is also 10 per cent (Litman, 2018). The land use pattern is shown in the figure 2 and figure 3 shows share of different types of land use.

Figure 3: Land use pattern in Jaipur



Source: Derived from Jaipur Strategic Plan 2011

3. Major Transport Networks in Jaipur

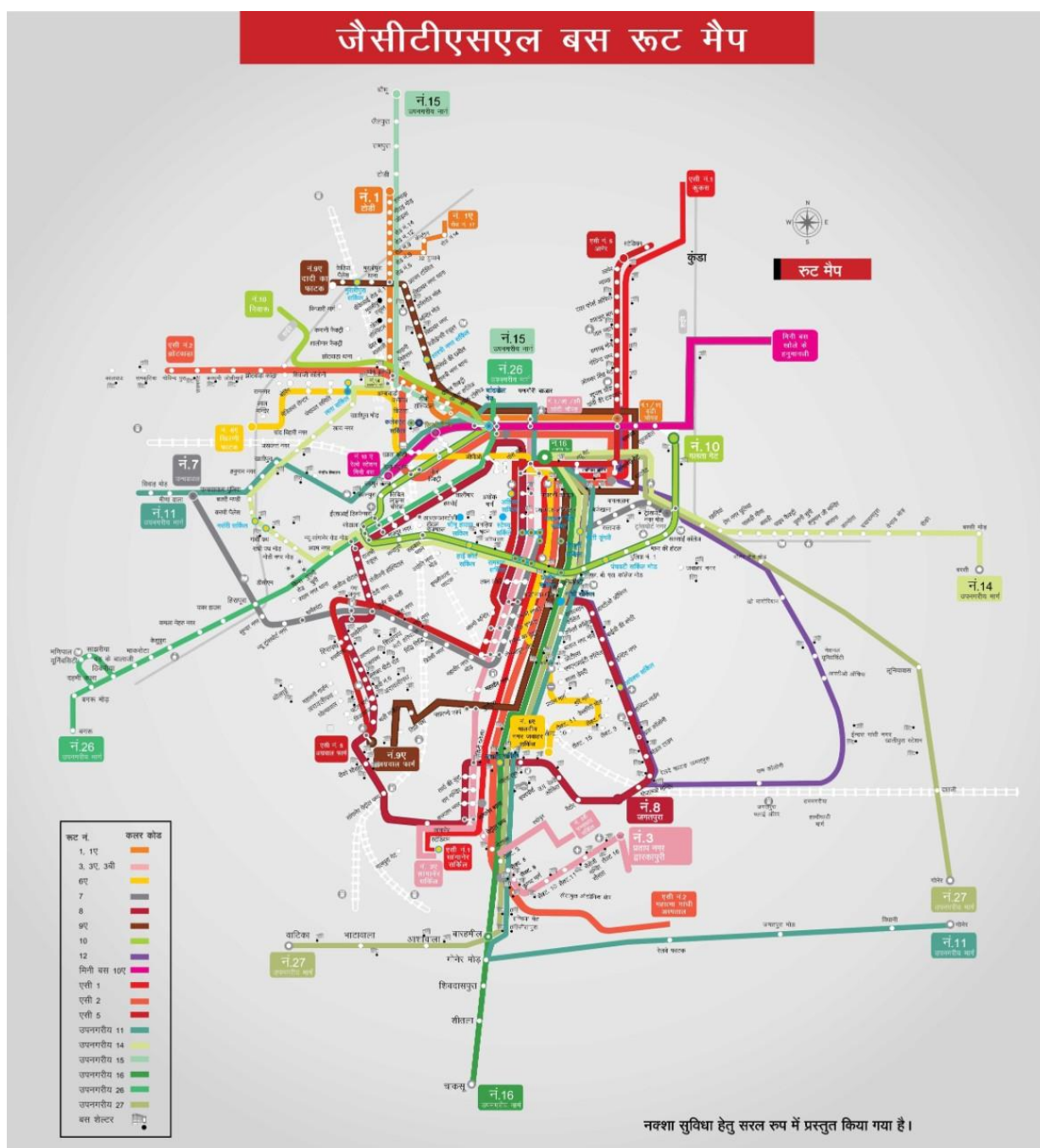
Jaipur city public transportation operates on two major networks- road and train. Almost three hundred years ago, the road network of the city was developed as hierarchal grid iron pattern² and it served well and city plans to continue with this system (Jaipur Development Authority, 1998). Jaipur City Master Development Plan 1998 proposed a system of hierarchy of roads consisting of nine levels- national highway, regional arteries, arterial roads, sub-arterial roads, collector roads, feeder roads, access ways, exclusive cycle tracks, and, pedestrian streets.

The road network in Jaipur city consists of ten radial and three circular roads, with a heavy focus towards the central place, popularly known as walled city. Since Jaipur city has grown around the walled city, radial pattern of road structure has become prominent. Ten major arterial roads crisscross the entire city - Ajmer road, Gopalpura bypass, NH8 bypass, Agra road, MI road, SMS road, Sardar Patel road, JLN road, Khatipura road, and express highway. Jaipur city road network consist of 2500 km long roads (Jaipur Development Authority, 2011). A 144 km ring road in the periphery of city centre is planned to enhance connectivity to the region.

Jaipur City Transport Services Limited (JCTSL) operates Bus Rapid Transit System (BRTS) on a small stretch of 6.6 km between Sikar and Pani Petch. Later, the project was discontinued due to lack of support from the new state government. Public bus transport in the Jaipur City is provided by a fleet of 400 low floor city buses operated by the Jaipur City Transport Services Limited (JCTSL) on 32 routes (refer figure 4) across the city, covering 143 bus stops throughout the city and satellite towns. Ten routes are defined as high traffic density routes. Besides, a fleet of about 55 minibuses owned by private operators, also provide public transport facility on the major routes.

² Hierarchal iron grid pattern road network caters to different uses and different levels of transportation.

Figure 4: Jaipur City Bus routes



Source: JCTSL webpage

Parking facilities in the city are far from being satisfactory. Due to high growth in the number of private vehicles, and limited popularity (due to less frequency and coverage) of the public transportation has resulted in congestion of, the main roads in the core city and exacerbated the parking problems in the major sub arterial roads. The problem of parking also gets compounded by the concentration of trading activities and consequent operation of freight traffic in the core city. Off street parking facilities are not available, except at a few places. Free on street parking

on most roads also accentuate the problem of traffic management, overcrowding and slow speed of vehicle movement.

Figure 5 Major road transport network in Jaipur



Source: Comprehensive Mobility Plan Jaipur

Jaipur Metro Rail Corporation (JMRC) provides public transportation through metro rail lines along the city's main arterial corridors—Line 1, with a running length of 12 km on the east–west corridor. Work on Line 2, with a running length of 23 km, along the north–south corridor, is likely to begin in 2020. Metro rail provide services on two major routes covering 11 metro stations. Figure 6 and 7 shows the spread of existing and planned metro network in the city.

Figure 6: Metro network in Jaipur city



Source: Jaipur Strategic Plan 2011

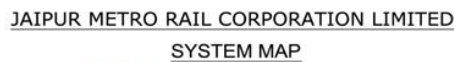


Figure 7 Metro network in Jaipur city

Source; Jaipur Metro

Existing Non-motorised transport (NMT) network both in terms footpath and cycle lane is far from being satisfactory. Although footpaths, subways, pedestrian crossing systems do exist but are neither comprehensive nor maintained properly. Footpaths are stretched over a running length of 210 km (Jaipur Development Authority, 2011), which is about a tenth of the total roads length in Jaipur city. Missing footpaths is a characterising feature of majority of the road

network. Not only the footpaths are inadequate but also a large part of them have been encroached by the informal traders, leaving little space for the pedestrians to walk and force them to compete for space with vehicles on the road. Safe pedestrian crossing systems are also missing on majority of the city roads. Bicycle lanes hardly exist despite large number of users. City plans to create a comprehensive mobility corridor that aims to integrate all the three modes- road, rail and NMT. The comprehensive mobility corridor plan aims to develop an outer ring road and six link roads. The outer ring road will connect to regional roads and radial roads within the city.

4. Motorisation level and Growth

Jaipur had 2,791,139 registered vehicles in 2017, which consists of almost 19 per cent of the total registered vehicles in the state of Rajasthan. Vehicle density in Jaipur was 25048 vehicles per square km, which is five times higher than for the entire state 4299 vehicles per square km (Bansal, 2017). Two wheelers and private cars hold a high share (83 per cent) of the registered vehicles in Jaipur. In 2017, two wheelers constituted 67 per cent of the registered vehicles, while private cars accounted for 16 per cent of the total registered vehicles.

Table 1: No of registered vehicles in Jaipur city

Year	TW	Cars
2010	1144561	232078
2011	1247571	260392
2012	1373576	293982
2013	1494451	321616
2014	1627457	354743
2015	1661634	380745
2016	1772963	415013
2017	1882887	450704

Source: Derived from (Bansal, 2017) and RTO, Jaipur

The number of registered vehicles in Jaipur compounded at an annual rate of 8.8 per cent since 2010, while cars have grown faster than two wheelers. JMRC currently operates the metro system in the city with 10 four coach trains, with a capacity of 1506 commuters per train.

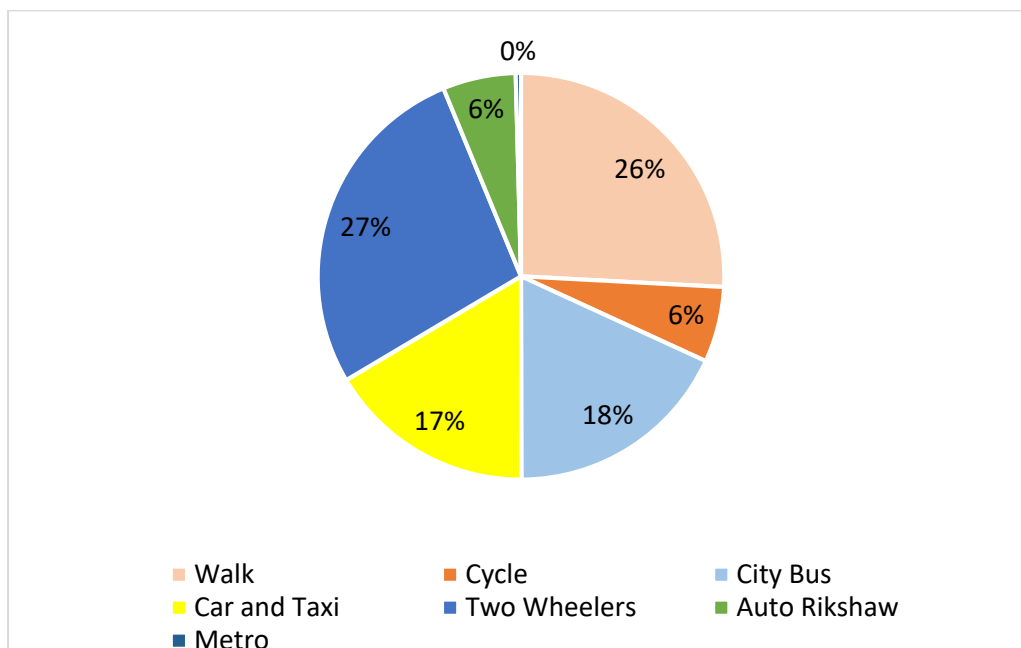
5. Travel Pattern

Modal share of public transport in Jaipur city is shown in the figure 8. Two wheelers account for 27 per cent share in public transportation in Jaipur, while cars and city buses contribute to 17 per cent and 18 per cent respectively. The NMT mode accounts for 32 per cent of which use of cycle is 6 per cent while the share of walk mode is 26 per cent. Metro has not yet been popular with only about 0.5 per cent of the commuters in Jaipur city using it. If we exclude NMT, the share of two wheelers and cars in motorised commuting mode rises to 40 per cent and 24 per cent respectively, while the share of city bus is 26 per cent (refer figure 8).

Table 2 reflects findings of Jaipur Home Interview Survey³ on the average trip share across various modes of public transport in Jaipur city. Cars and buses are used for longer trips; metro, auto rickshaw, and two wheelers are used for medium length trips; while walk and cycle are used for shorter trips. Average home based trip length is 8.7 km while, total trip length is 9.1 km. The survey revealed that 3.25 million trips a day are made in Jaipur (Jaipur Metro Rail Corporation Limited, 2018). The survey also found that about 2.1 million trips take place along North South direction, while remaining trips move along East West direction.

³ This survey was carried out for input for the Jaipur city Comprehensive Mobility Plan, 2018.

Figure 8: Modal Transport Share in Jaipur (in per cent)



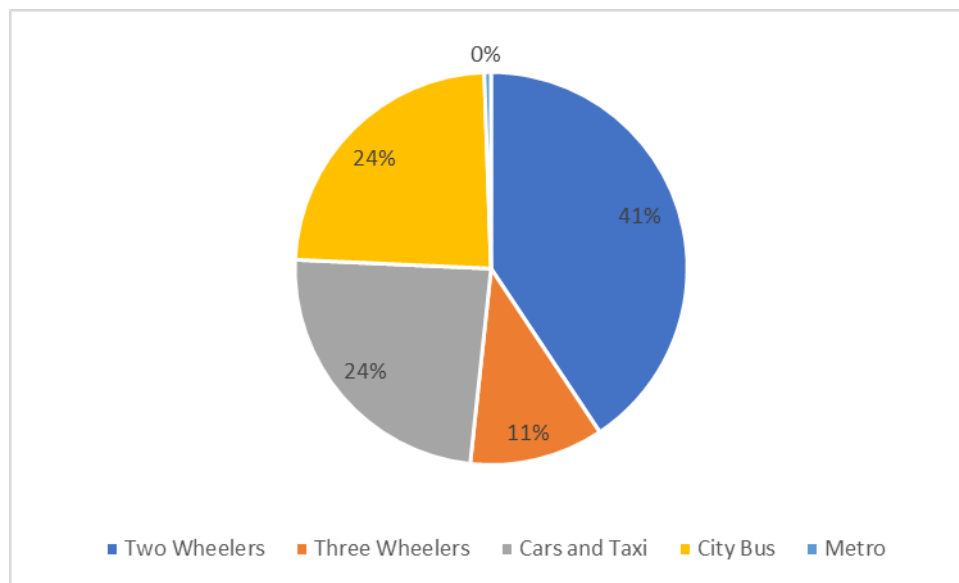
Source: Comprehensive Mobility Plan, Jaipur city, Vol 1, 2018

Table 2: Average Trip Length by various modes

Mode	Average Home-based Trip Length (in KM)
Bus	11.4
Car	12.6
Two Wheeler	5.8
Auto Rickshaw	5.4
Bicycle	2.4
Walk	1.8
Metro	6.1
Total home based trip	8.7
Total Non-home based trip	7.9
Total Trips	9.1

Source: Comprehensive Mobility Plan, Jaipur city, Vol 1, 2018

Figure 9: Modal Transport Share in Motorised trips (in per cent)



Source: Comprehensive Mobility Plan, Jaipur city, Vol 1, 2018

Average speed of movement in the city is 16.5 km per hour, while in the core city it is less than 10 km per hour. Low speed of the movement is caused by traffic congestion during peak hours, inadequate pedestrian infrastructure, encroachment on the footpaths and road and on street parking of the vehicles,

6. Urban Transport Governance and Institutions

The policy framework for the urban transportation in Jaipur is guided by the National Urban Transport Policy (NUTP), 2014. Ministry of Urban Development (MoUD), Government of India, encourages cities to prepare a Comprehensive Mobility Plan (CMP), which is integrated with land use plan, as part of a long-term urban transport strategy for sustainable improvements. NUTP aims to transform urban transport into a safe, efficient and convenient system by encouraging integrating land use and transport planning, use of public transport and non-motorized transport and establishment of quality focused multimodal public transport system.

Development of Jaipur city transportation system is primarily governed by two strategic plans- Comprehensive Mobility Plan (CMP) 2018 and Master Development Plan (MDP) 2025. Jaipur city's first CMP was designed in 2011. Basic motto of the CMP 2018 is to 'move people, not

vehicles’, it emphasizes the importance of public transport, non-motorised transport and integration of land use planning with transport network. CMP 2018 states the objective of city’s transport policy as - *“Transforming Jaipur Region into a world class Metro Region which will cater to tourism, IT and ITES and manufacturing with a vibrant economy and a globally comparable quality of life for all its citizens”*.

MDP 2025 for Jaipur region prepared by Jaipur Development Authority (JDA) also provides framework for urban transport system. It proposes a comprehensive circulation plan for the urban area.

Urban transport governance in Jaipur represents a multi-agency system of governance. Major agencies involved in the planning and implementation of the urban transport in Jaipur are- JDA, Jaipur Municipal Corporations (JMC), Public Works Department (PWD), Jaipur City Transport Service Limited (JCTSL), Jaipur Metro Rail Corporation Limited (JMRCL), Traffic Police and Transport Department and Unified Metro Transport Authority (UMTA). Based on the guidelines of the National Urban Transport Policy, the government of Rajasthan set up a Unified Metropolitan Transport Authority (UMTA) as a nodal agency for coordinating the efforts in a multi-agency setting. Besides, the Government of Rajasthan has also set up a unified urban transport fund to support the transportation system.

Table 3: Agencies and Their Role

Agency	Function
JDA	Coordination and formulating schemes for development of Jaipur region Including transport. Urban planning, Land use, master plan development, building bye laws, bridges, flyovers, Road/Rail over bridges, parking, to prepare master plan for traffic control& management, street lighting
JMC	Urban Planning including town planning, Regulation of land use, Urban amenities. Roads, bridges, flyovers, Road/rail over bridges, parking, Street lighting, Bus stops.
Transport Dept.	Policy for traffic control, Vehicle registration, setting standards including safety and environment
Traffic Police	Prepare and execute the Traffic plan, awareness on road safety, Recommends road engineering changes to PWD, JDA, JMC
JMRCL	Own, operate and maintain Metro Rail system (not involved in building the system)
JCTSL	Own, operate and maintain Bus Rapid Transport, System, Bus Terminals, Roads, Flyovers, Setting service quality standards

UMTA	Formulation of progressive land use and transportation policy for metropolitan area. <ul style="list-style-type: none"> • Framing rules and regulations for Urban Transport. • Appropriate tariff policy. • Route determination and modal integration. • Setting service standards. • Ensure fair competition on routes, network or geographical areas.
Rajasthan State Pollution Control Board	Prevention and control of environment pollution Enforcement of various relevant acts and rules

Source: Derived from desk review by author

Legislative power regarding urban transport is characterised by divided responsibility between central and state governments (Refer Table 4). There is no single law that comprehensively covers the requirements of the urban transport sector. Railways and Highways fall under union list (under central government); while roads, bridges and tramways fall under state list. Urban transport is a grey area which not comprehensively covered by union or state list. Bus rapid transport, light train transit, mono rail, transport planning, multimodal integration, safety, tariff and financing are not covered by any act. The existence of multiple laws leads to the constitution of distinct and different frameworks for various aspects of urban transport. Lack of adequate coordination among various agencies tends to stifle infrastructure development, effective management of transport demand and proper enforcement of rules and regulations.

Table 4: Legislation pertaining to urban transport in Jaipur

List of State acts	List of Central acts
Jaipur Development Authority Act 1982	Indian Railways Act, 1989
Rajasthan Municipalities Act 2009	National Highway Authority of India Act, 1988
Rajasthan Urban Improvement Act, 1959	Central Motor Vehicles Act, 1988
Rajasthan Motor Transport Vehicles Tolls Act 1991	Central Motor Vehicles Rules, 1989
Rajasthan Land Development Corporation Act, 1975	Central Road Funds Rule, 2007
Rajasthan Highways Act, 2014	
Rajasthan Air (prevention & control of pollution) Act 1981	
Rajasthan Air (prevention & control of pollution) Rules, 1983	

7. Demand Management

The urban transport policy of Jaipur aims to manage the increasingly unsustainable current demand pattern for public transport using a combination of reduce and shift strategies. It has four major approaches to manage the demand –

- 1) Moving people rather than vehicles: It is aimed to be achieved by augmenting the capacity of rail and bus transit, promoting BRT, differential pricing methods and promotion of smoother and seamless intra mode transit. For promoting people movement, factors such as population density, employment location, and current traffic volume will be considered in developing BRT and MRTS. A catchment area within a radius of 2.5 km of the transit stop will be considered for developing transit supportive land use so as to promote ridership.
- 2) Integration of land use and transportation: It aims to restructure land use distribution along transit nodes, develop of dedicated parking places, and expand grid network in outer areas. Rationalisation of residential densities using scientific approach is also taken as an important element of the demand management strategy.
- 3) Prioritisation of NMT: It aims at expansion and improvement of footpath system and pedestrian transfers, removing encroachments on footpaths, and create dedicated road space for NMT.
- 4) Optimising existing road and transit infrastructure: It focuses on road widening, upgrade high density corridors and shifting intercity terminal from the core city to the fringe.
- 5) A limited shift has taken place in the use of fuel in from carbon based fuel to electricity and CNG in the vehicles in Jaipur city. Except for the low floor city buses, all the city buses operated by private and public buses run on carbon fuel. Almost 99 per cent of the private vehicles, taxis and three wheelers use carbon-based fuel.

8. Major Concerns in Urban Transport Planning

Urban transport planning and its implementation is faced with some critical challenges that could hinder its sustainability. They are:

- a) Due to rapid growth of population and number of vehicles, the pressure on the transport infrastructure is rising in Jaipur. Major traffic and transportation related problems in Jaipur city are- vehicular congestion, parking difficulties, time delays, very low traffic speeds, bottlenecks and hazards, accidents and high carbon emission. Jaipur city has become a traffic nightmare. In a linear growth scenario, the number of peak hour motorised trips will rise from 235,000 in 2010 to 630,000 in 2031 and also the share of private cars will rise from 13 per cent to 36 per cent during this period.
- b) Mismatch of road hierarchy at various locations is one of the critical challenges that result into traffic congestions and accidents (Sharma & Sharma, 2017). Railway crossing on the main road at one location (Tonk Phatak) also contributes to congestion.
- c) Development of a hierarchical system of roadways and freeways to meet the comprehensive demand for travel and transport is constrained by funding source. To implement CMP 2018, a total budget of INR 242,000 million will be needed (Solanki & Gupta, 2011). Mobilisation of financial resources will remain a major challenge. BRTS and MRT are likely to face the major implementation challenges due to heavy investment oriented nature of these projects. Sectoral financing is solely based on budgetary allocation, user charge and own source plays a very limited role. Even PPP is not very significant.
- d) Mechanism for rationalisation of routes of major modes and freight service management system is very weak in Jaipur city. The public and private bus operators seems to compete rather than complement transport services. Although intra-modal transfer facility is improving, it is far from being satisfactory.
- e) Fare structures are set by agencies without considering the price structures of other modes of transport. This results in a gap with respect to modal fare fixing since the same makes it difficult to influence modal choice of users. Even within a particular mode of transport, fare structures vary widely.
- a) Based on the analysis of table 3, it can be inferred that a complex overlap of authority is present as multiple agencies are involved in one or more functions. In the absence of clarity of roles and desired coordination among various agencies, achievement of the goals of CMP will remain a major challenge. Despite multiple agency involvement, no agency has responsibility to develop and promote technology based solutions for the traffic management and transport planning.

- b) Limited development of pedestrian infrastructure and encroachment on a large part of footpaths has seriously jeopardised walk mode in the city. It not only affects growth of NMT but also raises issues of safety of the users.
- c) Limited off-street parking facilities and existence of free on-street parking on a majority of roads continues to remain a major challenge in the Jaipur city.
- d) About 1300 people are killed every year due to road accidents in Jaipur. High traffic fatality rates are a major area of concern. Existence of large regulatory gaps noticed in the area of road users' safety. The mechanism to monitor and regulate the private bus service operators is very weak and majority of private city buses are poorly maintained, highly overcrowded, and do not follow safety standards.

9. SUTI Index for Jaipur City

Define SUTI. Overall Sustainable Urban Transport Index (SUTI) for Jaipur is 41.5 (refer table 5)

The annual mean value of air quality, measured in terms of PM 10, for Jaipur is 193 microgram per meter cube. In the worksheet, the minimum value is take as 150 which is lower than PM10 value for Jaipur, This value is replaced by the worst polluted city in Asia – Ahwaz, in Iran , with annual mean value of PM10 at 372 (WHO, 2020).

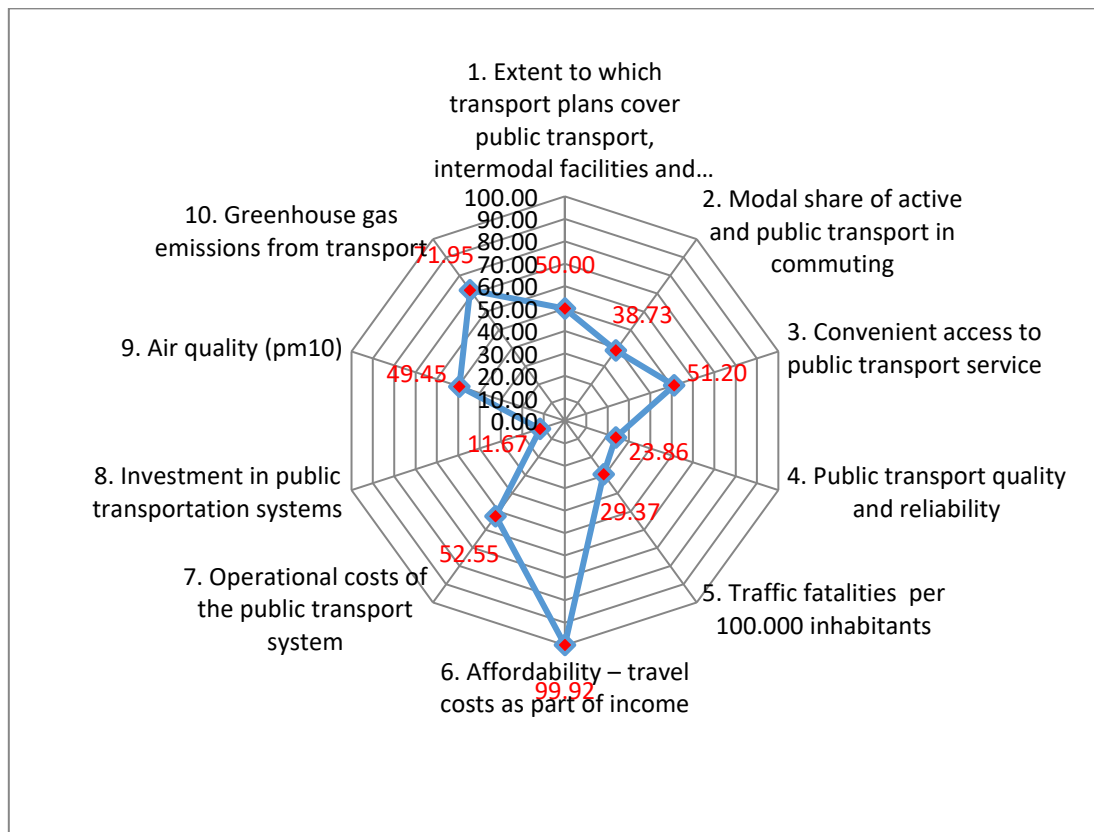
Jaipur scored below par on five indicators- 2, 4, 5, 8 and 9. Highest score are recorded for Affordability (travel costs as share of income) and greenhouse gas emissions from transport as captured by indicator numbers 6 and 10 respectively (refer table 2).

Table 5: SUTI for Jaipur City

S. No.	Indicators	Value	Normalized Score
1	Extent to which transport plans cover public transport, intermodal facilities and infrastructure for active modes	8	50.00
2	Modal share of active and public transport in commuting	41	38.73
3	Convenient access to public transport service	60.96%	51.20
4	Public transport quality and reliability	45.51	23.86
5	Traffic fatalities per 100,000 inhabitants	24.72	29.37
6	Affordability – travel costs as share of income	3.53	99.92
7	Operational costs of the public transport system	62.99%	52.55
8	Investment in public transportation systems	5.83%	11.67
9	Air quality (pm10) $\mu\text{g}/\text{m}^3$	193	49.45
10	Greenhouse gas emissions from transport, ton/capita/year	0.77	71.95
	SUTI Index		41.45

Source: Researcher calculation

Figure 10: SUTI Jaipur city spider graph



Source: Author's derivation

9.1 Indicator 1: Extent to which transport plans cover public transport, intermodal facilities and infrastructure for active modes

National Urban Transport Policy (NUTP) 2014 provides the policy umbrella framework for urban transport policies for the urban centres. It aims to provide a cost effective and equitable access to public transportation system. It aims to bring people at the centre and plan for their wellbeing and benefit and encourage the urban transport to emerge on a low carbon path. Based on the requirements of this policy, JDA has developed comprehensive mobility Plan (CMP) for Jaipur city known as CMP 2018. Besides CMP, Master Development Plan (MDP) 2025 also provides the policy framework for the development of city transportation system.

To evaluate the outcome on this indicator a detailed desk review of the following documents were undertaken:

1. National Urban Transportation Plan, 2014
2. Comprehensive Mobility Plan, 2011
3. Comprehensive Mobility Plan, 2018
4. Jaipur city Master Development Plan, 2011, Vol 1 and Vol 2
5. Jaipur city Master development plan, 2011, Vol 1 and 2
6. Jaipur city Master development plan, 2025, Vol 1 and 2

CMP 2011 and 2018, provide a comprehensive framework of a unified and integrated solution for city's transportation system. It clearly identifies the need to integrate land use and transport planning, promote public and non-motorised transport and foster safety.

It would be important to note that any single document by itself does not cover every element of assessment rubric provided in the updated SUTI data collection guidelines, 2018. Rubric was used for deciding score on each of the four elements covered by this indicator.

Table 6: Score and Explanation for each element of the Indicator 1

Aspects	Explanation	Score
I) walking networks (*)	National Transport policy specify the objective to promote walk and other NMT modes. JDA and JNN aims to promote pedestrian movement through a multiple intervention especially by removing encroachments and broadening. Yet, no specific targets are defined.	1
II) cycling networks (**)	A brief reference to the expansion of cycling track is mentioned in the CMP 2018, but no physical targets are defined and no budget is earmarked.	1
III) intermodal transfer facilities (***)	The policy aims to create a synergetic infrastructure to develop NMT, rail and city bus modes. It also aims to expand the coverage of radial roads. Physical targets for set in some and budgetary need for each is not adequately identified.	3
IV) public transport (****)	Sets a physical target for expanding the share of city buses BRT infrastructure, Metro and monorails systems development. Physical targets for BRT and MRTS projects are provided in the CMP but large budgetary gap exist to meet the planned investment of INR 242,000 million.	3
Total (sum)		8

Source: Desk review

Normalised score for indicator no 1 is 50, which is a low achievement. For motorised transport at least, physical indicators are identified but corresponding budgetary allocation is not provided. In such cases, it is not possible to assess sufficiency of funds allocated. In some cases, funds are allocated to achieve clubbed targets and therefore lack clarity on both physical and financial targets. Some of the core aspect of sustainability- promotion of low carbon public transport is virtually missing in the CMP 2011 and 2018, although it is mentioned as a vision in the NUTP 2014.

9.2 Indicator 2: Modal Share of Active and Public Transport in Commuting

To develop this indicator, data was taken from the Jaipur Metro Rail Corporation's (JMRC), Comprehensive Mobility Plan – Urban Transport Sector Assessment Report for Jaipur City (Volume 1). CMP analysis is based on the data collected from 91 wards in the city within which a sample size of 10,971 families was analysed. The report states that a total of 3.25 million internal trips are made every day within the city by a number of 3.65 million people. Home

base work and education trip constitute 44 per cent of total trips and home-based education trips make up for 41 per cent.

Table 7: Average number of trips per day

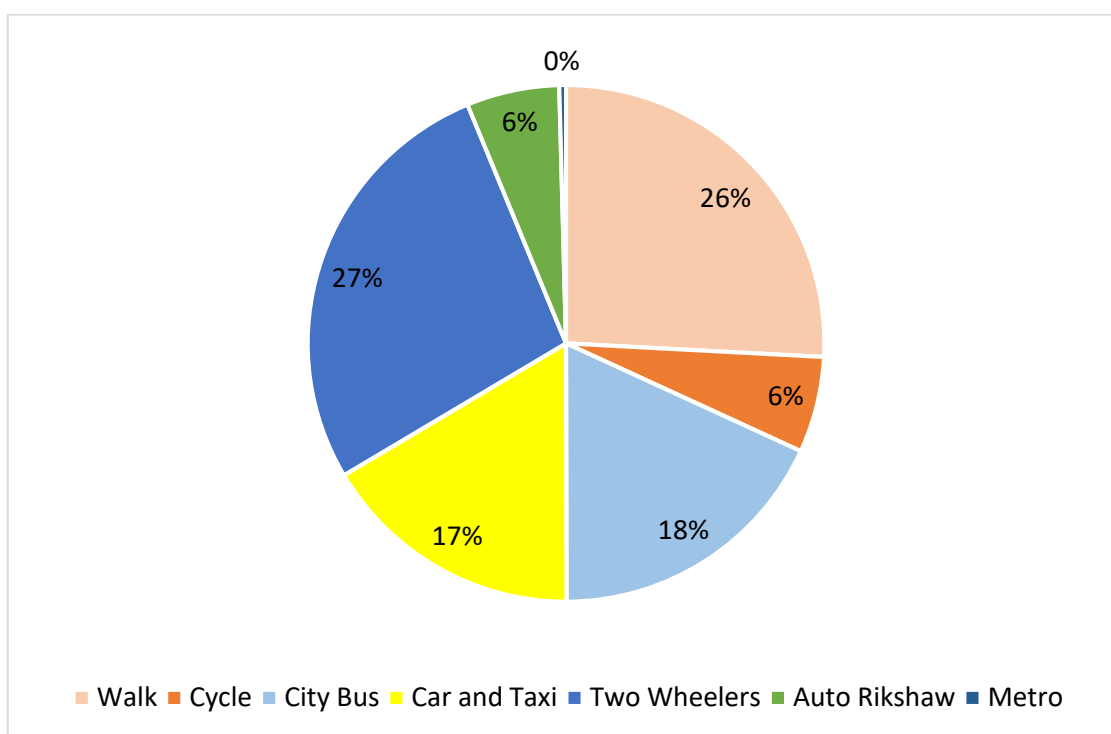
PURPOSE	COMMUTING	
	(WORK AND EDUCATION)	
MODE	#	Subtotals
a. Scheduled bus and minibus (*)	600925	
b. Train, metro, tram	13650	
c. Ferry	0.000	
d. Public transport	(a+b+c)	614575
e. Walking	521950	
f. Bicycle	195325	
g. Active transport	(e+f)	717275
h. Passenger car	608075	
i. 3W – Private	279825	
j. Shared Auto (Informal PT)	0	
k. Motorcycle	1030250	
l. Institutional Buses and Auto Rickshaws	0	
m. Other motorized (trucks,etc)	0	
n. Individual motorized (**)	(i+j+k+l+m)	1918150
o. Total	(e+h+o)	3250000
p. Public and active	(e+h)	1331850
q. Modal share of active and public transport		41.0

Source: Comprehensive Mobility Plan, Jaipur city, Vol 1, 2018

As per the 2017 data, 41 per cent of the total daily trips constituted active and public transport. 50.4 per cent of the total daily trips composed of private motor transportation. The use of two wheelers is predominant as 31.7 per cent of the total trips constituted of it.

Jaipur has scored low on this indicator- 38.73 irrespective of the affordable and relatively accessible public transport. One of the reasons for such an observation is that Jaipur has a relatively high per capita income which makes private automobile common among households.

Figure 11: Modal Share in Jaipur City Transportation (in per cent)



Source: Comprehensive Mobility Plan, Jaipur city, Vol 1, 2018

Analysis of modal share also indicates that the current pattern promotes energy inefficiency, causes traffic congestion, pollutes environment and pushes up the economic, personal and social costs of commuting.

9.3 Indicator 3: Convenient Access to Public Transport Service

Extent of the use of public transport is primarily determined by the access to public transport services. Greater use of such services helps the modern cities to foster sustainability. It is defined as “Proportion (percentage) of the population that has convenient access to public transport, defined as living 500 meters or less from a public transport stop with minimum 20-minute service.” It is consistent with SDG goal number 11.2 -“By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all”. Methodological framework suggested in the ‘Final Monograph Series on Urban Transport 2017’ is used to construct this indicator.

There are 143 city bus stops in Jaipur which cover an area of 262.6 Sq Km that serves a total of 1650685 inhabitants which constitutes around 54 per cent of the total population. Bus services are managed by both public and private managements. The public bus services

management is controlled by the Jaipur City Transport Service Ltd. (JCTSL) and the minibuses are managed by private operators. Inadequate accessibility is a result of the unorganized routes and operations of the mini bus services. The bus services are also concentrated in the areas where population density is large which prevents the rest of the inhabitants from using the services.

Jaipur has a total of 9 metro stations with a coverage area of 16.5 Sq Km. To derive the required information it was assumed that the coverage area of metro station is similar to the bus station in that similar locality. Metro stations serve a total of 6.76 per cent of the total population which is significantly less as compared to other metropolitan cities in India. The average ridership per day has been around 19,100. The reason behind the low value is the fact that there has been a continuous drop in the ridership. The Jaipur metro has been devoid of any major investments which have translated into being one of the shortest routes in the country. The study finds that about 61 per cent of Jaipur inhabitants have access to public transportation. This finding is also consistent with the findings of Comprehensive Traffic and Transport Study (CTT) conducted by Jaipur Development Authority (JDA) in Jaipur, which found that a total of 60 per cent of the Jaipur population have access to public transport. This helps to verify the findings.

Table 8: Population density, major bus stop and metro stop wise

Number of bus stops	Coverage area within a radius of 500m	Pop. density	Inhabitants
143	262.6	6285.9	1650685.2
Number of Metro Stops			
9	16.5	12472.0	206162.2
Total			1856847.4
Jaipur's Population (2019)			3046163
Per cent within 500 m Buffers			60.96%

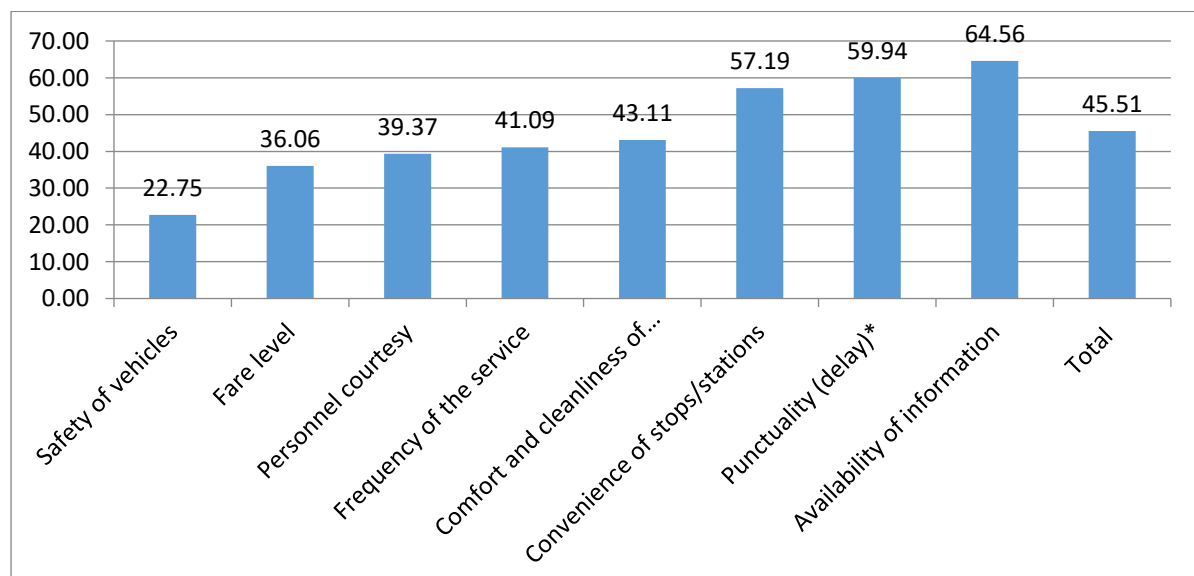
Source: Author's Calculation

9.4 Indicator 4: Quality and Reliability of Public Transport

Although ease of access to public transport is an important prerequisite for sustainable urban transport, its actual use is also determined by the quality and reliability of the public transport system. Better service delivery also enables the bus operators to attract riders and also enable them to make the venture financially profitable.

To construct this indicator, information was collected from the paper: Analysis of Service Quality Attributes for Jaipur Bus Transportation by Pankaj Sharma, J.K Jain and N. Srinivasa Reddy. The survey has a sample size of 1502 users (Sharma, Jain, & Reddy, 2017). The overall score for quality and reliability of public transport is 23.9 per cent. This is the lowest Jaipur has scored due to relatively high level of dissatisfaction among users in terms of safety of vehicles which received a total score of only 22.8 per cent. The mini buses are operated by private entities which fail to maintain standards and quality. There was also high level of dissatisfaction in terms of fare level, personal courtesy, frequency of the service and comfort and cleanliness of the vehicles. The finding of users satisfaction survey is shown in the figure 12.

Figure 1: Mean Values of the Quality and Reliability Variables of the Public Transport in Jaipur



Source: Derived from (Sharma, Jain, & Reddy, 2017)

The study also emphasise following aspects of quality of city bus services in Jaipur-

- a) About 30 per cent of the respondents opined that overcrowding and low frequency are major issues related to city bus services
- b) About 20 per cent respondents questioned the reliability of the services provided by the mini buses operated by the private operators. The printed information on the bus stops were found to be highly unreliable and often misleading.

9.5 Indicator 5: Traffic Fatalities per 100,000 Inhabitants

Sustainable public transportation needs to be safe for the users. SDG target 3.6 aims to reduce traffic related death and injuries to less than half by 2030. In India, all the cases of traffic accidents are recorded, maintained and published by the Ministry of Road Transport and Highways, Government of India. For this study, same source is used for the construction of this indicator. The data on Metro related accidents is maintained by the Jaipur Metro Rail Corporation Limited (JMRCL). The annual report of 2017-2018 for JMRCL was referred for the calculation of this index.

On this indicator, Jaipur has scored its worst at 29.37. This reflects that Jaipur has performed low on this indicator. The low score is a result of an important fact that Jaipur is the city with third highest cases of accidents reported after Delhi and Chennai. The number of fatalities per 100,000 inhabitants was calculated to be 24.7 and all was contributed by road accidents. Fatalities from metro related accidents have been zero as per the annual report 2017 – 2018 of (JMRCL).

According to a study by CUTS, the significantly high cases of accidents in Jaipur are a result of rapid urbanization. The study reveals that in 2014, 98 accidents occurred in Tonk Road in which 35.7 per cent of the accidents resulted into deaths and remaining 64.2 per cent resulted into injuries. More than 50 of the accidents which occurred were either during early morning or early evening hours which could possibly be due to the excessive speeding and non-compliance to traffic rules and regulations (Mehta, 2019). The study also noted that drivers in city do not care about the pedestrian rights and city buses violate traffic rules in terms of over speeding and neglect traffic signals. It is quite evident that enforcement of traffic rules is very weak. Accident severity index, a measure of severity and seriousness of the accident in terms

of number of deaths per hundred accidents, is very high and rising over the period time. The index rose from 27 in 2006 to 57 in 2016 (Nama, Lata, & Nagar, 2017).

9.6 Indicator 6: Affordability- Travel Cost as a Ratio of Income

Affordability is an important feature of sustainable public transport. Transport constitutes an important share of the house hold expenditure. It consists of spending on purchase of vehicles, its maintenance and fuel, and also the commuting fare. A Consumer expenditure survey in USA reveals that share of transport in household expenditure was about 17.5 per cent in 2017(Bureau of Labour Statistics USA, 2019).

This indicator was constructed using secondary data obtained from three major sources-

- Jaipur Metro Corporation (JMC) notification on fare structure for metro operations by JMRCL.
- Jaipur City Transport Services Limited (JCTSL) city bus schedules and fare charts.
- Times of India Bus Fare Jaipur
- NCAER: The Next Urban Frontier: 20 Cities to watch.

Findings of this study reflects that average monthly transportation cost for commuters using city bus and metro is about 3.53 per cent of their income. Normalised score for this indicator is 99.92, which is the highest normalized score of Jaipur.

The score indicates that public transportation facilities in Jaipur are highly affordable. Despite low fares, modal share of public transportation is very low. This paradox can be explained by a variety of factors, such as, choice for private vehicles due rising per capita income and poor quality perception about city buses.

9.7 Indicator 7: Operational cost of Public Transportation System

Ability of the public transportation operators to provide an easily accessible, affordable, efficient and sustainable service depends on the magnitude of the operating cost. Higher operational cost creates trade-off between affordability, efficiency and sustainability. Higher operational cost affects the operator's ability to remain profitable and affordable, provide

efficient services and also improve the services. Subsidisation may only improve affordability but would adversely affect other features of a sustainable transport.

This indicator was derived by using information three sources-

- a) “Overcoming Challenges of Integrating Urban Transport System” (Bhatt, 2019): Information on operating cost and revenue per km for city buses in 2012 of Jaipur was taken from this source. It is assumed that it remained unchanged since 2012.
- b) Comprehensive Mobility Plan for Jaipur city 2018: this source is used to get average kilometres per day travelled by city buses in Jaipur city and the total number of city buses in Jaipur city in 2017.
- c) Annual reports 2016 and 2017 of Jaipur Metro Corporation: Operating cost operating revenue of Metro trains in Jaipur is taken from this source.

Operating cost (revenue) for 2017 is calculated by multiplying average cost (revenue) per km with number of buses in 2017 and average km travelled in a day in 2017.

For public bus services, the balance sheet for Jaipur City Transport Services Limited (JCTSL) was unavailable. Therefore the operating costs and revenue were estimated from available data on operating costs and revenue per kilometre. Normalised score for Jaipur on SUTI indicator number 7 is 52.55, which implies a moderate performance.

The Fair Box Ratio of MRT services is 25 per cent which indicates that only 25 per cent of the total operating expenditures can be funded by the fares. The ratio is significantly low as metro fares are highly subsidized by the government. The Fair Box ratio of metro services is high at 70 per cent because of the efficient Public Private Partnership (PPP) projects.

Table 9: Fare Box Ratio for City Bus Operators in Jaipur

Operator	Market shares	Fare box ratio
City Bus	90%	25%
Jaipur Metro	10%	70%

Source: Derived from information obtained from Jaipur Metro Annual Report and others

9.8 Indicator 8: Investment in Public Transportation System

Investment in the public transportation system in a city is necessary to achieve desired objectives and also to maintain similar service standards in the face of rising population pressure. This indicator is constructed by taking into account per cent of transport investment spending on a five yearly average basis.

Data for this indicator was obtained from one source-

- 1) Jaipur Development Authority (JDA), Comprehensive Mobility Plan (CMP) for Jaipur 2010.

Due to unavailability of a reliable document on the investment in public transportation system, the investment estimates by CMP had to be utilized for calculation of the index. The investments in public transport facilities include bus procurement and construction of bus stops and the total investment in transport include roads, foot paths, parking space, bridges, bicycle lanes, BRTS, metro rail and mono rails.

Five year running average share of investment in public transport facilities in total transport investment was 5.83 per cent. Normalised score on this indicator is 11.67, which is equivalent of a poor performance.

There is a dire need for greater investment in public transportation facilities to reduce the current challenges and bottlenecks. This will help improve the efficiency of the public transportation system and improve quality and safety which will attract more users. The benefit of doing so is reduction in ever growing share of private vehicles.

9.9 Indicator 9: Air Quality (PM 10)

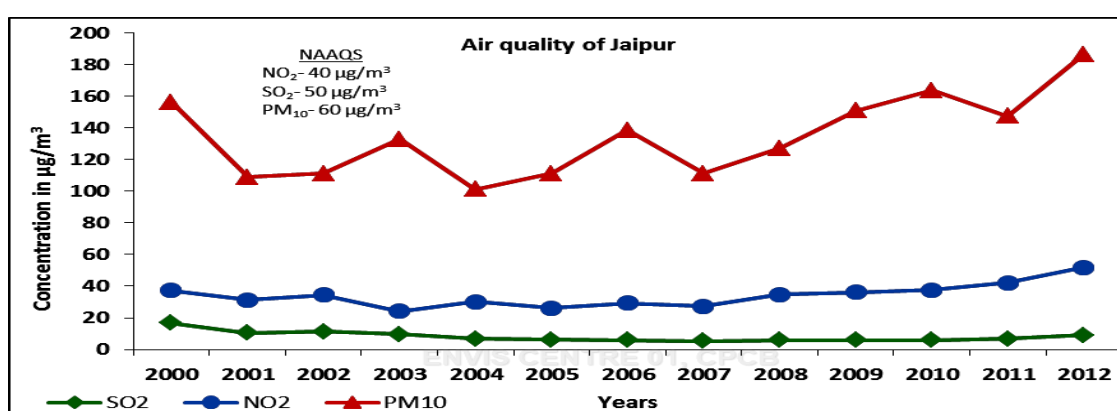
This indicator is used for SUTI in order to monitor SDG Target 11.6 “reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management”.

Air quality data in Jaipur city is measured at 6 stations but this indicator is constructed using information drawn from WHO Pollution report 2019. The air quality index shown in figure 13 reflects that PM 10 level in Jaipur has increased significantly since 2000. Jaipur is known to be

the most polluted city in Rajasthan. The concentration of PM 10 is 193, which is significantly higher than the limit of 150. According to WHO, any value higher than PM 150 is considered to be alarming and can pose serious danger to health. The high value of PM 10 is however not a result of growing number of automobiles but due to industrial emissions.

The methodological requirement, as suggested by SUTI monograph, for calculation of this indicator is that PM10 level value more than 150 shall be taken as the minimum of 150. Since PM 10 for Jaipur is 193, it is treated as 150 for the calculation of this indicator, the value of normalized index becomes zero.

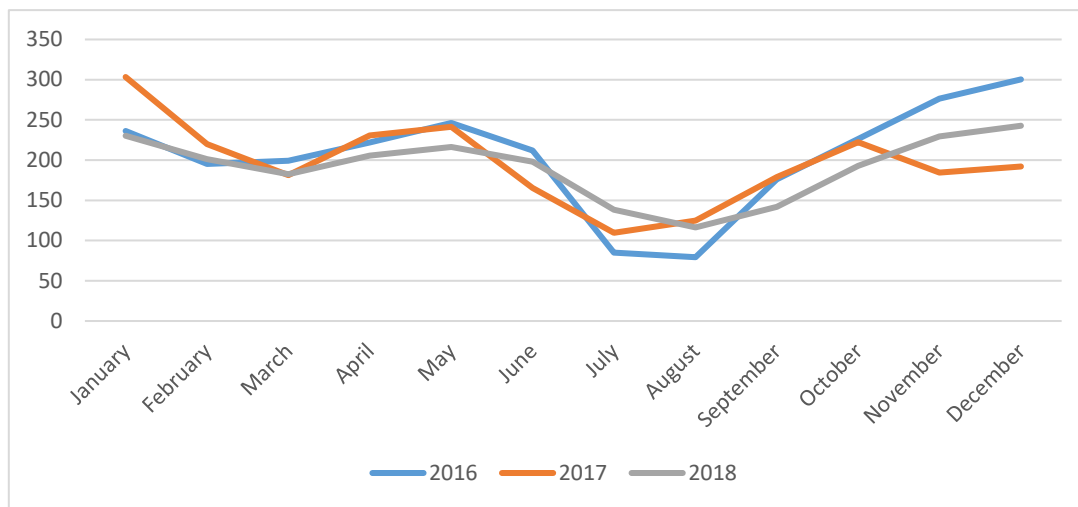
Figure 2: Annual Average level of Air Quality Index in Jaipur



Source: ENVIS Centre on Control of Pollution of Water, Air and Noise

Mean annual value of PM 10 in Jaipur was 204.5 in 2016, which fell to 196.2 in 2017 and to 191.4 in 2018. This trend reflects a comforting trend that PM 10 level in Jaipur is declining, albeit marginally. The trend also reflects seasonal fluctuations in PM10 levels- rises during summers, declines during monsoons and then rises again during winters (refer figure 14).

Figure 3: Mean monthly PM10 in Jaipur city



Source: Derived from (Jain & Mandowara, 2019)

9.10 Indicator 10: Green House Gas Emission from Transport

This indicator aims to capture the transport related emission and helps to monitor all the Transport related CO₂ emission. It provides an evaluation framework for alternative strategies of public transport systems. Environment outcome of Shift, Avoid and Improve strategies can be evaluated using this indicator.

Methodological framework to construct this indicator involved data collection on annual sale of petrol and diesel sold in the city. This information was obtained from the stakeholder consultation with the association of the petrol dealers in Jaipur.

Following simplifying assumptions were made to compute this indicator-

- All the petrol and diesel sold in the city is used for intra-city transport.
- Operating cost and revenue per km of travel remain unchanged since 2012.

Through stakeholder consultation it was revealed that a total of 434,802,553.40 Litres of petrol and a total of 509,097,907.30 Litres of diesel were sold in 2018. The total GHG emission generated from the consumption of fuel was 2350000 tons. High total emission level is offset by the large population of 3046163 inhabitants, because of which the per capita emission of

GHG by motorised vehicles/transport is low in Jaipur. This makes Jaipur city achieve a high normalized score of 71.95 in the greenhouse gas emissions from transport.

10. Conclusions

- 1) Jaipur's SUTI score is 41.45, which can be interpreted as a low performance. The score conveys that Jaipur's city public transport is unsustainable in its present form. There is need to bring about a much-desired shift from private motorized transport towards mass public transport system and NMT. Topographical constraints in the North East part of the city tends to pose a major issue in expanding the connectivity. Besides, rising rate immigration, high funding gaps, and limited integration of land use and transport planning have contributed to increased demand supply gaps in the city transportation system. High growth rate of private vehicles and two wheelers is likely to continue in a no change scenario. Rising per capita income will further boost the demand for vehicles in Jaipur city.
- 2) Mismatch between road hierarchies at major traffic locations tends to amplify the traffic congestion problem in the city. The problem of traffic congestion is also rising due to limited NMT infrastructure that supports pedestrian cum cycle movement, while encroachment on the footpaths and roads and on street parking adds to the problem of congestion in the city.
- 3) Metro trains in the city tends to remain highly underutilised. Limited coverage of metro trains on the major routes and ineffective intra transport integration are the major reasons of limited use of metro trains for city transportation.
- 4) Urban transport governance in Jaipur represents a multi-agency system of governance. Legislative power regarding urban transport is also characterised by divided responsibility between central and state governments, with some areas remaining outside the scope of both. Limited coordination between various agencies involved in the urban transport system tends to pose a major challenge to systematically develop sustainable transport system.
- 5) City transport planning seems to be highly inadequate to develop sustainable public transport. Although plan documents have identified major objectives, they are not supported by time bound specific targets and provision of dedicated financial resources. It is not evident how the planners aim to achieve these objectives and monitor the progress. To meet the CMP 2018 objectives, the estimated budgetary shortfall is about

INR 245,000 million. It is not clear how this shortfall will be bridged. It is very likely that most plans, in the want of resources, will not materialise.

- 6) Inadequate accessibility of city buses, irrational route planning, limited information and overcrowding tends to adversely affect the quality perception of the city bus services and therefore explain its limited use. Private operators tend to inefficiently compete on the so called profitable routes and lack coordinated approach with public buses. Rationalisation of routes and coordinated approach between public and private bus operators and between city bus and metro train is required for developing effective public transport services.
- 7) Jaipur has one of the most unsafe roads in Indian cities. City transport is characterised by high fatality rates, about 25 per 100,000, and 57 death from every 100 accidents. The greater concern is growing magnitude of this problem.
- 8) Jaipur is one of the highly polluted cities in India. Emission level, measured in terms of annual mean value of PM10, PM2.5 has consistently been higher than the specified limits by NAAQ and much higher than WHO benchmark. High level of air pollution contributed by growing traffic is a major challenge to the sustainability of city transportation system.

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