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Master's Thesis

Enhancing Rural Mobility through Demand-Responsive Transport in India:

A Socio-spatial Analysis of Katol-Narkhed Subdistricts

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Abstract

The thesis explores the potential of Demand-Responsive Transport (DRT) systems to address critical mobility challenges in rural India, focusing on the Katol-Narkhed sub-districts of Nagpur. Traditional rural public transport, characterised by infrequent and unreliable services, fails to meet local mobility needs, hindering socio-economic development, limiting access to essential services, and widening the rural-urban divide.

Key objectives of the thesis include evaluating current transport policies and their impact on rural mobility in India, briefly assessing the effectiveness of Maharashtra State Road Transport Corporation (MSRTC) services and understanding user perceptions and demand for DRT systems through a survey. The thesis contextualises rural India's transportation challenges, highlighting disparities between urban and rural systems. It then explores DRT benefits, including improved accessibility, reduced congestion, environmental impact, user satisfaction, and economic advantages. The study examines successful DRT schemes and analyses failures to extract key lessons and best practices.

The methodology is a mixed-method approach with stakeholder analysis, surveys, and advanced spatial analysis. The survey, conducted among Katol and Narkhed subdistricts (taluka) residents, reveals a strong interest in DRT services, with 97% of 106 respondents showing interest in using such a system and 90% intended to pay a higher fare than traditional bus services for an innovation transport system. Spatial analysis integrates demographic data from the 2011 Census of India, geographical data from the PMGSY National GIS portal, and bus timetable data from MSRTC. The thesis employs advanced spatial techniques to map existing essential infrastructure and identify service gaps. Techniques like Kernel Density Estimation (KDE) analysis, Spatial Autocorrelation, Transport Frequency Analysis, Essential Services Density Analysis, and Isochrones Analysis. The layered data approach uses the H3 spatial index, a hexagonal grid system, to integrate various data layers, including population density, public transport frequency, and service availability. This evidence-based weighted scoring approach identifies underserved areas that would benefit most from DRT solutions, guiding the strategic planning of DRT services.

The thesis concludes by highlighting improved PT accessibility with DRT by outlining the spatial process of DRT service design including identifying high-value towns, service coverage areas, DRT service models, and stop locations. The DRT model integrates traditional bus services with flexible, on-demand detours to enhance last-mile connectivity, aiming to further improve accessibility and mobility for residents of Katol-Narkhed subdistricts.

Abstract in Italiano

La tesi esplora il potenziale dei sistemi di Trasporto a Domanda Rispondente (DRT) per affrontare le sfide critiche della mobilità nelle aree rurali dell'India, concentrandosi sui sottodistretti di Katol-Narkhed a Nagpur. Il trasporto pubblico rurale tradizionale, caratterizzato da servizi infrequenti e inaffidabili, non riesce a soddisfare le esigenze di mobilità locali, ostacolando lo sviluppo socio-economico, limitando l'accesso ai servizi essenziali e ampliando il divario tra aree rurali e urbane.

Gli obiettivi principali della tesi includono la valutazione delle attuali politiche di trasporto e il loro impatto sulla mobilità rurale in India, una breve valutazione dell'efficacia dei servizi della Maharashtra State Road Transport Corporation (MSRTC) e la comprensione delle percezioni degli utenti e della domanda per i sistemi DRT tramite un sondaggio. La tesi contestualizza le sfide del trasporto rurale in India, evidenziando le disparità tra i sistemi urbani e rurali. Successivamente, esplora i benefici del DRT, inclusi il miglioramento dell'accessibilità, la riduzione della congestione, l'impatto ambientale, la soddisfazione degli utenti e i vantaggi economici. Lo studio esamina schemi DRT di successo e analizza i fallimenti per estrarre lezioni chiave e migliori pratiche.

La metodologia adottata è un approccio misto che comprende analisi delle parti interessate, sondaggi e analisi spaziali avanzate. Il sondaggio, condotto tra i residenti dei sottodistretti di Katol e Narkhed (taluka), rivela un forte interesse per i servizi DRT, con il 97% dei 106 intervistati che si dichiara interessato a utilizzare un tale sistema e il 90% disposto a pagare una tariffa superiore rispetto ai servizi di autobus tradizionali per un sistema di trasporto innovativo. L'analisi spaziale integra i dati demografici del Censimento dell'India del 2011, i dati geografici dal portale GIS nazionale PMGSY e i dati degli orari degli autobus della MSRTC. La tesi impiega tecniche spaziali avanzate per mappare le infrastrutture essenziali esistenti e identificare le lacune nei servizi. Le tecniche utilizzate includono l'analisi Kernel Density Estimation (KDE), l'Autocorrelazione Spaziale, l'Analisi della Frequenza del Trasporto, l'Analisi della Densità dei Servizi Essenziali e l'Analisi delle Isochrone. L'approccio a dati stratificati utilizza l'indice spaziale H3, un sistema a griglia esagonale, per integrare vari livelli di dati, inclusi la densità di popolazione, la frequenza del trasporto pubblico e la disponibilità dei servizi. Questo approccio basato su prove con un punteggio ponderato identifica le aree sotto-servite che trarrebbero maggior beneficio dalle soluzioni DRT, guidando la pianificazione strategica dei servizi DRT.

La tesi conclude evidenziando il miglioramento dell'accessibilità al trasporto pubblico con il DRT delineando il processo spaziale di progettazione del servizio DRT, incluso l'identificazione dei centri abitati di alto valore, delle aree di copertura del servizio, dei modelli di servizio DRT e delle posizioni delle fermate. Il modello DRT integra i servizi di autobus tradizionali con deviazioni flessibili su richiesta per migliorare la connettività dell'ultimo miglio, con l'obiettivo di migliorare ulteriormente l'accessibilità e la mobilità per i residenti dei sottodistretti di Katol-Narkhed.

Acknowledgement

I want to express my gratitude to my supervisors, Professor Elisabetta Vitale Brovarone and Professor Magda Bolzoni, whose constant guidance, invaluable suggestions, and indispensable support have been instrumental in completing this thesis. Their expertise and encouragement have significantly contributed to the improvement of my work, and for this, I am profoundly grateful.

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List of Abbreviations

AM	Ante meridiem
AS	Accessibility Score
DBOD	Dubai Bus on Demand
DRT	Demand-responsive Transport
FDI	Foreign Direct Investment
GIS	Geographic Information System
GST	Goods and Services Tax
HVT	High-Value Town
ICT	Information and Communications Technology
ITS	Intelligent Transport System
KDE	Kernel Density Estimation
MaaS	Mobility as a Service
MSRTC	Maharashtra State Road Transport Corporation
NA	Not Available
NMT	Non-motorised Transport
PM	Post meridiem
PPP	Public-Private Partnership
PT	Public Transport
PMGSY	Pradhan Mantri Gram Sadak Yojna
ST	State Transport
UTAUT	Unified Theory of Acceptance and Use of Technology

1. Introduction

"Look at all the buses now that want exact change, exact change! I figure if I give them exact change, they should take me exactly where I want to go"

- George C. Wallace

In the ever-evolving arena of Indian transportation, this thesis explores the complexities and prospects that shape public transit, particularly in rural areas. Amidst rapid urbanisation and the advent of innovative technologies in urban centres, the focus shifts to rural landscapes, where infrastructure, connectivity, accessibility, and affordability play pivotal roles in defining transportation dynamics. In India, the transportation system has been crucial in meeting the needs of passengers. However, the mismatch between transport demand and the existing infrastructure significantly impacts the economy and the environment. In India, rapid urbanisation and an increasing vehicle population have pronounced effects on human life and the environment (Neeta & Geeta, 2013). A major hindrance to achieving sustainable transportation in rural areas is the swift urbanisation across India. While urbanisation was gradual in the pre-independence era, it gained momentum post-independence, especially after the economic reforms of the 1990s (Kundu, 2011). This urban shift has also led to a disproportionate investment in urban infrastructure at the expense of rural areas. The decline in government investment in infrastructure and basic amenities in smaller towns has exacerbated disparities within the urban economy (Kundu, 2011).

Currently, around 65% of the population is living in rural areas. Rural people are more dependent on agriculture and related income, but economic reforms are mostly concentrated on urban areas and industries. Income inequality, slow growth of literacy, problems of rural employment, low quality of life and many more, the rural people were more affected by the economic reforms in India compared to the urban areas. (Wahab, 2022).

In 1901, 88.6% of India's population resided in rural areas, a figure that decreased to 71.47% in 2001 and further to 68.84% in 2011 (Census of India, 2011). By 2030, it is projected that 59.24% of the population will still reside in rural areas (United Nations, 2007), representing a sizeable portion of the population. India's urban areas are set to magnify manifold: by 2050 (Figure 1-1), when the country is projected to be more urban than rural, the rural areas are set to be neglected even more.

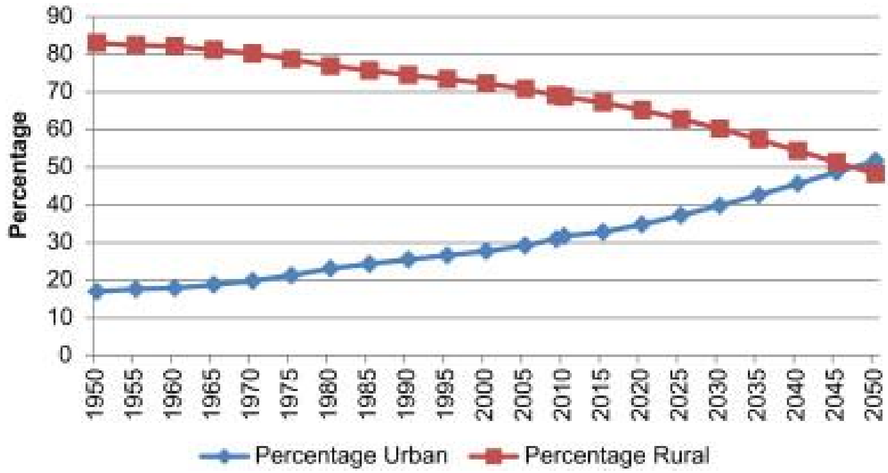


Figure 1-1 Urbanisation in India. Source: UN, 2012a.

A dismal situation continues even after massive governmental investment in rural development, poverty alleviation and employment generation. Only 15% of Rs 20,000 crores of annual subsidies and grants, under various schemes, has reached the beneficiaries. Increasing allocation for rural development in successive Five-Year Plans has not improved the situation. Only an efficient Rural Transport system can allow people to take advantage of the massive investment envisaged for rural development (Ramaswamy, 1998).

This study casts a spotlight on the potential role of Demand-Responsive Transport (DRT) systems in enhancing public transportation in rural India. While public DRT systems have seen successful implementation worldwide, their application in rural India remains largely unexplored in the literature. High-populated areas generally have high demand, where regular bus service is more cost-efficient as large buses can absorb the demand without significant changes in the schedule or number of vehicles, but DRT is significantly more cost-efficient and environmentally friendly in scenarios with low demand (Dytckov et al., 2022).

1.1. Research Questions

The research is designed around two main questions:

1) How accessible is public transportation within the Katol-Narkhed subdistrict for regional travel?

2) How can a Demand Responsive Transport (DRT) system improve the accessibility and effectiveness of public transportation in the Katol-Narkhed sub-district?

Through the integration of theoretical insights and empirical data, this thesis aims to provide significant contributions and actionable recommendations for policymakers and practitioners striving to develop sustainable and inclusive rural transportation solutions in India.

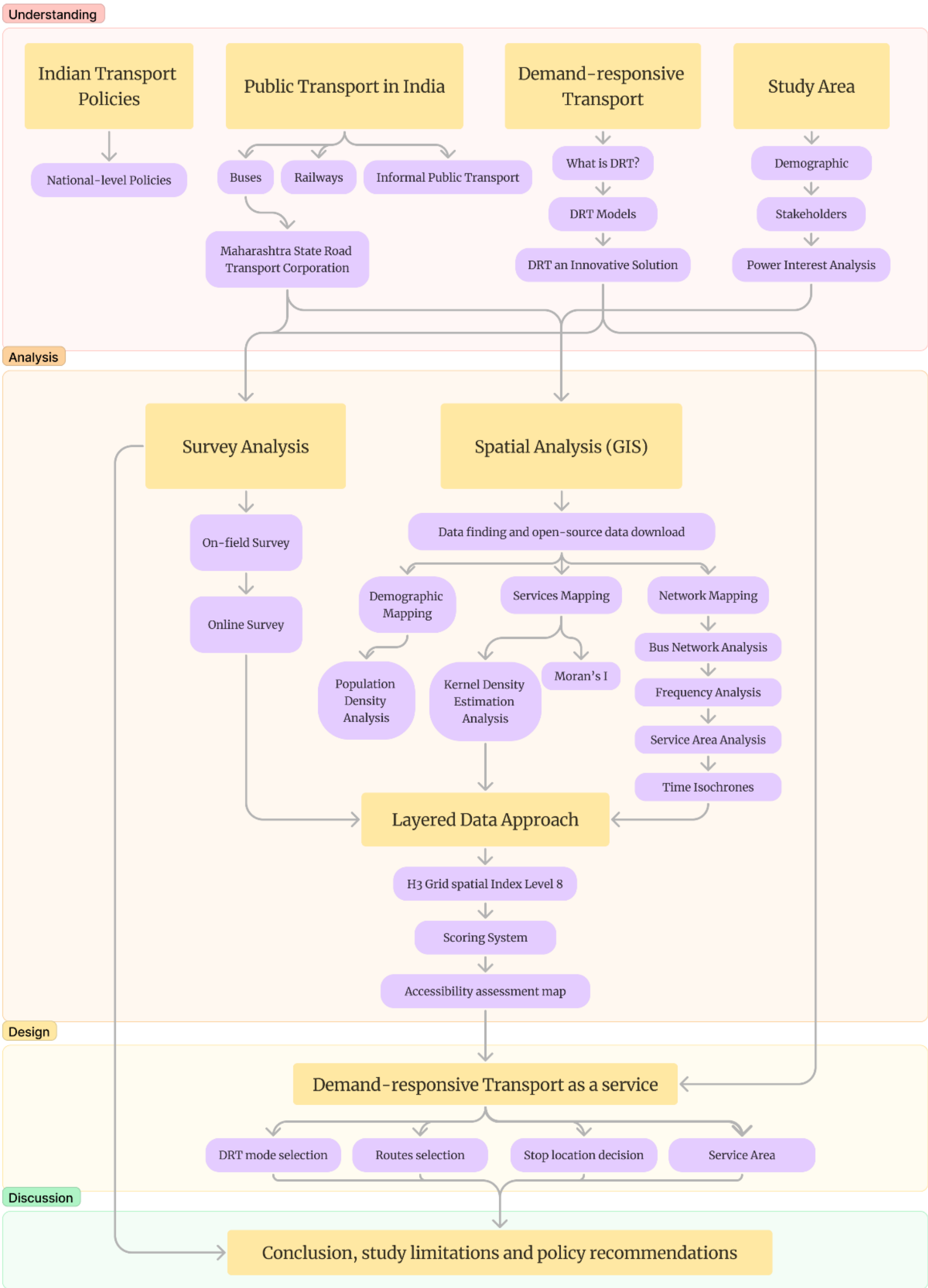


Figure 1-2 Thesis flowchart

Following this introduction, the thesis is organised as follows:

Section 2 provides a detailed transportation analysis, comparing transportation-related policies in India and giving a general overview of the Indian transport scenario.

Section 3 reviews Demand-Responsive Transport (DRT) literature and discusses case studies of successful and failed DRT systems globally.

Section 4 introduces the study area and stakeholders.

Section 5 describes the methodology used in the research.

Section 6 survey findings, and spatial analysis of the study area, and discusses the results.

Section 7 explains the DRT system design and specifications

Section 8, the final section, concludes with a summary of the findings, provides policy recommendations, discusses limitations, and suggests directions for future research.

2. Transport Policies and challenges in rural India

This section of the thesis delves into the current state of the Indian transport system, with a primary focus on road transport and specifically the public transport system in rural India. It presents a comprehensive analysis and synthesis of existing research and publications, concentrating on three critical areas: national transport-related policies, public transport in India, and the Maharashtra State Road Transport Corporation (MSRTC).

National transport-related policies are examined to understand the framework and strategic initiatives guiding the development and regulation of transportation across the country. These policies provide insight into government priorities, investment strategies, and regulatory measures aimed at improving connectivity, safety, and sustainability in urban and rural settings.

Public transport in India is briefly analysed to identify the unique challenges and opportunities within the sector, particularly in rural areas. The study explores various modes of public transport, their reach, efficiency, and impact on rural communities. It also considers how public transport systems can be enhanced to better serve the needs of these communities, improving accessibility and economic opportunities.

The Maharashtra State Road Transport Corporation (MSRTC) is specifically highlighted as a case study to provide a detailed understanding of the operational dynamics, challenges, and successes of a major state-run transport corporation.

Overall, this section aims to establish a foundational understanding of the current state of knowledge for this thesis. Synthesising existing research and publications, sets the stage for further investigation and discussion within the scope of this study, paving the way for the development of informed recommendations and strategies for enhancing rural public transport in India.

2.1. Key Transport-related Policies in India

Policies	Goals				Focus	
	Urbanisation	**Motorisation**	**Infrastructure**	**Environment**	**Area**	**Type**
The Road Transport Corporations Act, 1950	NA	To start public bus transportation and provide equitable services for all.	To establish Road Transport Corporations.	NA	Urban and Rural	Public and Private

Policies	Goals				Focus	
	Urbanisation	Motorisation	Infrastructure	Environment	Area	Type
Metro Railways (Construction of Works), 1978 Act and Amendment Act in 1982	NA	NA	Development of Improved urban transportation system, Regional Rapid Transit System, MetroLite, MetroNeo, and WaterMetro	NA	Urban	Public
Air (Prevention and Control of Pollution) Act, 1981	NA	NA	NA	Set vehicle emission standard	Urban and Rural	Private
Motor Vehicle Act, 1988	NA	Motor vehicle registration, vehicle control through permits, license of drivers, etc.,	NA	NA	Urban and Rural	Private
Pradhan Mantri Gram Sadak Yojana (PMGSY) 2000	NA	NA	Aims to provide all-weather road connectivity to unconnected Indian villages	NA	Rural	Public and Private
Integrated Transport Policy, 2001	Mass transit system	NA	Improve infrastructure, Encourage private sector participation	NA	Urban	Public
National Auto Fuel Policy, 2003	NA	NA	NA	Issues of vehicular emissions, Applying fuel quality standards	Urban and Rural	Private
National Urban Transport Policy (NUTP), 2006	Improve urban transport, Integrated land use, and City planning	Encourage private transport, Sustainable transport	Better infrastructure for road safety	Strict environmental norms, Reduce pollution levels,	Urban	Private
National Road Safety Policy, 2010	NA	NA	Better infrastructure for road safety. Improved designs and maintained roads.	NA	Urban and Rural	Public and Private
National Electric Mobility Mission Plan (NEMMP) 2013	Electric public and private transport system	Encouraging people to shift to electric vehicles	Promoting the adoption of electric and hybrid vehicles	Lower pollution levels	Urban and Rural	Private

Policies	Goals				Focus	
	Urbanisation	Motorisation	Infrastructure	Environment	Area	Type
National Urban Transport Policy, 2014	Integrated land use and transport planning, CMP, TDM	Control private vehicles, plans for freight movement	Expansion of road network, equitable allocation of road space, universal accessibility, parking, MRT	Promote NMT, reduce emission levels, control noise pollution	Urban	Public
Road Transport and Safety Bill, 2014	Urban planning, City safety, and Traffic management program	Road safety, Vehicle regulation, Unified driving license and vehicle regulation system, Punishment for traffic law violators	Parking places and halting stations, Road infrastructure development	Alternative vehicle fuel	Urban	Private
Make in India, 2014	100 Smart Cities programs	NA	Investment in railway, Roads and highways, Aviation industry, Modernization of ports and shipping, FDI, GST on logistics	NA	Urban	Public
India Transport Report: Moving India to 2032 (2014)	Improve urban transport, Emphasis on public transport	Raising safety standards, Discourage private vehicle	Investment in transport structure development	Emission controlling measures, NMT,	Urban	Public
Smart Cities Mission, 2015	Develop cities with essential infrastructure, using 'Smart' solutions, Affordable housing for all, Safety and security of women, children and the elderly	Transit Oriented Development (TOD), public transport and last-mile para-transport connectivity	Efficient urban mobility and public transport	Waste Management, Energy Efficient and Green Buildings, Focus on Renewable Sources of Energy	Urban	Public and Private
Green Urban Mobility Scheme, 2017	Sustainable urban mobility, Strategies for urban freight movement, TDM	Promote public transport	Safe pedestrian pathways, Cycling track, public bike sharing	Sustainable vehicle and fuels, Reduction in GHG emission	Urban	Public
National Policy on Transit-Oriented Development, 2017	Rapid transit stations promote public transport	Reduce private vehicles	New metro rail policy	Promote NMT	Urban	Public

Policies	Goals				Focus	
	Urbanisation	Motorisation	Infrastructure	Environment	Area	Type
Metro Rail Policy 2017	NA	NA	Aims to responsibly meet the growing metro rail demand in many cities	NA	Urban	Public
Motor Vehicles (Amendment) Bill, 2017)	Children, women, and senior citizen safety,	Reduce accident rates, hefty penalty to law violators, third-party insurance	Infrastructure development for smooth mobility	Environmental protection	Urban and Rural	Private
National E-Mobility Programme, 2018	NA	Aims to accelerate the adoption of electric vehicles (EVs) in the country	NA	Reducing fuel consumption and carbon emissions	Urban and Rural	Private
National Policy on Biofuels, 2018	NA	NA	Promote the use of biofuels in the country's energy and transport sectors over the coming decade	Mitigate climate change by rapidly replacing fossil fuels	Urban	Public and Private
Motor Vehicles Act (Amendment Bill, 2019)	NA	Registration and licensing of motor vehicles	Enhance road safety, regulate traffic, transform the transportation system, identify areas of development, improve connectivity	NA	Urban and Rural	Private

Table 2-1 Key Transport Policies in India. Source: Taken from (Ahmad & Chang, 2020) and modified and expanded by the Author in the context of this thesis.

Policy Insights

Rural infrastructure has seen significant improvements through policies such as PMGSY 2000, which aim to enhance connectivity and access in rural regions. This foundational infrastructure supports both public and private transport services in these areas. Safety and regulation have been emphasised through initiatives like the National Road Safety Policy, 2010, and the Motor Vehicles (Amendment) Bill, 2019, which focus on road safety and traffic regulation critical to urban and rural settings. Improved safety standards result in more reliable and safer public transport services in rural regions. Sustainability and emissions reduction are being addressed through policies promoting electric mobility and biofuels, such as the National E-Mobility Programme, 2018. These policies mark a shift towards sustainable transport solutions, benefiting public transport systems in urban area. Although many policies are urban-focused, their principles and goals offer valuable insights for enhancing rural public transport systems. There are several gaps in overall transportation policies that we observed through this analysis as explained in Table 2-2. By understanding and integrating these gaps, rural areas can achieve more efficient and sustainable public transport solutions.

Gaps in Policies		
Gap 1	**Integration of Urban and Rural Transport Policies**	There is a distinct separation between urban-focused and rural-focused policies, but limited emphasis on policies that integrate urban and rural transport systems.
Gap 2	**Comprehensive Public Transport Strategy for Rural Areas**	While urban public transport receives significant attention (e.g., Metro Railways Act, National Urban Transport Policy), there is less focus on developing a new robust public transport strategy for rural areas.
Gap 3	**Sustainable and Green Transport in Rural Areas**	Policies promoting sustainable and green transport (e.g., National E-Mobility Programme, Green Urban Mobility Scheme) are primarily urban-focused.
Gap 4	**Accessibility and Inclusivity in Transport Policies**	There is limited mention of policies specifically targeting the transport needs of vulnerable populations, such as people with disabilities, the elderly, and economically disadvantaged groups, particularly in rural areas.
Gap 5	**Technological Integration and Innovation**	Policies like Smart Cities Mission focus on technological integration in urban areas, but there is no emphasis on how such innovations can be extended to rural transport systems.
Gap 6	**Focus on Non-Motorized Transport (NMT) in Rural Areas**	While policies like the Green Urban Mobility Scheme promote NMT (e.g., cycling tracks, pedestrian pathways) in urban areas, there is less focus on promoting NMT in rural areas.

Table 2-2 Analysed Gaps in Policies. Source: Table created by the Author.

2.2. Public Transport in India

India, a nation pulsating with life, culture, and diversity, stands at the cusp of transformative urbanisation. As cities burgeon and populations soar, the demand for efficient and accessible public transportation has never been more pressing. Public transportation in India is at a crossroads, facing a confluence of urbanisation, demographic shifts, and technological advancements. As megacities expand and smaller towns burgeon, the strains on existing transportation systems become increasingly apparent.

The challenges are manifold. Overcrowded and underfunded public transport infrastructure, exacerbated by rapid urbanisation, has led to congested roads, prolonged commute times, and a resource strain. The socio-economic disparities across regions amplify the differences in transportation accessibility, leaving some population segments on the margins of the transit grid. Additionally, the environmental toll of burgeoning private vehicle usage threatens sustainable urban living. However, within these challenges lies a trove of opportunities. Innovations in technology, policy interventions, and community-driven solutions offer glimpses of a more resilient and responsive public transportation system.

The exploration within this thesis extends beyond the realm of transportation infrastructure. It delves into the social, economic, and environmental dimensions of public transportation, acknowledging that an effective system transcends the mere movement of people from one point to another. It is a catalyst for economic growth, a facilitator of social inclusion, and a steward of the environment.

Public transport in India is continuously evolving, with ongoing efforts to enhance connectivity, improve infrastructure, and promote sustainable modes of transportation. The combination of different modes of transport helps cater to the diverse needs of the population in this vast and populous country. Public transport in India encompasses a diverse range of services catering to the mobility needs of its vast population. The key modes include buses, railways, airways, waterways, local private informal transport, and modern app-based services like Ola and Uber. But for this study, the focus will be mostly on road-based public transportation.

Road Transport

Road transport has been a vital and affordable means of transportation for centuries, acting as the lifeline of a nation by enabling the movement of goods and people from one place to another. This mode of transportation is especially favoured for its convenience, offering door-to-door service. Despite the growing networks of air and rail travel, road transport remains a popular choice, largely due to its accessibility in challenging terrains such as hilly areas, cost-effectiveness compared to other modes, and suitability for short-distance travel. In countries like India, where the rural population outnumbers the urban, road transport is essential in meeting the transportation needs of people at an affordable rate. Historically, road transport has been a go-to mode of conveyance, and an efficient road network is crucial for economic development.

With India having the second-largest road network globally, roads facilitate the transportation of about 64.5% of all goods and handle 90% of the country's passenger traffic[1]. This extensive use underscores the critical nature of road transport in India's social and economic fabric. The impact of road transport on India's economy is significant. The transport sector contributed approximately 5.5% to the nation's GDP in 2007, with road transport being a major component. The extensive road network is not only vital for urban-rural connectivity but also supports economic growth by improving access to markets, services, and resources[2].

Buses serve as the backbone of public transport in India, connecting various parts of cities and towns. They are affordable and widely accessible, making them a popular choice for daily commuters. However, issues such as inadequate infrastructure, lack of last-mile connectivity and irregular schedules pose challenges to their efficiency.

Maharashtra State Road Transport Corporation (MSRTC)

The Maharashtra State Road Transport Corporation (MSRTC), a state transport undertaking in Maharashtra, India, stands out as one of the largest state road transport corporations[3]. The Maharashtra State Road Transport Corporation was founded by the State Government of Maharashtra by Section 3 of the RTC Act of 1950. It is renowned for providing economical and dependable passenger road transport services in the public sector. MSRTC caters to a wide array of needs by offering a variety of bus services, ranging from ordinary to luxury, for the travelling public. Its operations span across Maharashtra and extend to neighbouring states, offering both daytime and nighttime services to accommodate passenger needs. Additionally, MSRTC provides intercity and semi-urban services. Beyond regular routes, it offers daily tours to tourist destinations, package tours, and parcel services. The corporation also extends free or concessional travel facilities to students, freedom fighters, state government awardees, daily commuters, the physically handicapped, cancer patients, and others. By ensuring road connectivity to

[1] https://www.insightsonindia.com/indian-economy-3/infrastructure/roads-and-road-transport-system-in-india/
[2] https://www.worldbank.org/en/news/feature/2011/09/23/india-transportation
[3] https://swarajyamag.com/news-brief/explained-everything-about-the-msrtc-employees-strike-that-has-gone-for-over-60-days-now

all regions within the state, MSRTC has played a significant role in fostering balanced regional development. However, in recent years, it has faced challenges such as employee strikes and unstructured fare rates, which have impacted both its operational and financial performance[4].

A state transport entity is committed to fulfilling its social obligations, especially given India's diverse urban, semi-urban, and rural areas based on Section 3 of the RTC Act of 1950. A significant number of people from rural regions rely on state transport buses, commonly known as ST buses, for daily commutes to urban or semi-urban areas for their livelihoods.

A notable pattern observed is that these buses often begin their day with very few or no passengers when heading towards rural areas but return with full occupancy. Despite this variability in occupancy rates, MSRTC maintains its commitment to serve rural areas, operating buses irrespective of the number of passengers. The transportation system primarily consists of roadways, with buses run by MSRTC being a common mode of transport. Occupancy ratios, which measure the proportion of seats filled in a bus, fluctuate significantly throughout the day. MSRTC buses experience peak occupancy during morning hours (7 AM to 11 AM) and evening hours (5 PM to 8 PM). However, outside these peak times, occupancy can drop below 50%. Regardless of these lower occupancy levels, MSRTC adheres to its schedules, ensuring that buses run as planned, even if the revenue from a single trip doesn't cover its costs (Maldar, 2021).

MSRTC also faces the challenge of competition from Informal PT (private transport operators) in rural Maharashtra, which offer shared-taxi services mostly in the form of 12 to 15-seater Taxis and Jeeps. In rural areas, especially on weekends, the frequency of MSRTC buses is notably lower, and adherence to scheduled timings is not always strict. This inconsistency often forces people, especially those who depend on timely transportation for their daily work, to resort to private transportation options due to delays in bus arrivals. This situation highlights the need for MSRTC to address these operational challenges to better serve its passengers and fulfil its social mandate effectively. These private transport operators often have unregulated fare policies, resulting in higher fares that exploit passengers. Despite this, many people opt for private transport due to the perceived advantages of delays and long waiting times of MSRTC bus services.

[4] https://swarajyamag.com/news-brief/explained-everything-about-the-msrtc-employees-strike-that-has-gone-for-over-60-days-now

Figure 2-1 Usual Bus Terminus in India. Bus stations and Terminus hosts public and private buses and provide connectivity to urban and rural areas

Credits: Image taken by the author

Figure 2-2 Local Railway station, Surathkal, Karnataka.

Credits: Image taken by the author

Informal Public Transport

These include auto-rickshaws, cycle rickshaws, shared taxis and others mentioned below that operate in both urban and rural areas. While providing last-mile connectivity and flexibility, they often lack regulation leading to issues like overcharging and safety risks. Following are a few examples of informal public transport (Kumar et al., 2016).

- Minibus: A small bus with a seating capacity of 20 passengers
- Tata Magic: A four-wheeled, van-like vehicle with a designed seating capacity of 7 passengers
- Auto-rickshaw: A three-wheeled vehicle with a designed seating capacity of 3 passengers
- Vikram: A three-wheeled auto-rickshaw/tempo-like vehicle
- Mahindra Gio: A four-wheeled passenger cab with open sides and a seating capacity of 6 passengers
- Maruti Omni: A typical urban four-wheeled van
- Force Cruiser: A large four-wheeled vehicle with a designed seating capacity of 13 passengers
- Jeep: A four-wheeled vehicle, usually with open sides/rear; operates well in rugged topography
- Kaduka: A locally manufactured four-wheeled vehicle that runs on diesel generator sets (generally used for irrigation purposes), has a rear passenger trailer made of wooden planks, and carries up to 20–25 passengers per trip (according to drivers)
- Chakda: A three-wheeled vehicle comprising a motorcycle chassis retrofitted with a rear trailer; carries up to 20 passengers (according to drivers)
- Cycle rickshaw: A tricycle running on pedal power; generally, carries 2 passengers at a time

Rail Transport

Indian Railways is one of the largest rail networks globally, playing a crucial role in long-distance travel. Trains offer comfort, affordability, and connectivity across different regions. Despite this, congestion, safety concerns, and maintenance issues persist.

Figure 2-3 Photographs of typical informal public transport modes studied in the target cities/city regions

(Left to right, top to bottom: Minibus, Tata Magic, Auto-rickshaw, Vikram, Mahindra Gio, Maruti Omni, Jeep, Force Cruiser, Chakda, Kaduka).

Source: (Kumar et al., 2016)

2.3. Usage Patterns and Impact

People in India utilise these modes based on factors such as affordability, convenience, speed, safety, and comfort. In urban areas, buses are popular among daily commuters due to their extensive coverage and cost-effectiveness. Railways are preferred for inter-city travel owing to their speed and connectivity. Local private informal transport fills gaps in accessibility for short distances.

App-based services have gained traction in urban centres for their ease of booking and comfort. They cater to diverse needs ranging from solo rides to shared options like pool services. However, their adoption in rural areas is limited due to infrastructure constraints. The challenges faced by government-provided public transport due to resource constraints take centre stage, highlighting the indispensable role of privately operated informal transport systems. Local private informal transport such as shared auto-rickshaws, Vikrams (shared taxis), mini-buses, and Tata Magics (shared taxis) are vital contributors to mobility needs, especially in urban areas where formal public transport is limited (Kumar et al., 2016).

Acknowledging the limited presence of government-provided transport services in many cities, the literature underscores the population's dependence on various modes, including walking, cycling, non-motorised transport, personal vehicles, and informal public transport. While emphasising the positive aspects of informal systems—frequent, convenient, flexible, and affordable services—it also raises concerns about negative externalities such as traffic congestion, air and noise pollution, and traffic accidents. The neglect of the informal transport sector in policymaking and planning processes is attributed to a lack of understanding of its cost-benefit dynamics. The text categorises informal transport vehicles based on seating capacity, illustrating the diversity of the informal transport fleet. These informal systems play diverse roles, acting as the main public transport on significant road networks or reaching intra-city pockets inaccessible to formal systems. Despite the noted challenges and negative impacts, the literature concludes by advocating the recognition of informal public transport modes in urban planning. It emphasises the need to understand related policy and regulatory issues and formulate strategies to improve service performance, contributing to enhanced public transport services in Indian cities (Kumar et al., 2016).

Shifting gears to the rural landscape, literature related to road infrastructure in rural India offers a detailed overview of the pivotal role rural connectivity plays in the country's overall development. The positive correlation between rural connectivity, mainly through the development of rural roads, and various facets of socio-economic progress is firmly established. The evolution of road development plans in India, from the Nagpur Plan in 1943 to the Lucknow Plan in 1981-2001, underscores a continuous recognition of the importance of rural roads in fostering balanced and faster development in rural areas (Samanta, 2015).

A significant highlight is the Pradhan Mantri Gram Sadak Yojana (PMGSY), launched in 2000, aiming to provide all-weather roads to previously unconnected habitations. This initiative promotes accessibility and connectivity in rural areas, emphasising the importance of durable and permanent assets with provisions for drainage, protection works, and quality control during construction and maintenance. Integrating rural road development into broader rural development programs, such as Bharat Nirman, reflects a holistic approach to uplifting core infrastructure sectors in rural areas.

While the literature effectively communicates the positive impact of rural road development, it also sheds light on challenges, particularly in maintenance and funding. The maintenance of the extensive rural road network is identified as a critical issue affecting agricultural growth and access to social facilities. The limited attention and funding that rural roads often receive compared to other segments of the road network are highlighted, with the text arguing for public investment due to the perceived lack of profitability for private sector participation in rural road development (Samanta, 2015).

The literature comprehensively explains rural public transport and rural road development in India. It navigates the historical trajectory, policy interventions, and challenges associated with these aspects, emphasising their critical roles in socio-economic development. Whether in bustling urban centres or remote rural areas, sustained attention, investment, and policy reforms are paramount to bridging development disparities.

2.4. Urban versus Rural Public Transport

The narrative of public transportation in India unfolds diversely across its urban and rural landscapes. The juxtaposition of these two spheres reveals a stark contrast in challenges, infrastructural dynamics, and transit modes.

Urban Conundrums

In the sprawling urban landscapes of India, public transportation is often characterised by the intricate dance of buses, trains, metros, and emerging technologies. The challenges here are shaped by the sheer volume of commuters, rapid urbanisation, and the perpetual struggle to match supply with an insatiable demand. Traffic congestion, insufficient last-mile connectivity, and the environmental toll of vehicular emissions become emblematic of the urban public transportation puzzle.

However, urban areas also witness the emergence of innovative solutions. Though often grappling with implementation hurdles, Metro systems and rapid transit networks represent a stride toward efficient mass transit—technology-driven platforms offering real-time updates, mobile ticketing, and ride-sharing services present potential catalysts for change. Thus, the urban landscape becomes a canvas on which the juxtaposition of challenges and solutions paints a nuanced portrait of modern India's public transportation state.

Rural Realities

In contrast, rural India unveils a narrative shaped by vast expanses, limited resources, and unique challenges. Public transportation in rural areas grapples with issues of connectivity, accessibility, and affordability. Remote villages find themselves distanced from urban centres and the very arteries of transportation networks. Limited road infrastructure, sparse public transport services, the reliance on conventional modes such as motorcycles and bicycles, and unconventional modes like bullock carts and manual rickshaws underscore the rural transportation landscape.

While the challenges are pronounced, opportunities emerge through community-driven solutions and localised approaches. Shared transportation modes, such as community vans and locally managed transport services, become lifelines in areas where traditional public transport may be scarce. Furthermore, integrating rural transportation into broader national and state-level strategies becomes pivotal in fostering inclusive growth and bridging the urban-rural divide.

2.5. Challenges in Rural Public Transportation

Highly populated rural areas in India face myriad challenges in public transportation, creating a complex landscape that hinders the mobility and accessibility of residents. The following are key challenges that could be explored in a thesis focused on this topic:

Challenges	Description
Limited Infrastructure	• The lack of adequate transportation infrastructure is a significant challenge in many densely populated rural areas. • Poor road conditions, insufficient public transport facilities, and a dearth of connecting routes contribute to a restricted transportation network (Mohapatra et al., 2023).
Uneven Distribution of Services	• Public transportation services in high-populated rural areas are often unevenly distributed. Some regions may be well-connected, while others remain isolated due to limited-service coverage. • This imbalance exacerbates accessibility issues for residents in remote villages

Inadequate Frequency and Reliability	• Irregular and infrequent public transportation schedules are common challenges. • Residents face long waiting times, and unreliable service schedules can disrupt daily routines, making it difficult for individuals to plan their activities (Panda & Singh, 2022).
Dependency on Non-Motorised Modes	• In rural areas of India, people often rely on non-motorised modes of transportation, such as walking or cycling, due to low income and the lack of accessible public transportation options. • This dependency can result in long commute times and limit the ability of individuals to access essential services and opportunities (Puneeth & Nethravathi, 2021).
Affordability and Economic Constraints	• Financial constraints pose a significant barrier to accessing public transportation services. • High ticket prices relative to income levels and limited economic opportunities in rural areas make it challenging for residents to afford regular transportation (Puneeth & Nethravathi, 2021).
Lack of Integration with Other Services	• Poor integration between different modes of transportation and other essential services further compounds the challenges. • Limited coordination between buses, trains, and other transport modes makes planning seamless and efficient journeys difficult for residents.
Technological Divide	• The digital divide is another impediment, particularly in remote rural areas. • Limited access to technology and information about transportation schedules through digital platforms can hinder the adoption of innovative solutions that might improve public transportation efficiency (Based on the survey done by the author).
Environmental and Health Implications	• Inadequate public transportation options in rural India led to reliance on private vehicles. • The lack of sustainable and eco-friendly transportation alternatives can exacerbate environmental degradation and health issues (Peshin et al., 2024).

Table 2-3 Challenges in Rural Public Transport.

3. Demand-Responsive Transport

3.1. What is Demand-Responsive Transport (DRT) Systems?

Demand-responsive transport systems (also known as on-demand services) are public transport services that aim to provide flexible, efficient, and convenient transportation or delivery options tailored to individual needs. There are some mixed DRT services with fixed passages and additional ones on demand. Such vehicles usually pick up and drop off passengers at specific locations based on passenger needs and may include cabs, buses, or other vehicles (Ambrosino et al., 2004).

Demand-responsive transport (DRT) represents a significant shift in how public transportation can be managed and delivered, especially in regions where traditional fixed-route services are inadequate. DRT systems, often characterised by flexible routes and schedules, are designed to adapt to the specific demands of passengers. This flexibility makes DRT an attractive option for enhancing mobility in rural areas, low-density urban regions, and other underserved areas (Deka et al., 2023).

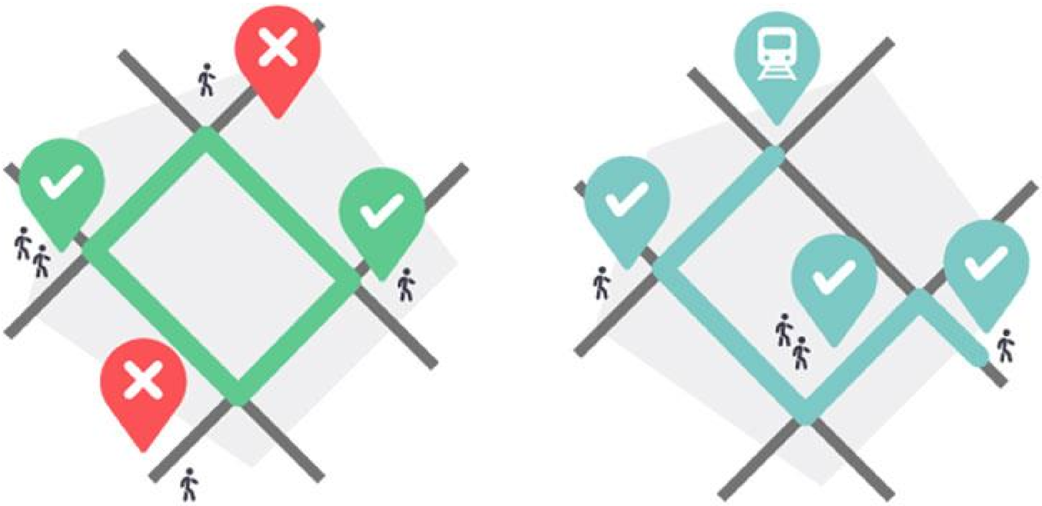


Figure 3-1 Image showing traditional Public Transport system (green) vs Demand-responsive Transport (light blue). The public transport system has fixed stops whereas DRT can flexibly adapt to the demand.

Sources: https://www.lek.com/insights/ei/five-key-steps-deliver-successful-demand-transport

However, despite its potential, the implementation of DRT systems is fraught with challenges. High operational costs, regulatory hurdles, and the need for sophisticated technology are significant barriers. Many promising DRT projects have failed, underscoring the importance of understanding both the benefits and limitations of these systems (Enoch et al., 2006).

Demand-responsive transport (DRT) systems are characterised by their flexibility in operation, allowing for routes and schedules to be adjusted based on real-time passenger demand. This concept starkly contrasts traditional public transport systems, which operate on fixed routes and schedules. DRT services typically utilise smaller vehicles, such as minibuses or vans, which can be more easily adapted to varying passenger numbers and route demands (Deka et al., 2023).

The resurgence of interest in DRT can be attributed to several technological advancements. The proliferation of smartphones and mobile applications has made it easier for passengers to book rides and for operators to manage and optimise routes. Real-time data from GPS and vehicle tracking systems enable dynamic route planning, improving service efficiency and responsiveness (Enoch et al., 2006).

Historically, DRT systems have been implemented in various forms. For instance, jitney services in Atlantic City in the early 20th century were an early example of DRT, providing flexible transport options based on passenger demand (O'Leary, 1982). More recently, the concept has evolved to include sophisticated systems that leverage digital platforms for booking and routing, as seen in modern ride-hailing services like Uber and Lyft (Erhardt et al., 2019).

DRT systems can:

- Complement traditional public transport services by facilitating access (first and last-mile connections).
- Replace unprofitable traditional public transport services in smaller cities or rural and mountain areas with low populations and high spatial dispersion.
- Serve new user segments that do not use public transport, offering greater flexibility and quality.
- Increase the overall efficiency of public transport systems.

DRT are public services that can be placed between Taxi services and traditional public transport:

- They are as flexible as taxis (which do not have fixed rides or timetables but adapt to demand), offered with increased capacity vehicles (generally a minimum of nine seats) and with the need to optimise trips to increase the number of passengers (higher load factor).
- Traditional public transport services aim to meet social rather than commercial and economic needs.

So, where a traditional public transport service is financially unsustainable because it is potentially affected by low and rarefied demand, DRT systems services can be a valid alternative, offering a service closer to the user's needs (personalisation, duration, travel comfort, etc.).

DRT systems are mainly characterised as services:

- Adaptable, depending on the area or type of users to be served.
- "User-oriented," as they adapt routes, schedules, and frequency to the demand needs.
- Accessible, using specific platforms that allow booking trips, optimise routes to increase load factor, offer cashless payment systems, and integrate the service with other mobility systems (MaaS) to synchronise on-demand mobility with traditional line systems.

The elements that can condition the development of DRT systems can be summarised as follows:

- Availability of innovative technologies (ITS, ICT, Internet, smartphones, etc.).
- Depopulation of rural areas and settlement sprawl in urban centres make complex trips Within the cities.
- The attitude of the population toward sharing mobility.
- It increased environmental and health awareness.

3.2. Benefits of Demand-Responsive Transport

Demand-responsive transport (DRT) offers several compelling benefits that make it a promising solution for modern urban and rural mobility challenges. These benefits include improved accessibility, reduced congestion, lower environmental impact, and enhanced user satisfaction.

Benefits	Description
Improved Accessibility	One of the primary benefits of DRT is its ability to provide transportation services in areas where traditional public transport is inefficient or non-existent. This includes rural areas, low-density suburbs, and regions with irregular travel patterns (Brake et al., 2004). By offering flexible routing and scheduling, DRT can bridge the gap between isolated communities and essential services, thereby enhancing social inclusion (Shu et al., 2021).
Reduced Congestion	DRT can help reduce traffic congestion by promoting shared rides and reducing the number of single-occupancy vehicles on the road. This is particularly relevant in urban areas where traffic congestion is a significant problem. Studies have shown that shared mobility services, including DRT, can lead to a substantial decrease in vehicle miles travelled (VMT) and overall traffic volume (Greenblatt & Shaheen, 2015).
Environmental Impact	Environmental sustainability is a critical consideration for modern transportation systems. DRT services, especially those utilising electric or hybrid vehicles, can

	significantly reduce greenhouse gas emissions compared to traditional private car use. By optimising routes and minimising empty vehicle trips, DRT systems can further enhance their environmental benefits (Djavadian & Chow, 2017). Moreover, the integration of autonomous vehicles into DRT fleets has the potential to enhance efficiency and reduce the environmental footprint of transportation services (Bösch et al., 2018).
User Satisfaction	DRT services are designed to offer a higher level of convenience and comfort compared to traditional public transport. By providing door-to-door service and reducing wait times, DRT can significantly improve the overall travel experience for users. This is particularly important in attracting new users who might otherwise rely on private vehicles (Kamargianni et al., 2016). High levels of user satisfaction are often reported in DRT systems, which is crucial for their long-term viability and success (Bürstlein et al., 2021).
Integration with Existing Transport Networks	DRT systems can complement existing public transportation networks by providing first-mile/last-mile connectivity. This integration helps to extend the reach of traditional public transport and makes it more accessible to a broader range of users. For instance, DRT can serve as a feeder service to major transit hubs, facilitating seamless multi-modal journeys (Balcombe et al., 2004).
Economic Benefits	While the initial investment in DRT systems can be significant, the long-term economic benefits are substantial. DRT services can reduce the need for costly infrastructure projects, such as building new roads or expanding existing public transport networks. Additionally, by improving accessibility and mobility, DRT can boost local economies and support community development (Gomes et al., 2015).

Table 3-1 Benefits of DRT

3.3. Challenges in Implementing DRT Services

Despite the numerous benefits, the implementation of Demand-Responsive Transport (DRT) systems faces several significant challenges. These challenges include high operational costs, complex service planning, and the need for advanced technology and infrastructure. Additionally, regulatory and institutional barriers, competition with traditional public transport services, and resistance from local authorities can complicate the successful deployment of DRT systems (Enoch et al., 2006).

High Operational Costs

One of the most significant challenges for DRT systems is the high operational cost. The need for a fleet of vehicles that can respond flexibly to passenger demands, along with the requirement for sophisticated scheduling and dispatching systems, drives up costs. Additionally, the cost of employing drivers and maintaining vehicles adds to the financial burden. Studies have shown that many DRT services struggle to achieve financial sustainability, relying heavily on subsidies to remain operational (Davison et al., 2014).

Complex Service Planning

DRT services require complex planning to optimise routes, schedules, and vehicle utilisation. Unlike fixed-route services, DRT systems must dynamically adjust to changing passenger demands, which necessitates sophisticated algorithms and real-time data processing. This complexity can lead to operational inefficiencies if not managed correctly. Effective service planning must account for various factors, including passenger demand patterns, traffic conditions, and vehicle availability (Marković et al., 2016).

Need for Advanced Technology and Infrastructure

The successful implementation of DRT systems depends on advanced technology and infrastructure. This includes real-time tracking systems, mobile applications for booking and payment, and sophisticated dispatching software. These technologies require significant investment and ongoing maintenance, which can be a barrier for many cities and regions. Moreover, ensuring reliable internet and GPS coverage is crucial for the effective operation of DRT services (Djavadian & Chow, 2017).

Regulatory and Institutional Barriers

Regulatory and institutional barriers can also hinder the implementation of DRT systems. In many regions, regulations designed for traditional public transport services do not adequately accommodate the flexible nature of DRT. This can lead to legal and bureaucratic hurdles that delay or prevent the deployment of DRT services. Additionally, institutional resistance from established public transport operators, who may view DRT as a threat to their market share, can create further challenges (Cervero, 2004).

Competition with Traditional Public Transport

DRT systems often face competition from traditional public transport services, such as buses and trains. While DRT can complement these services by providing first-mile/last-mile connectivity, there can be conflicts over funding, passenger demand, and service areas. For instance, in some cases, DRT services have been perceived as "cream skimming" by taking away high-revenue routes from traditional public transport operators, leading to tension and resistance (Cervero, 2004).

Managing Demand and Ensuring Reliability

Ensuring consistent demand and reliable service is another significant challenge for DRT systems. Variability in passenger demand can lead to periods of low ridership, making it difficult to maintain cost-effectiveness. Additionally, ensuring that vehicles are available and can meet demand promptly is crucial for maintaining user satisfaction. Strategies such as demand forecasting, dynamic pricing, and adaptive scheduling can help address these challenges but require sophisticated technological solutions (Djavadian & Chow, 2017).

Integration with Existing Transport Networks

Integrating DRT services with existing public transport networks is essential for their success but can be challenging. This integration requires coordination between different transport modes and operators, data sharing, and sometimes the restructuring of existing services. Effective integration can enhance the overall efficiency and attractiveness of the public transport system but requires significant planning and cooperation (Kamargianni et al., 2016).

3.4. Demand Responsive Transport (DRT) Models

For a clear view of possible organisational models for DRT systems, the ENEA document "Demand Responsive Transport Services: Towards the Flexible Mobility Agency" (Ambrosino et al., 2004) proposes a classification of services with increasing flexibility on routes and transit times. There are many DRT models developed but here are a few shown in Table 3-1 which can be used for this thesis.

Legend

- ■ Predefined stop, always served, with scheduling
- □ Predefined stop, with scheduling, served only on request
- ○ Predefined stop, without scheduling, served only on request
- ⌂ Virtual stop stop identified by an address or, for example, by the name of a place/building

	**Extension of a traditional service with a predefined route and schedule**	Stops and routes are known. Some extension stops can be served on demand. The feasibility of such a service is limited because the extension route may lead to severe delays on the non-demand route.

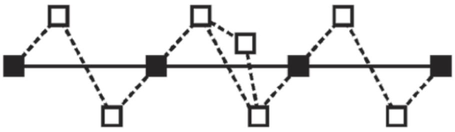
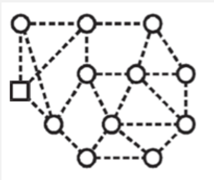
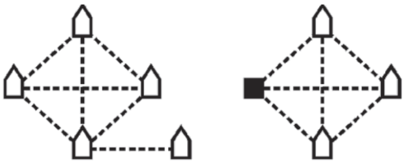
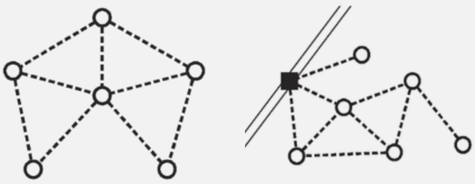
	**Detour of a scheduled service along predefined routes**	The detour leads to increased direct route times, so seeking the right balance between detour and default route is essential. Users must be informed about delay margins on fixed service stops.
	**Predefined stops in an area, but served only on demand**	Fixed or variable routes. The service structure is closely related to the stops to be served. Service feasible with the introduction of limitations on possible routes or in case of user flexibility on times and routes
	**Virtual stops in an area**	Represents the service with the most excellent flexibility, where stops and routes can vary freely within a given area
	**Stand-alone or integrate**	A DRT can be designed as: stand-alone service, with no spatial or temporal relationship with traditional public transport services integrated service with conventional public transport services, both road and rail

Table 3-2 Types of DRT models. Source: ENEA, Demand Responsive Transport Services: Towards the Flexible Mobility Agency

3.5. How can Demand-Responsive Transport (DRT) Systems be an innovative solution?

The exploration of flexible and demand-responsive transport systems as a promising solution for enhancing rural public transport is underscored by the works of (Brake & Nelson, 2007) and (Kirchhoff, 1995). Demand-Responsive Transport (DRT) system, positioned as an intermediate form between regular bus routes and personalised taxi services, adapts routes and timetables based on changing demand (Brake et al., 2004; Wang et al., 2015). (Laws, 2019) anticipates a broader adoption of DRT systems, particularly in urban areas, where they have the potential to serve as feeder systems for first and last-mile transport, potentially replacing individual motorised transport (Akdeniz University et al., 2016; Chandra et al., 2013). However, (König & Grippenkoven, 2020) highlight that DRT services, on average, experienced low utilisation rates in 2015, prompting the need to investigate the factors contributing to this phenomenon.

Recognising the significance of the user perspective, researchers like (Wang et al., 2015), Ryley et al. (2014), and Finn et al. (2004) advocate for studying psychological motivators and barriers to better understand the dynamics of DRT system adoption. Moreover, the introduction of DRT systems is likened to the introduction of new transport technology, suggesting the applicability of technology acceptance models, such as the Unified Theory of Acceptance and Use of Technology (UTAUT) by (Venkatesh et al., 2003), to comprehend DRT adoption factors. This model, encompassing constructs like Performance Expectancy, Effort Expectancy, Social Influence, and Facilitating Conditions, is proposed as a promising framework.

Additionally, the role of attitude is reintroduced to the UTAUT, with modifications suggested to include attitudes towards public transport and private cars, aiming to explore the underlying factors influencing DRT use (Emmert & Wiener, 2017). The literature underscores the significance of studying factors influencing DRT adoption, from system characteristics to individual attitudes. It proposes the UTAUT model with specific modifications as a comprehensive framework for examining this complex phenomenon.

(König & Grippenkoven, 2020) Conducted a survey study in the operational areas of two German Demand-Responsive Transport (DRT) systems, specifically the DRT Anruf-Auto Rodenberg and the DRT RufBus Nuthe-Urstromtal, to address the dearth of empirical research on psychological factors influencing the intention to use DRT systems. In terms of methodology, the study distributed questionnaires physically and online, targeting specific townships and obtaining a sample size of 2000 and 1000 for Rodenberg and Nuthe-Urstromtal, respectively. Data analysis employed Structural Equation Modeling (SEM), revealing that the model accounted for 47% of the variance in Behavioral Intention to use DRT, a significant improvement compared to prior studies utilising UTAUT in transportation contexts (König & Grippenkoven, 2020).

The study identified Performance Expectancy, Facilitating Conditions, and Attitude towards Cars as influential predictors. In contrast, Effort Expectancy, Social Influence, and Attitude towards Public Transport did not exhibit statistical significance. Notably, Performance Expectancy emerged as the strongest predictor of Behavioral Intention, emphasising the pivotal role of perceived usefulness in shaping the intention to use DRT services. The literature suggests practical implications, emphasising the need to prioritise perceived usefulness over ease of use in system design, operate an efficient DRT system aligned with user needs, and integrate it into the local public transport network. However, the unexpected insignificance of Effort Expectancy warrants further investigation (König & Grippenkoven, 2020).

The study (König & Grippenkoven, 2020) provides valuable insights into the psychological determinants of DRT usage, supported by SEM analysis. It offers practical recommendations for system enhancement, as evidenced by previous works such as (Emmert & Wiener, 2017). Lack of funding from the governments, traditional public transportation systems like MSRTC are encountering unprecedented challenges (Maldar, 2021). Due to crumbling public transportation, the demand for efficient, flexible transportation solutions becomes more critical. In response to these challenges, DRT Systems have emerged as a transformative and innovative solution poised to revolutionise urban mobility. DRT systems represent a departure from the conventional fixed-route, fixed-schedule public transportation model. Unlike traditional systems, DRT systems leverage advanced technologies and dynamic routing algorithms to tailor transportation services to passengers' needs and preferences (Gkavra et al., 2023). By harnessing the power of real-time data, mobile applications, and intelligent algorithms, DRT systems optimise routes, minimise waiting times, and maximise resource utilisation, offering a personalised and responsive alternative to traditional mass transit.

3.6. Successful DRT Schemes

While many DRT schemes have faced challenges, there are also successful examples that provide valuable insights into best practices for implementation, such as FlexDanmark, Kutsuplus and Bus on demand in Dubai, that are briefly presented below.

FlexDanmark in Denmark

FlexDanmark operates a national DRT service that integrates various forms of flexible transport, including services for the elderly and disabled. The system uses advanced scheduling and dispatching software to optimise routes and ensure efficient service delivery. FlexDanmark's success is attributed to strong government support, effective coordination between different transport providers, and the use of advanced technology to manage demand and improve service quality (Enoch et al., 2006).

Operationally, FlexDanmark is highly effective, facilitating approximately 2 million rides annually with a fleet of over 500 vehicles, including minibuses and accessible transport vans. The booking system, which supports online, app-based, and phone bookings, has seen significant uptake, with over 75% of bookings made through digital platforms. This system ensures real-time scheduling and efficient route planning, contributing to the service's reliability and user-friendliness.

Efficiency is a hallmark of FlexDanmark's DRT services. The average waiting time for a booked ride is around 15-20 minutes, with an impressive on-time performance rate of approximately 95%. Advanced route optimisation techniques further enhance efficiency by reducing the average distance travelled per ride by 10-15% compared to traditional fixed-route services. These optimisations not only improve service quality but also contribute to significant cost savings, estimated at up to 20% compared to traditional public transport

Kutsuplus in Helsinki, Finland

Kutsuplus was a pilot DRT service in Helsinki that offered on-demand minibus rides booked via a mobile app. The service operated with dynamic routing and pricing, allowing for efficient utilisation of vehicles and high levels of customer satisfaction. Although the pilot was eventually discontinued due to high costs, it demonstrated the potential for DRT services to complement traditional public transport and provide flexible, user-friendly transportation options (Enoch et al., 2006).

During its operation, Kutsuplus served the Helsinki metropolitan area, covering key urban and suburban regions and reaching a population of approximately 1 million residents. The service facilitated tens of thousands of rides annually with a fleet of around 15 minibuses. Most bookings were made through the mobile app and online platform, highlighting the convenience of digital access. The average waiting time for a booked ride was approximately 10-20 minutes, and the service maintained a high on-time performance rate. Although specific metrics varied, the dynamic routing system enabled efficient ridesharing, reducing the distance travelled per passenger.

Bus on Demand in Dubai, UAE

The Bus on Demand (DBOD) service in Dubai is a prime example of how DRT can provide significant benefits. Operating under a Public-Private Partnership (PPP) model, DBOD has demonstrated high utilisation rates and customer satisfaction. The service's success is attributed to its advanced booking and tracking technologies, which optimise routes and ensure efficient service delivery (Deka et al., 2023). The DBOD service has also contributed to reducing traffic congestion and enhancing the overall public transport network in Dubai.

Since February 2020, the service has shown high utilisation rates, particularly during peak hours, demonstrating the efficiency and potential of DRT services in urban settings (Deka et al., 2023). The DBOD service has successfully integrated advanced tracking and booking technologies, leading to high customer satisfaction and increased ridership (Bürstlein et al., 2021).

The DBOD service operates in selected areas of Dubai, providing flexible and efficient transportation options for residents and visitors. The service's success is attributed to several factors, including its advanced technology platform, efficient fleet management, and effective marketing strategies. The use of real-time data and GPS tracking allows for dynamic route adjustments, ensuring that vehicles are utilised efficiently and that passengers experience minimal wait times (Deka et al., 2023).

3.7. Failed DRT Schemes

Several DRT schemes have failed due to various factors. These failures provide valuable lessons for future implementations, highlighting the importance of careful planning, realistic cost assessments, and effective stakeholder engagement. Below are the four examples of the failed DRT schemes.

Dial-a-Bus Service in Milton Keynes, UK

The Dial-a-Bus service in Milton Keynes, UK, was one of the early attempts at implementing DRT. Launched in the 1970s, the service faced numerous challenges, including high operational costs, inflexible operations, and insufficient political support. Despite initial public acceptance and popularity, the service failed due to the lack of a sustainable financial model and operational inefficiencies. The service was eventually replaced by a fixed-route minibus service (Enoch et al., 2006).

Translink Service in Shellharbour, Australia

The Translink service in Shellharbour, Australia, operated on a fixed base route with deviations on request. The service aimed to test state-of-the-art technology, including automated traffic light activation and real-time information systems. However, technical difficulties and poor marketing led to disappointing patronage. The lack of support from the local bus operator further compounded these issues, leading to the service's discontinuation and reversion to a conventional line-haul service (Enoch et al., 2006).

Plus Bus in Truro, UK

The Plus Bus service in Truro, UK, was modelled after the successful Dutch Trein-Taxi concept. It aimed to provide shared taxi services linking a railway station with surrounding areas. However, the service struggled with low ridership, operational challenges, and opposition from local taxi operators. The failure to achieve financial sustainability and the inability to adapt the Dutch model to the local context led to the service's eventual discontinuation (Enoch et al., 2006).

Corlink Service in Plymouth, UK

The Corlink service in Plymouth, UK, aimed to attract commuters travelling into the city from rural areas. The service faced several issues, including software problems, communication difficulties, and a lack of coordination between different local authorities. Additionally, the target group of commuters did not use the system as expected, leading to low demand and financial unsustainability. The service was discontinued after the cessation of government financial support (Enoch et al., 2006).

3.8. Reasons for Failures of DRT Systems

DRT systems often fail due to a combination of unrealistic cost estimations, overly flexible services, and the inclusion of costly technological systems. Additionally, DRT requires significant marketing efforts and partnership skills, which are often lacking in traditional public transport operations. Lessons from failed DRT schemes highlight the need for careful planning, realistic market assessments, and incremental implementation approaches (Enoch et al., 2006).

DRT failure reason	Description
Unrealistic Cost Estimations	One of the primary reasons for the failure of many DRT systems is the underestimation of operational costs. Many projects are launched with optimistic cost projections that do not account for the full range of expenses, including vehicle maintenance, driver wages, fuel costs, and technological investments. As a result, these services quickly become financially unsustainable, requiring substantial subsidies to continue operations (Gomes et al., 2015). For example, the Plus Bus service in Truro, UK, failed to cover its operational costs, leading to its discontinuation (Enoch et al., 2006).
Overly Flexible Services	While flexibility is a key feature of DRT systems, too much flexibility can lead to operational inefficiencies. Services that offer highly customizable routes and schedules can struggle to group passengers efficiently, resulting in increased travel times and higher operational costs. The Dial-a-Bus service in Milton Keynes, UK, faced this issue, as its highly flexible service model led to long journey times and low vehicle utilisation (Enoch et al., 2006).
Costly Technological Systems	The implementation of advanced technological systems, such as real-time tracking and dynamic routing software, is essential for the efficient operation of DRT services. However, these systems can be expensive to develop and maintain. Projects that invest heavily in technology without a clear plan for cost recovery often face financial difficulties. The Translink service in Shellharbour, Australia, struggled with the high costs of implementing and maintaining its technological infrastructure (Enoch et al., 2006).
Lack of Marketing Efforts	Effective marketing is crucial for the success of DRT services. Many failed projects did not invest sufficiently in promoting their services to potential users, leading to low awareness and ridership. The Corlink service in Plymouth, UK, suffered from

	poor marketing efforts, which contributed to its low demand and eventual failure (Enoch et al., 2006).
Insufficient Partnership Skills	DRT services often require collaboration between various stakeholders, including government agencies, private operators, and technology providers. Successful partnerships are essential for ensuring efficient service delivery and financial sustainability. However, many DRT projects fail due to a lack of skills in managing these partnerships. The failure of the Dial-a-Bus service in Milton Keynes, UK, was partly due to insufficient political support and coordination between stakeholders (Enoch et al., 2006).

Table 3-3 DRT failure reasons

3.9. Key Insights

Demand-responsive transport (DRT) services possess the potential to transform public transportation by offering flexible, efficient, and sustainable mobility solutions. The success of DRT systems hinges on several critical factors, including effective planning, realistic cost assessments, advanced technology integration, and robust stakeholder partnerships. Despite the challenges and failures encountered by numerous DRT projects, the lessons derived from these experiences can steer future implementations toward greater success and sustainability (Enoch et al., 2006).

DRT services are particularly notable for their significant flexibility in routing and scheduling, which makes them ideally suited for areas with low or variable demand. However, this inherent flexibility must be judiciously balanced with operational efficiency to ensure financial sustainability. The integration of advanced technology, such as real-time tracking and dynamic routing, is paramount for the effective operation of DRT services. Investing in these technological advancements can substantially enhance service quality and user satisfaction. The establishment of public-private partnerships (PPPs) leverages the strengths of both sectors, thereby enhancing the viability and effectiveness of DRT services. Successful instances, such as the Bus on Demand service in Dubai, underscore the potential of this collaborative approach (Deka et al., 2023). Achieving environmental, economic, and social sustainability is crucial for the long-term success of DRT services. Strategies including the integration of electric vehicles, optimization of routes, and ensuring equitable access can significantly contribute to these sustainability goals (Bösch et al., 2018).

Moreover, analysing the reasons behind the failures of past DRT projects offers invaluable insights into potential pitfalls and areas for improvement. Key factors for success include incremental implementation, effective marketing, and the establishment of strong partnerships (Enoch et al., 2006).

The future of DRT services lies in the integration of emerging technologies and innovative service models. Autonomous vehicles, artificial intelligence, and machine learning can further enhance the efficiency and responsiveness of DRT systems. Additionally, the concept of Mobility as a Service (MaaS), which integrates various transportation modes into a single, seamless service, offers new opportunities for expanding the reach and impact of DRT (Djavadian & Chow, 2017).

4. The study area

The study area for this thesis has been selected based on several key considerations, including the author’s familiarity with the region. The research focuses on the Nagpur district's Katol and Narkhed sub-districts (Talukas) as shown in Figure 4-1. These areas represent many rural regions facing significant challenges due to the lack of efficient and comprehensive public transportation systems. The Narkhed sub-district, located on the periphery of the Nagpur district and adjacent to another district of Amaravati and the state of Madhya Pradesh, exemplifies the connectivity and development issues typical of rural areas. Its administrative isolation contributes to its underdevelopment and inadequate connectivity compared to other sub-districts in the Nagpur district, impacting economic, social, and developmental metrics.

The author's connection to the Narkhed sub-district, being a native, provides an in-depth understanding of the local geography, socio-economic dynamics, occupational patterns, climatic conditions, and transportation infrastructure. This firsthand knowledge is essential for comprehending the challenges and opportunities within the study area. Stakeholder analysis for the Demand-Responsive Transport (DRT) system implementation is a structured approach to identify and understand diverse individuals, groups, and organisations with a vested interest or influence over the initiative.

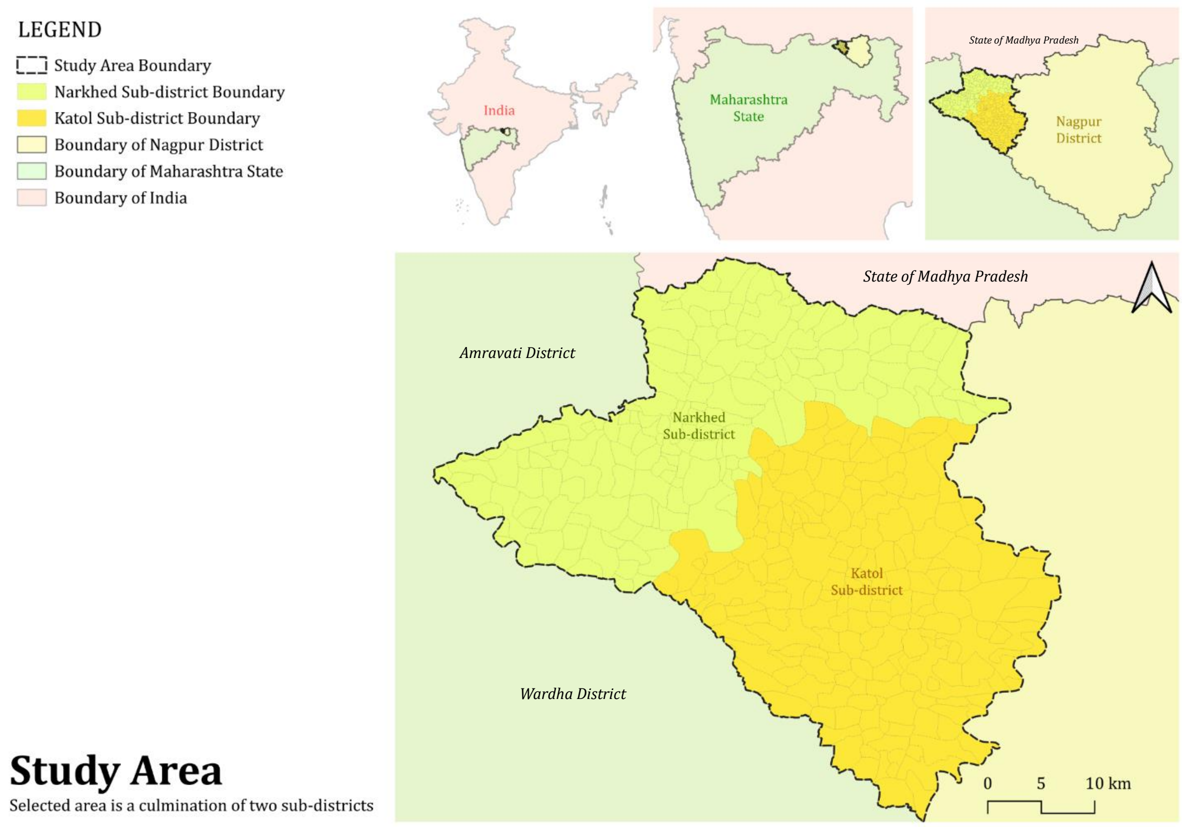


Figure 4-1 The study area. Map created by the Author.
(Map illustrated by Author. Source: Open Government Data (OGD) Platform India)

Katol-Narkhed Subdistricts

The Katol and Narkhed subdistricts, known locally as Talukas, are two distinct administrative regions. The proximity of major towns within these subdistricts, coupled with the frequent daily movement of people between them, led the author to select both subdistricts as the focus of the study. The selection of Katol and Narkhed sub-districts as focal points for this study is substantiated by a unique confluence of factors that make these areas particularly relevant for an investigation into rural transportation and development. This choice is not arbitrary; it is rooted in a blend of personal insights and strategic geographical positioning, coupled with the representational challenges these sub-districts present.

Firstly, the personal insights derived from preliminary observations and engagements with local stakeholders provide a deep understanding of the intrinsic socio-economic dynamics and cultural landscape, which are crucial for tailoring the study to reflect local realities. These insights ensure that the research approach and subsequent interventions are contextually relevant and culturally sensitive.

Secondly, the geographical positioning of Katol and Narkhed within the broader region plays a significant role. Their location provides a critical case study for examining the interactions between rural

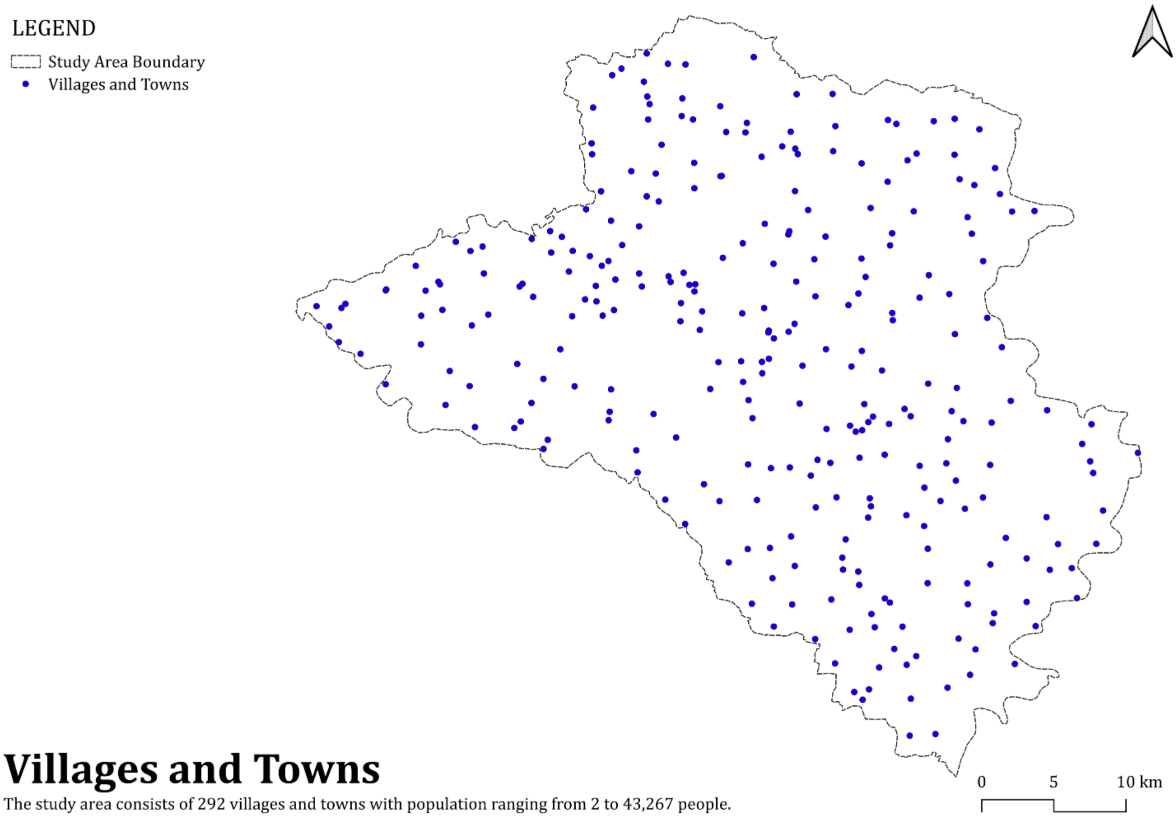


Figure 4-2 The dots represent Villages and Towns in the Katol-Narkhed subdistricts.
(Map illustrated by Author. Source: Boundary layer from Open Government Data (OGD) Platform India, Village and Town data from PMGSY)

communities and transport infrastructures, offering insights that are potentially generalisable to similar rural settings.

Lastly, these sub-districts represent a variety of challenges typical of rural areas in developing contexts, such as limited accessibility, inadequate public transportation systems, and the resultant socio-economic implications. By focusing on Katol and Narkhed, the study aims to delve into these issues, providing a comprehensive analysis of how geography and governance intersect with demography and economic conditions to influence rural transportation networks and development outcomes. This investigation thus contributes to a nuanced understanding of rural development processes, informing policy and planning in similar contexts.

Population and Demographics

Both Katol and Narkhed are rural with a significant portion of their population living in villages. The population is diverse, comprising various communities and cultures, with Marathi being the primary language spoken. The region is known for its mix of agricultural communities and small-scale agriculture-related industries.

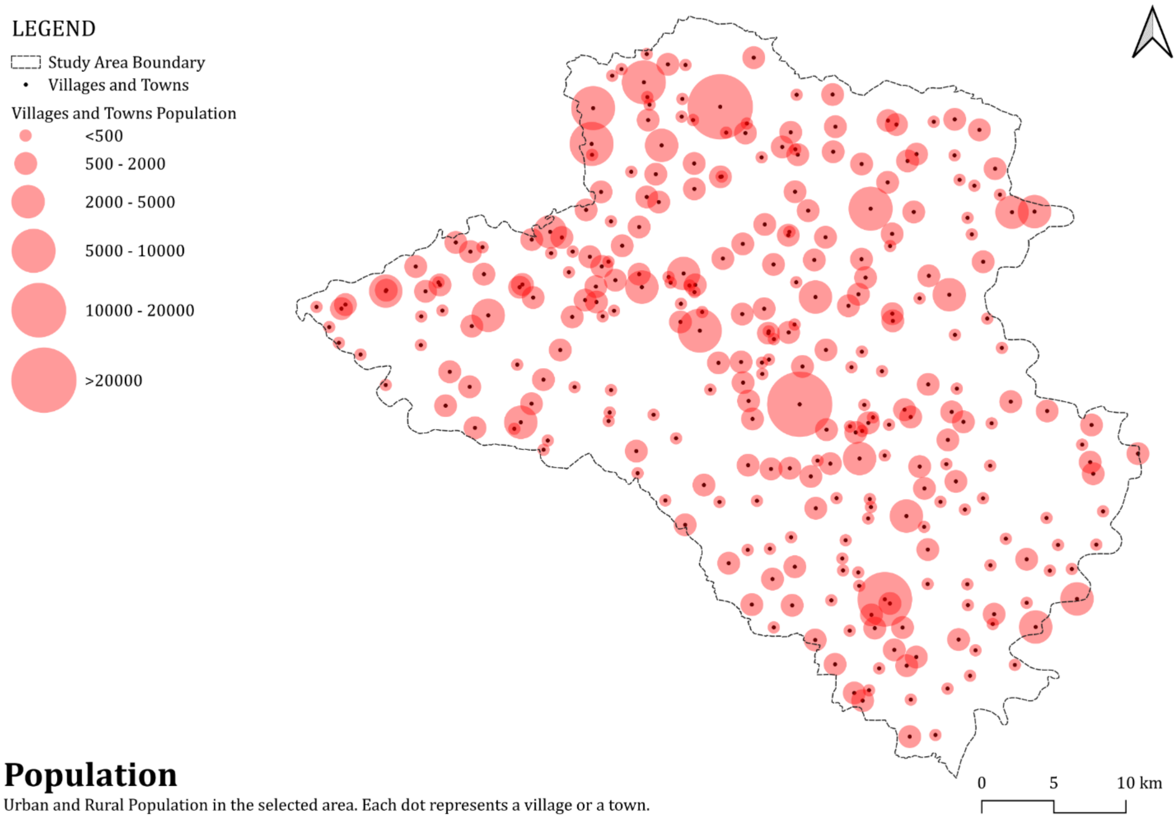


Figure 4-3 The red circles represent the population size of villages and towns in study area. (Map illustrated by Author. Data Source: Census India, 2011)

• **Population: 311,715** (Census India, 2011)
• **Area: 1607 sq. km**
• **Population Density: 194 people/sq.km**
• **Male Population: 159,910** (51.3%)
• **Female Population: 151,805** (48.7%)

Economic Activities

Agriculture is the backbone of the local economy, with farmers primarily engaged in the cultivation of crops like cotton, soybeans, and pulses. In addition to agriculture, small-scale industries and businesses are contributing to the economy. The region also has a few markets that cater to the local needs. Agriculture-related Industries such as Cotton mills, Agricultural Products, and storage facilities are in a large number. Another form of work is day labour in the farms and construction work, private shop owners and government jobs.

Social and Cultural Aspects

The region has a rich cultural heritage with various festivals, customs, and traditions. The local communities are known for their hospitality and predominantly follow lifestyles that are closely tied to agricultural cycles.

Infrastructure and Development

While there has been development in terms of infrastructure, there is still room for improvement, especially in the sectors of transportation, healthcare, and education.

5. Methodology

The thesis addresses two primary research questions: the accessibility of public transport in the Katol-Narkhed sub-districts and the potential for Demand-Responsive Transport (DRT) to enhance this accessibility. The methodology employs an empirical approach, including stakeholder analysis, surveys, and spatial analysis of the area. The stakeholder analysis seeks to understand the various users and actors who would benefit from and influence the implementation of DRT services. The survey aims to capture respondents' travel habits, preferences, and issues related to public transport, as well as interest in innovative DRT systems to improve current services. The spatial analysis maps bus frequency, facilities, and services that generate demand and identify gaps in the current public transport system. This methodology makes use of limited data to explore the potential of DRT in rural India and to map overall improvements in public transport accessibility.

5.1. Stakeholder Analysis

Stakeholder analysis is a critical component of project management and strategic decision-making. It enables organisations to identify and understand the interests, influences, and potential impacts of various stakeholders on a project. This understanding is essential for developing tailored communication strategies that effectively address the diverse needs, concerns, and expectations of different stakeholder groups, thereby enhancing engagement and support. Additionally, stakeholder analysis contributes to risk management by anticipating and mitigating risks associated with negative stakeholder reactions. It also assists in prioritising resource allocation, ensuring that resources are deployed where they can have the most significant impact on stakeholder buy-in.

The insights gained from stakeholder analysis are crucial for making informed strategic decisions, especially when considering the dynamics of potential alliances and conflicts among stakeholders. By engaging stakeholders early and continuously managing these relationships, organisations can secure long-term support and ensure the sustainability of their initiatives. This ongoing engagement is particularly important for the success and longevity of projects that require broad organisational involvement or community participation.

In the context of this thesis, a fundamental stakeholder analysis is conducted to identify and categorise the stakeholders involved in public transport and the potential implementation of a demand-responsive transport (DRT) system in the Katol-Narkhed subdistricts. This analysis provides an overview of all relevant stakeholders, with a focus on key players. It also highlights the strengths, weaknesses, opportunities, and threats (SWOT) these stakeholders might encounter, considering both internal and external influences on the implementation of the DRT system. Based on their interests and influence scores, a power-interest map is created to visualize stakeholder dynamics.

5.2. Survey

A survey was conducted among everyday transport users in the study area to gather insights into the community's transportation needs and perspectives on implementing a DRT system. A total of 106 individuals participated in the survey, which employed both in-person visits to villages and online data collection through the website SurveyMonkey. The survey methodology and objectives included assessing transportation needs, understanding and awareness of DRT, user preferences and expectations, and feedback on potential DRT solutions. Specifically, the survey aimed to collect detailed information about current transportation habits, challenges, and unmet needs to identify critical gaps in transportation infrastructure and services. It also measured the level of understanding and awareness of DRT among the population, gathered data on preferences for routes, timing, cost, and vehicle types, and collected opinions on various aspects of DRT solutions to tailor the system to meet local needs and expectations effectively.

Given the extensive size of the study area, encompassing 292 towns and villages, and the limitations of time and financial resources, a 10 km radius from the author's hometown was selected. Figure 5-1 shows the extent of the survey area on the map. This selected area includes several villages and towns identified as having no or low transport connectivity. The survey covered villages chosen based on discussions with residents, ensuring a focus on areas with significant transportation challenges. Due to low or no public transport connectivity, personal transport mode (TVS Jupiter motorbike) was used to access these villages and towns for the survey. From January 20th to January 27th, 2024, the survey was conducted using a questionnaire designed to gather detailed information about respondents' daily travel routines, frequency and mode of transportation, reasons for choosing specific modes, and openness to adopting new transportation solutions. The questionnaire comprised 33 questions, including multiple-choice, Likert scale, and open-ended formats to balance quantitative data with qualitative insights. The survey included questions in English and Marathi for easy understandability for the respondents in the study area. The full survey can be found in the Appendix section at the end of this thesis report.

The survey was administered using both field-based and online methods. The field survey, conducted in person, directly engaged with respondents from selected villages, leading to higher response rates and the opportunity to clarify questions immediately. This portion of the survey commenced on January 20th, 2024, and concluded on January 24th, 2024. Each day, the author started from his hometown, visited 2-3 villages, and surveyed approximately 20 individuals. Given the proximity

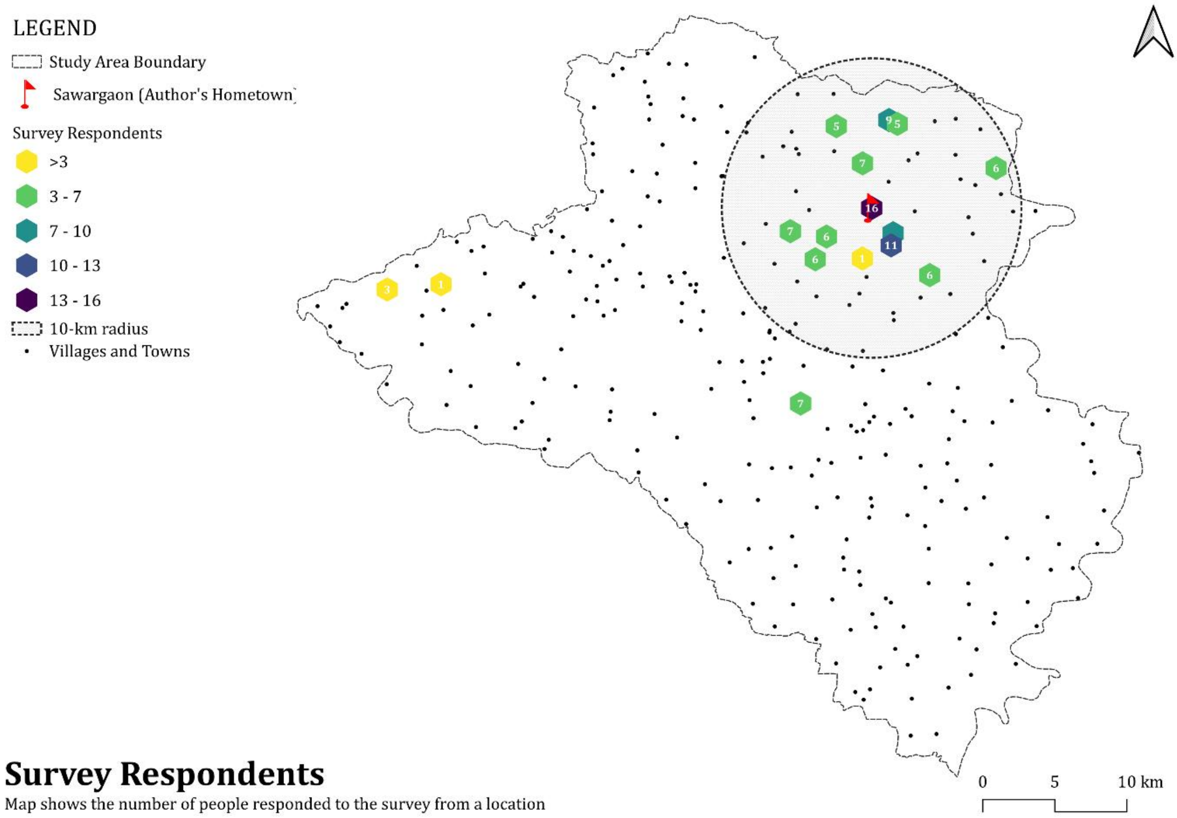


Figure 5-1 The extent of the Survey area. (Source: Author)

of these villages, the author returned to his hometown each evening and continued the process over five days. This approach yielded 78 responses, representing most of the sample. The online survey, facilitated through SurveyMonkey, was launched on January 20th, 2024, and remained live for a month. The final response was received on January 27th, 2024, marking the conclusion of the online survey. This method extended the survey's reach and obtained 28 responses, thereby enhancing the overall sample's diversity. The survey was distributed via the WhatsApp messaging app through friends and family to a broader audience within the Katol-Narkhed subdistricts. The online method attracted a higher concentration of working professionals who regularly use public transportation, contributing valuable insights to the study. The initial spatial analysis identified regions with inadequate public transportation links, guiding the focus of the survey. Survey responses were mapped to visualize the geographic distribution and identify potential patterns or anomalies. Responses were cleaned and coded for analysis. Quantitative data were analysed using Microsoft Excel to identify trends and correlations, while qualitative data from open-ended questions were thematically analysed to extract common themes and insights.

Surveyed Village/Town	Population *(2011 Census India)*	On-field Survey Respondents	Online Survey Respondents	Date of Survey	Public Transport Connectivity*
Agra	1,254	6	-	22/01/2024	Low
Ambada D	1,150	5	-	22/01/2024	No
Baradpawni	532	-	3	24/01/2024	Low
Bori	506	6	-	20/01/2024	No
Gollarkhapa	266	11	-	20/01/2024	No
Gondidigras	1,278	6	-	24/01/2024	Low
Katol	43,267	-	7	20-27/01/2024	High
Khamli	601	6	-	22/01/2024	No
Khedi	517	9	-	21/01/2024	Low
Mannath	753	5	-	21/01/2024	Low
Mhasora	1,732	7	-	21/01/2024	Low
Mukni	229	7	-	24/01/2024	No
Sakharkheda	730	-	1	21/01/2024	Low
Sawargaon	8,037	-	16	20-27/01/2024	High
Sonoli	1,572	-	1	22/01/2024	Low
Tapni	620	10	-	20/01/2024	No
TOTAL	**63,044**	**78**	**28**		

*Table 5-1 Details of the survey locations. *Based on daily usage and perception of locals. (Source: Survey done by the Author)*

Several limitations were identified in this survey study. The higher concentration of responses from the author's home subdistrict may introduce bias, as the survey area does not fully represent the entire Katol-Narkhed subdistrict area, potentially affecting the generalisability of the findings to other areas in the subdistricts. With only 106 responses, the sample size is relatively small. While sufficient for exploratory analysis, a larger sample would provide more robust insights and enhance the statistical power of the findings. Response bias could also be a factor, as the presence of the interviewer might have influenced on-field survey respondents, potentially leading to social desirability bias. Online responses might be biased towards individuals with internet access and a predisposition to participate in online surveys, excluding those less tech-savvy or without internet access. Additionally, the limited timeframe for conducting the survey restricted the ability to reach a more diverse and representative sample. Resource limitations impacted the breadth and depth of data collection, potentially omitting perspectives from other less accessible regions.

5.3. Spatial Analysis

Data Acquisition

This study utilised population data from the 2011 Census of India, projecting demographic trends to 2036 and disaggregated at the village level by gender downloaded as Microsoft Excel files. Geographic data for roads and other facilities were sourced in shapefiles formats via the PMGSY National GIS portal, which, while not frequently updated, was supplemented with detailed local surveys and contacts for enhanced spatial analysis. Additionally, MSRTC bus timetables from Katol, Kondhali and Sawargaon bus terminuses, prepared in 2016 but still relevant, were crucial for understanding regional transport dynamics. The time isochrones data was gathered in QGIS 3.30 via the ORS plugin and API from openrouteservice.org.

Spatial Mapping

Spatial analysis of the study area involves a detailed visual examination of available services and facilities, population distribution, the geographical positioning of villages, transportation network analysis, and time isochrones through open-source GIS software QGIS 3.30. Geographic Information System (GIS) technology is instrumental in mapping the locations of various services and facilities, providing a visual representation of their spatial distribution within the Katol and Narkhed sub-districts. This analysis is crucial for understanding the spatial dynamics and transportation needs of the local population with the existing infrastructure and understanding the accessibility and reach of essential services and facilities across these regions.

To understand overall accessibility, several terms and techniques are used in this thesis:

Density analysis evaluates the concentration of services, facilities, and populations within the study area. This method identifies regions with high or low service density, providing insights into areas that may require further infrastructure development to ensure equitable access to services. Kernel Density Estimation (KDE) is a statistical technique used to estimate the probability density function of a random variable. In this study, KDE visualizes the distribution and intensity of various services within the sub-districts, identifying areas with differing levels of service availability. This visualization helps in pinpointing regions with inadequate service provision. Spatial autocorrelation, measured by Moran's I, assesses the degree to which similar values, such as service availability, are clustered or dispersed in space. This measure identifies patterns of spatial clustering or dispersion of services, providing insights into regional inequalities and informing targeted interventions. Isochrones, lines on a map connecting points of equal travel time from a specific location, are used in time-isochrones analysis to understand service accessibility based on travel time. This analysis highlights underserved areas by showing regions that are farther from essential services, thus requiring improved transportation infrastructure. Network analysis involves examining the transportation network to understand the connectivity and accessibility of different areas. This analysis maps out the bus connectivity reach, and hourly and daily bus frequency, and identifies critical nodes and links in the transportation network, understanding the movement within the sub-districts. The classification of road network layers based on typologies, including National Highways, State Highways, Major District Roads, and Village Roads, provides a comprehensive overview of the distribution and maintenance of various road types. National Highways, which are regularly maintained, exhibit high traffic volumes and robust infrastructure, ensuring reliable transportation routes. Conversely, Village Roads often suffer from poor maintenance and consequently offer limited reliability. This disparity highlights significant inequalities in road infrastructure, impacting accessibility and mobility, particularly in rural areas.

5.4. Layered Data Approach

The layered data approach term used by the author in this thesis is synonymous with the weighted overlay approach in scientific terms. Various studies have used a weighted overlay approach from assessing flood risk (Alharbi, 2024) to finding potential catchment areas (Awanda et al., 2017) to assessing potential sites for solar power plants (Atak et al., 2019). In this thesis, the layered data approach integrates various spatial analysis results into a georeferenced grid, i.e. H3 spatial index to understand the distribution of services and transportation needs within the Katol and Narkhed sub-districts. H3 is a geospatial indexing system developed by Uber that divides the world into a grid of hexagons at multiple resolutions (Uber Technologies, Inc, 2019). It offers several advantages over traditional rectangular grid systems, including the hexagonal shape which provides a unique advantage in spatial indexing due to its closer approximation to a circular shape, allowing for more consistent

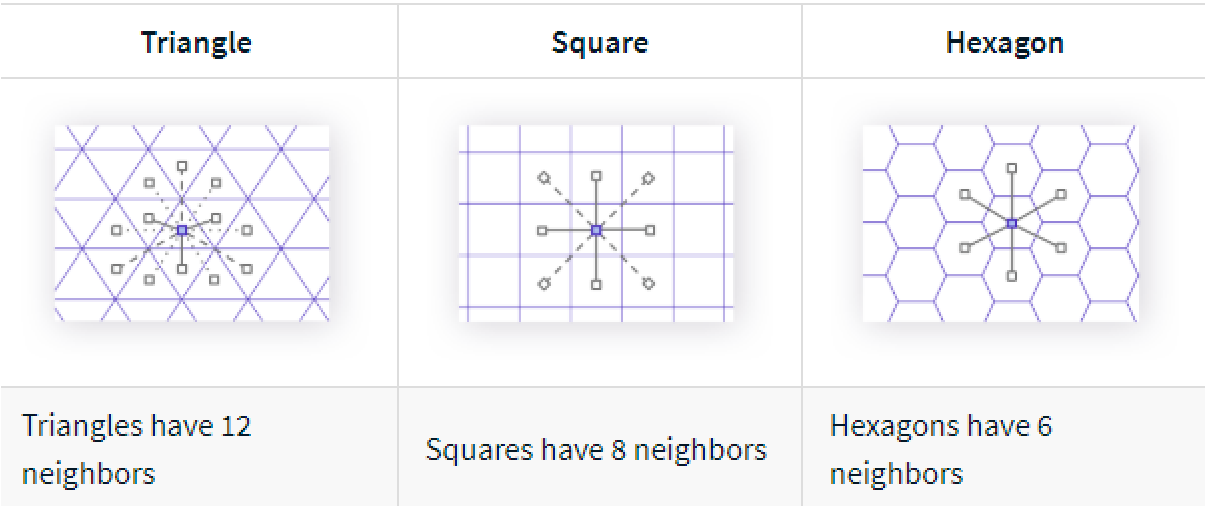


Figure 5-2 Distances from a triangle to its neighbours (left), a square to its neighbours (centre), and a hexagon to its neighbours (right). Source: Uber Technologies, Inc, 2019

distances between cell centres and better preservation of locality as shown in Figure 5-2. Additionally, H3 provides a hierarchical grid system with multiple resolutions, enabling seamless zooming in and out for various levels of detail. It also facilitates efficient spatial queries, such as finding nearby points, aggregating data within a specific area, and determining distances between points. The H3 spatial index has been used successfully in many studies and has shown its usefulness and benefits over other spatial indexes. One such study by (Aini et al., 2023) explores the potential of H3 spatial indexes in earthquake risk assessments and identifies that the H3 spatial index provides accurate and detailed risk assessment over normal indexes. The study also lists some limitations of H3 related to potential inconsistency and the need for computational resources and technical expertise. In the context of this thesis, the H3 spatial index is used to assess the overall public transport accessibility of Katol-Narkhed subdistricts.

The H3 spatial indexing begins by overlaying the study area with an H3 hexagonal grid at level 8 resolution. The resolution 8, as shown in Table 5-2, is chosen as the hexagon area is enough to accommodate each village. Each data layer, including service and facility density, population, public transport frequency, time isochrones, and road category, is assigned to the corresponding H3 hexagons. This creates a layered data structure where each hexagon contains aggregated information about its contents.

The process involves creating several layers for analysis. The Service Density Layer maps the distribution and availability of services and facilities. High service and facility density indicate areas with ample access to these services, crucial for residents' well-being. The Public Transport Frequency Layer

H3 Resolution	Average Hexagon Area (km^2)	Average Hexagon Edge Length (km)	Number of unique indexes
0	4,250,546.8477000	1,107.712591000	122
1	607,220.9782429	418.676005500	842
2	86,745.8540347	158.244655800	5,882
3	12,392.2648621	59.810857940	41,162
4	1,770.3235517	22.606379400	288,122
5	252.9033645	8.544408276	2,016,842
6	36.1290521	3.229482772	14,117,882
7	5.1612932	1.220629759	98,825,162
8	0.7373276	0.461354684	691,776,122
9	0.1053325	0.174375668	4,842,432,842
10	0.0150475	0.065907807	33,897,029,882
11	0.0021496	0.024910561	237,279,209,162
12	0.0003071	0.009415526	1,660,954,464,122
13	0.0000439	0.003559893	11,626,681,248,842
14	0.0000063	0.001348575	81,386,768,741,882
15	0.0000009	0.000509713	569,707,381,193,162

Table 5-2 Different H3 resolutions. Source: Uber Technologies, Inc, 2019

depicts the frequency and availability of public transportation options, highlighting regions with robust connectivity and those that are underserved. The Population Density Layer includes demographic data to understand the socioeconomic landscape of the area. Driving-Time Isochrones Layer represents areas accessible within specific travel times from services and facilities, specifically from 10 to 45 minutes. The Road Categories Layer includes national highways, state highways, major district roads, and village roads. Spatial aggregation is then performed within each hexagonal cell using spatial joins.

A scoring system is then developed to combine layers into a single score, providing a comprehensive view of service distribution and transportation needs called Accessibility Score as shown in Figure 5-4. Each hexagonal cell is assigned a score based on data aggregation, ranging from 0 to 1 to indicate low to high values. A weighted score is assigned to different layers, reflecting their relative importance, this relative importance is selected based on the survey. For this study, the total weights for all variables sum up to 1 to maintain proportionality.

Accessibility Score Formula

To combine service density, public transport frequency, population density, time-isochrones and Road Category Layers into a single hexagon cell, a scoring system is used. This formula integrates each of the following variables based on their relative importance to the overall analysis.

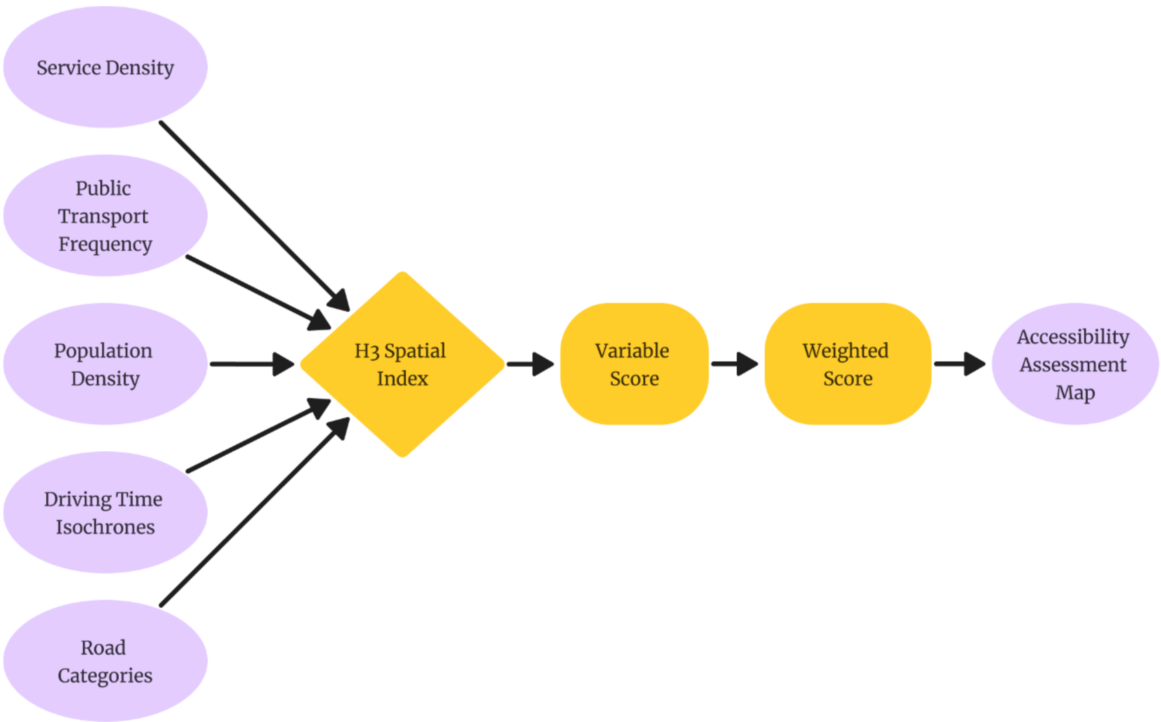


Figure 5-3 The layered Data Approach Model, Graphic created by the author based on the Weighted Overlay Model from ESRI. Original Source: [How Weighted Overlay Works—ArcGIS Pro | Documentation]

Variable Score – A Variable Score is a value between 0 and 1 that evaluates the performance of a specific feature or layer. For instance, a bus route with a high frequency would receive a score close to 1, indicating excellent performance, while a bus route with a low frequency would score near 0, reflecting poor performance. This scoring system helps in understanding and comparing the effectiveness of different features based on their performance levels.

Weighted Score – A Weighted Score is a value, also between 0 and 1, that reflects the relative importance of a feature or layer compared to other assessed features or layers. When evaluating multiple features, such as Transport Frequency, Population Density, and Road Category, each feature is assigned a weighted score that indicates its significance. For example, if Transport Frequency is deemed the most important, it might receive a weighted score of 0.4, while Population Density and Road Category might each receive a weighted score of 0.3. The sum of all weighted scores must equal 1, ensuring that the total importance is evenly distributed among the features. This system allows for a balanced consideration of various factors, emphasising their relative importance in the overall assessment.

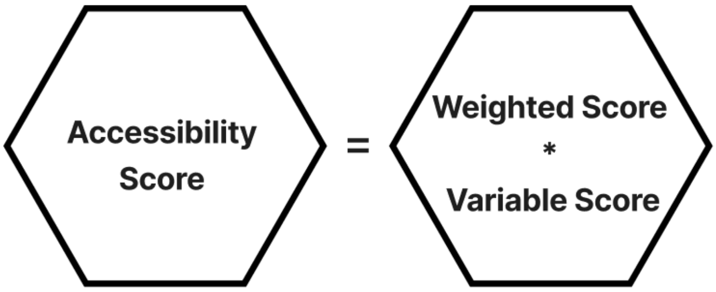


Figure 5-4 Accessibility Score formula

Table 5-3 Table of Variables and Weights

Variable Name	Variable Layer	Variable Score	Weighted Score
Service Density (SD_i)	Administrative	$SDAd_i$	ω_{SDAd}
	Public Transport	$SDPT_i$	ω_{SDPT}
	Educational	$SDEd_i$	ω_{SDEd}
	Healthcare	SDH_i	ω_{SDH}
	Agricultural	$SDAg_i$	ω_{SDAg}
	Other Essential	$SDEs_i$	ω_{SDEs}
Public Transport Frequency (PTF_i)	Railway	$PTRailF_i$	$\omega_{PTRailF}$
	Bus	$PTBusF_i$	ω_{PTBusF}
Population Density (P_i)	Population	P_i	ω_{P}
Time Isochrones (TI_i)	Time Isochrones	TI_i	ω_{TI}
Road Category (RC_i)	Road Category	RC_i	ω_{RC}

$\mathbf{SD}_i$	*Service density at Hexagon Cell i*
ω_{SD}	*Weight for service density*
$\mathbf{PTF}_i$	*Public transport frequency at Hexagon Cell i*
ω_{PTF}	*Weight for public transport frequency*
$\mathbf{D}_i$	*Demographic score at Hexagon Cell i*
ω_{D}	*Weight for demographics*
$\mathbf{TI}_i$	*Time score from time isochrones at Hexagon Cel li*
ω_{TI}	*Weight for time isochrones*
$\mathbf{RC}_i$	*Road Category at Hexagon Cell i*
ω_{RC}	*Weight for Road Category*

Accessibility Score at Hexagon Cell i

$$\text{Accessibility Score } (\mathbf{AS}i) = W_{SD} * \mathbf{SD}_i + W_{PTF} * \mathbf{PTF}_i + W_P \times \mathbf{P}_i + W_{TI} \times \mathbf{TI}_i + W_{RC} \times \mathbf{RC}_i$$

Where:

$\omega_{SD} + \omega_{PTF} + \omega_{D} + \omega_{TI} + \omega_{RC} = 1$ *(The weights should sum up to 1 to maintain proportionality.)*

By employing the H3 spatial index alongside spatial analysis techniques, this methodology offers a robust framework for understanding the spatial dynamics of services and transportation needs in the Katol and Narkhed sub-districts. The layered data approach ensures a detailed and nuanced analysis, facilitating informed decision-making to enhance accessibility and mobility for residents.

6. Analysis and Results

This section employs the developed methodology to conduct a comprehensive analysis of the Katol-Narkhed sub-districts, demonstrating the results of this comprehensive analysis. Through this detailed examination, the section showcases how the methodology can be applied to real-world scenarios, highlighting key findings and insights that underscore the potential benefits of implementing Demand-Responsive Transport (DRT) in rural areas. The analysis aims to provide a clear and empirical basis for understanding the effectiveness of DRT in enhancing the local public transport system.

6.1. Stakeholders

The stakeholder analysis is conducted to identify and categorise the stakeholders involved in public transport and the potential implementation of a demand-responsive transport (DRT) system in the Katol-Narkhed subdistricts. This analysis provides an overview of all relevant stakeholders and focuses on key players.

- Everyday Transport Users
  - Farmers
  - School Children
  - Healthcare Seekers and Provides
  - Office Workers
  - Labors
- Local Communities
- Transport Operators
  - MSRTC
  - Railways
  - Informal PT operators
- Business Communities
- Local Governments
- Academia
- Civil Society Organisations (NGOs, Environmental Groups)
- Regional & National Governments
- Tourists
- Government Agencies (Police, Vehicle Regulation Agencies)
- External Funding Agencies
- Political Bodies (Opposition Parties)

Transport Operators

MSRTC Bus service

The Maharashtra State Road Transport Corporation (MSRTC) can significantly contribute to modal integration at the rural level by enhancing connectivity and ensuring seamless travel for rural communities. By increasing bus service frequencies to remote areas, introducing dedicated feeder services to link these areas with major transportation hubs, and collaborating with local transport operators like Jeeps and Autos, MSRTC can create a more accessible and efficient network. Implementing a digital platform for real-time information on schedules and connections, alongside affordable pricing, and integrated ticketing systems, will further facilitate ease of travel. This approach not only improves the mobility of rural residents but also encourages the use of public transportation by offering a cohesive, user-friendly system that integrates various modes of transport efficiently.[5]

Railways

The Indian Railways can significantly enhance modal integration at the Katol-Narkhed level by acting as a key connector between rural areas and major urban centres, facilitating access to broader national and regional transportation networks. By extending rail services to reach more rural locations or improving connections at existing rural stations, the Indian Railways can ensure that rural populations have better access to efficient, reliable transportation. Collaborating with local transport services, such as MSRTC buses, autos, and jeeps, to coordinate schedules and create seamless transfer points can assist in bridging the last-mile gap for rural commuters. Moreover, the introduction of integrated ticketing systems that cover both rail and local transport services can simplify the travel process, making it more convenient and affordable for rural residents to travel across different modes of transportation. This integrated approach can significantly enhance mobility for rural communities, opening access to economic opportunities, education, healthcare, and more.

Informal PT Operators

To enhance the transportation network in Katol-Narkhed Taluka and ensure a seamless travel experience, it is crucial to not only focus on the primary modes of transportation such as buses and railways but also to effectively regulate and integrate Jeeps and Autos, which serve as vital feeder services. These privately owned shared transport options, already instrumental in bridging the gap between main transport hubs and final destinations, should adhere to a set of

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[5] https://www.freepressjournal.in/mumbai/best-undertaking-to-train-msrtc-drivers-and-conductors-on-various-mumbai-routes

regulations aimed at upholding both vehicle standards and passenger satisfaction. This includes regular maintenance checks to ensure safety and reliability, as well as adopting a customer service-oriented approach to improve the overall travel experience.

Furthermore, to optimise their role in the transportation ecosystem, Jeeps and Autos should be coordinated with the schedules of buses and trains. This synchronisation would ensure that these feeder services are available to meet increased demand during peak hours, effectively managing the flow of passengers and reducing wait times. By aligning their operations with the primary transport timetables, these shared transport services can better cater to the needs of commuters, providing a timely and efficient service that complements the broader public transportation network. This integrated approach not only enhances connectivity but also promotes a more efficient and user-friendly public transportation system.

Local Governments

Nagar Parishad (Municipal Council)

A Nagar Parishad, or city council, represents a critical urban political entity in India, analogous to a municipality. Defined as an urban local body, it governs populations ranging from 20,000 to 100,000 inhabitants. These bodies play a significant role in local self-governance, endowed with specific duties and responsibilities as delineated and prescribed by the Constitutional (74th Amendment) Act, 1992. Within the scope of the present study, Katol, Narkhed, and Mowad are identified as three Nagar Parishads within the designated study area, serving as focal points for examining the implementation and impact of urban governance models.

Municipal Corporation of Nagpur - As the urban local body responsible for Nagpur city, it oversees infrastructure development, planning, and maintenance. The corporation would be involved in coordinating urban sections of the transportation project, ensuring compliance with city planning norms, and facilitating necessary approvals.

Panchayat Samiti (Sub-district Council)

The Panchayat Samiti is the taluka level (sub-district level) of the rural local-self-government system in India. They form the middle level of the Panchayati Raj Institutions in India. It acts as a link between Gram Panchayats (Village Council) and Zila Parishad (District Council).

The panchayat samiti collects all the prospective plans prepared at the Gram Panchayat level and processes them for funding and implementation by evaluating them from the angles of financial constraints, social welfare, and area development. It also identifies and prioritises the issues that should be addressed at the block level.

The income of the panchayat samiti comes from:

- Land and water use taxes, professional taxes, liquor taxes and others.
- Income-generating programs
- Grants-in-aid and loans from the state government and the local zila parishad
- Voluntary contributions
- For many panchayat samiti, the main source of income is state aid. For others, the traditional taxing function provides the bulk of revenues. Tax revenues are often shared between the gram panchayats and the panchayat samiti.

Katol and Narkhed Panchayat Samiti - These are local municipal bodies for the towns of Katol and Narkhed, respectively. Like the Municipal Corporation of Nagpur but on a smaller scale, these bodies manage town-level infrastructure projects, local roads, and public services. They would play a significant role in the segments of the project within their towns, from planning to implementation, ensuring the project aligns with local development goals.

Gram Panchayat (Village Council)

Gram Panchayat (village council) is the only grassroots-level Panchayati Raj formalised local self-governance system in India at the village level. These are the local self-government organisations in rural areas. Each Gram Panchayat covers a cluster of villages. Their role in the project would involve liaising with the rural population, identifying local infrastructure needs, and ensuring that the transportation project serves the rural areas effectively. They are crucial for gathering grassroots-level input and facilitating project acceptance among rural communities.

SWOT of Stakeholders

Stakeholders	Strengths	Weaknesses	Opportunities	Concerns
Everyday Transport Users	• DRT beneficiaries • High Adoption	• Adoption resistance • Benefit unawareness	• Accessibility • Convenience • Cost savings.	• Reliable • Efficient DRT • Cost-effective
Transport Operators	• Local expertise • Established infrastructure • Can support DRT operations	• Financial risks • Resistance to change	• New business models • Expanded reach	• Investment costs, • Competitive Sector • Sustainability of DRT
Local Governments	• DRT regulation authority • Larger Integration capability	• Rural financial constraints • Expertise gaps in innovative transport	• Enhanced infrastructure • Increased Public satisfaction.	• Political acceptance • Long term funding

Local Communities	• Local insights • Community-driven success	• Diverse needs • Potential local resistance	• Community cohesion • Feedback-driven improvements	• Disruption risk • Equitable access
Business Community	• Transport demand for employees and goods • Investment opportunities	• DRT reliability dependency • Investment reluctance without proven success	• Enhanced access to inner locations • Economic strengthening	• ROI impact • Logistics integration
Civil Society Organizations	• Inclusive mobility advocacy • Community Feedback	• Limited influence on policy and decisions • Resource constraints	• Partnership-driven designs • Community engagement	• DRT social and environmental alignment • Inclusive representation of all
Academia	• Research Capabilities • Evidence-based innovation	• Research-practical gap • Possible local lack of focus due to broader research goals	• Industry collaborations • Specialized training	• Funding security • Research-community alignment
Regional & National Governments	• Scaling capacity • Regulatory support	• Bureaucratic delays • Misaligned rural strategies with national priorities	• Transform rural transport • Enhance mobility	• Balance development • Ensure sustainable support
External Funding Agencies	• Capital for pilots • Interest in innovative and sustainable projects	• Stringent requirements • Outcome-dependent funding	• Global model projects • Rural transport advancements	• Project risk • Fund management
Government-funded Agencies	• Specialized expertise • Resource Access	• Coordination challenges • Execution variability	• Set DRT benchmarks • Demonstrate innovation	• Managing regulatory compliance
Political Bodies	• Policy influence • Legislative fast-tracking	• Political agendas • Election cycle influence	• Leverage DRT as a Political win • Enhanced service delivery and voter satisfaction	• Backlash risk in case of DRT failure • Political risk management
Tourists	• Additional demand for DRT services	• Seasonal demand • Tourist prioritisation	• Tourism enhancement • Economic benefits	• Balanced local-tourist services

Table 6-1 The table shows the strengths, weaknesses, opportunities and concerns of stakeholders related to the Implementation of DRT. Source: Table prepared by the Author.

Power Interest Analysis

To create a power-interest analysis map for the stakeholders that could be involved in a Demand Responsive Transport (DRT) implementation in Katol-Narkhed subdistricts, we assigned weights to each stakeholder group based on the insights from SWOT analysis in Table 5-1. The weights are assigned on a scale from 1 to 10 for both interest and influence, where 1 is the lowest and 10 is the highest.

Monitor (Low Interest, Low Influence)	Keep Informed (High Interest, Low Influence)
• Tourists: Interest = 2, Influence = 2 • Business Communities: Interest = 3, Influence = 3	• Academia: Interest = 8, Influence = 3 • Local Communities: Interest = 9, Influence = 4 • Civil Society Organisations: Interest = 7, Influence = 4
Keep Satisfied (Low Interest, High Influence)	**Key Player (High Interest, High Influence)**
• Regional & National Governments: Interest = 4, Influence = 9 • Transport Operators: Interest = 3, Influence = 8 • Government Agencies (Police, Vehicle Regulators): Interest = 3, Influence = 7 • Political Bodies: Interest = 4, Influence = 8	• Local Governments: Interest = 8, Influence = 8 • Everyday Transport Users: Interest = 10, Influence = 7 • External Funding Agencies: Interest = 7, Influence = 9

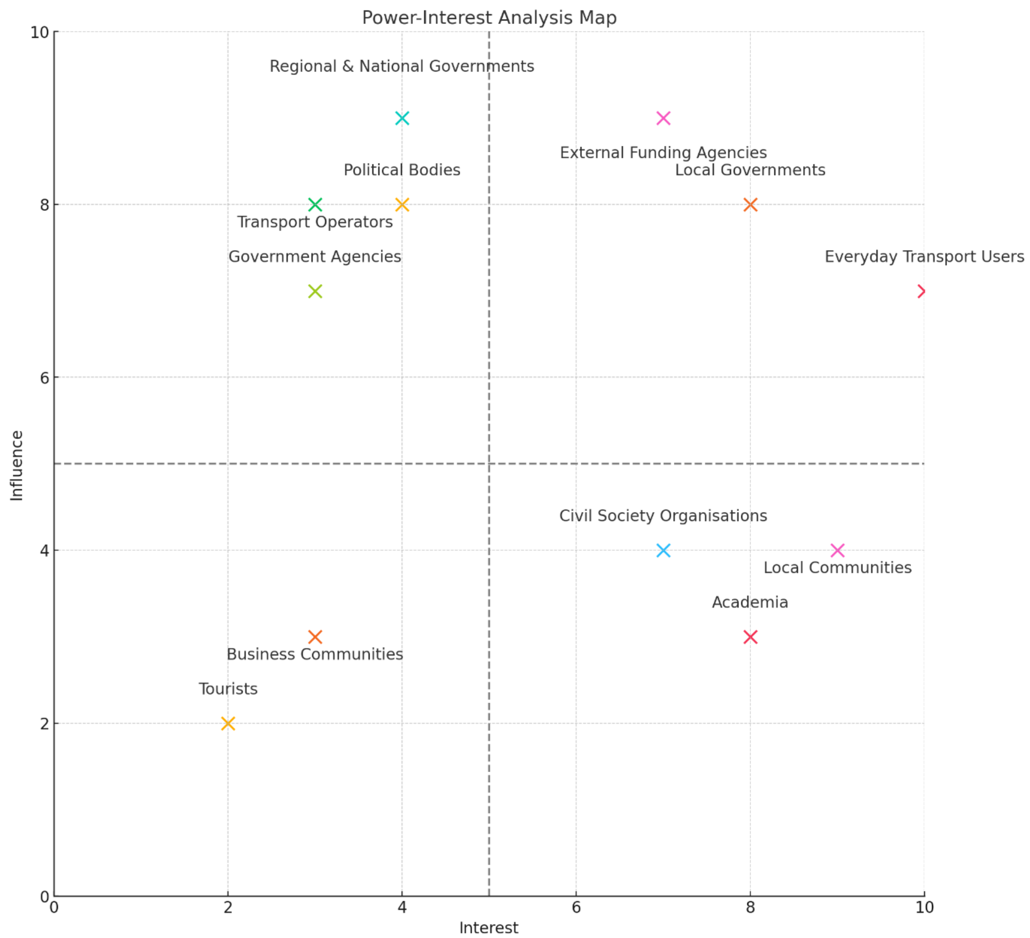


Figure 6-1 Power-Interest Analysis. Source: The graph created by the Author.

6.2. Survey Analysis

As detailed in the methodology section, the survey resulted in a total of 106 responses. The following sections provide a comprehensive analysis of the survey results, offering insights into the data collected and its implications for the study. Figure 6-2 presents the gender distribution of the population in the Katol-Narkhed subdistricts alongside the gender distribution of the survey respondents, highlighting a similar representation of genders in both the general population and the survey sample.

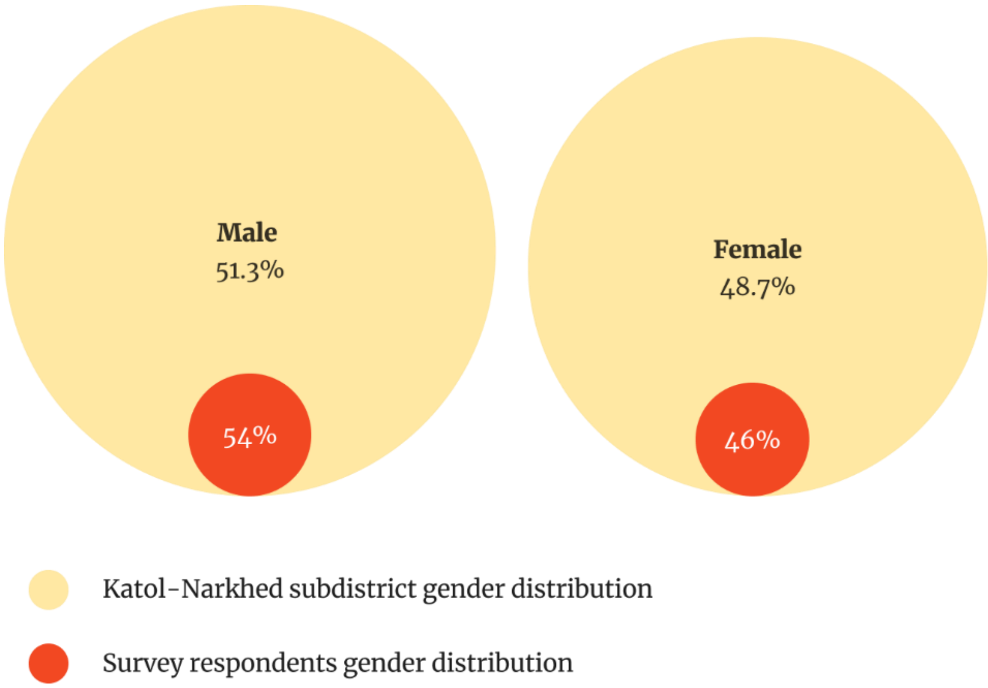


Figure 6-2 Gender Distribution across subdistrict and survey respondents.

Characteristics of Respondents

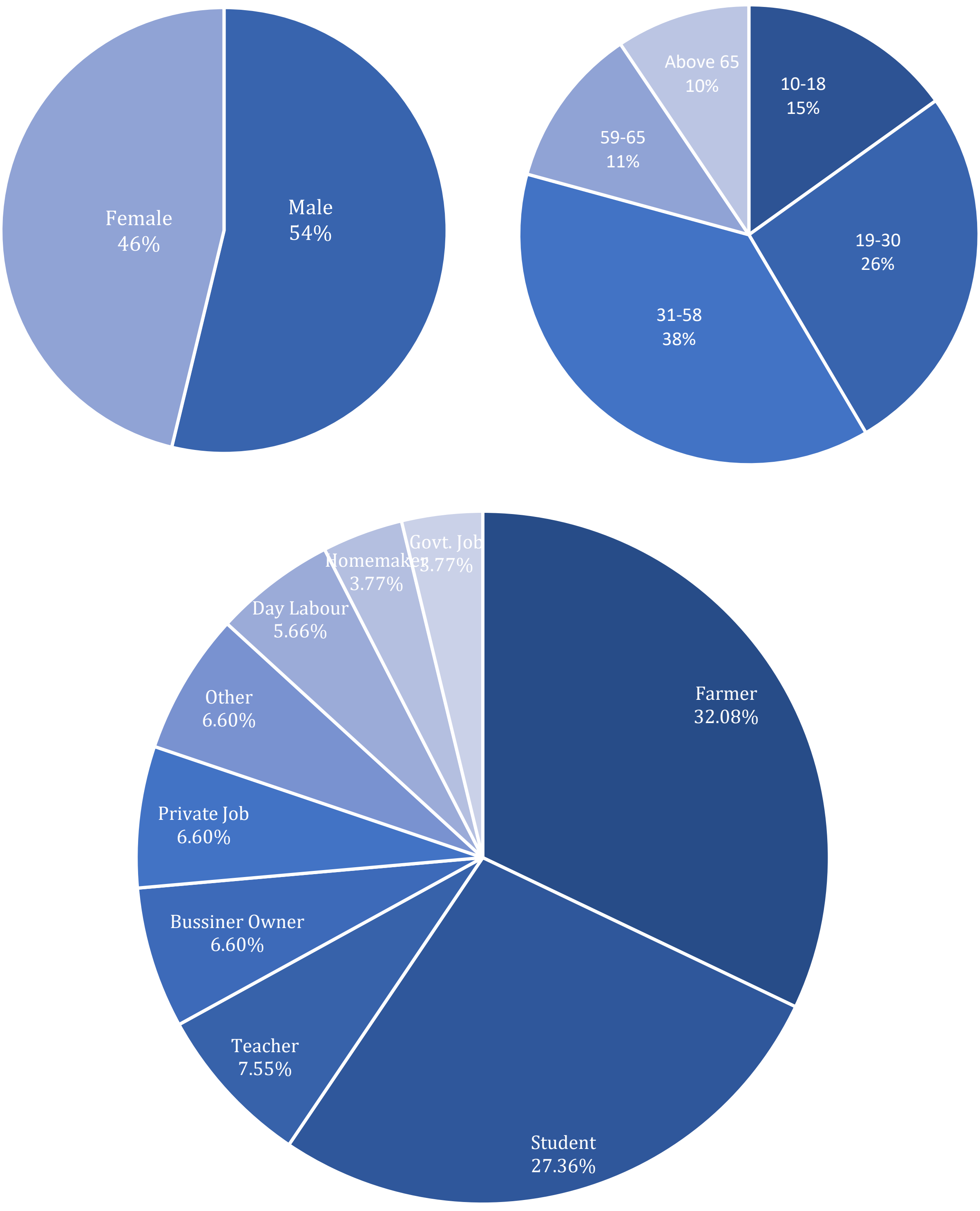
The pie charts under consideration meticulously detail the demographic characteristics—age, gender, and occupational distinctions—of participants in a survey concerning the adoption of the Demand-responsive Transport (DRT) system in a rural locale.

The top left Pie chart in Graph 6-1 delineates the age distribution of the respondents, presenting a significant insight into the age-based dynamics of interest in DRT systems. Notably, the preponderance of respondents falls within the 'school or youth' category with the 10-30 age group, constituting 41.51% of the total participant pool. This demographic, encompassing the youngest cohort, highlights a vigorous engagement from younger individuals which may correlate with their mobility needs or a heightened awareness and acceptance of new transportation modalities. Following closely, the 'middle age' group, representing individuals aged between 31 and 58, accounts for 37.74% of the survey participants, suggesting a solid representation of this economically active segment of society. Conversely, the 'senior or retired' group forms 20.55% of the total, indicating lesser but still significant engagement among older adults, who may have distinct transportation needs or limitations.

The Pie chart at the top right in Graph 6-1 elucidates the gender distribution among the respondents, revealing a slight male predominance with males representing 54% of the survey participants, slightly higher than the region's male population percentage of 51% as reported by the Government of India. Females accounted for 46%, slightly below the actual female demographic representation of 49% in the same region. This discrepancy suggests varying levels of accessibility or interest in the DRT system by gender, which could influence targeted outreach strategies.

The bottom Pie chart in Graph 6-1 categorises respondents by occupation, offering a granular view of the economic backgrounds of the participants. Farmers are the most represented occupational group, comprising 32.08% of the respondents, underscoring the rural characteristic of the survey demographic and pointing towards specific needs related to agricultural activities. Students make up the second largest group with 27.36%, reinforcing the trend seen in the age distribution graph regarding active participation by younger people. The smallest represented groups are homemakers[6] and government employees, each accounting for merely 3.77% of the total, highlighting less participation from these sectors. Other occupations, such as teachers, business owners, day labourers, and private sector employees, each represent less than 10% of the total, indicating a broad but uneven occupational spread among respondents.

[6] Homemaking - Wikipedia. Homemaker is person who looks after the home, also known as a housewife or a househusband.



Graph 6-1 (Top left) The graph shows the percentage of respondents. Females are 48.7% and Males are represented 51.3%. (Top right) The graph represents the age distribution of the respondents. (Bottom) The graph shows the occupations of the respondents. N=106. (Source: Graphs created by the Author)

Travel Habits

This survey analysis provides insights into travel habits, predominantly focusing on journey specifics, modes of transport, and issues faced with existing transport services. A detailed examination of the dataset reveals several key trends and patterns, which are critical for understanding the current state of transportation and identifying areas for improvement.

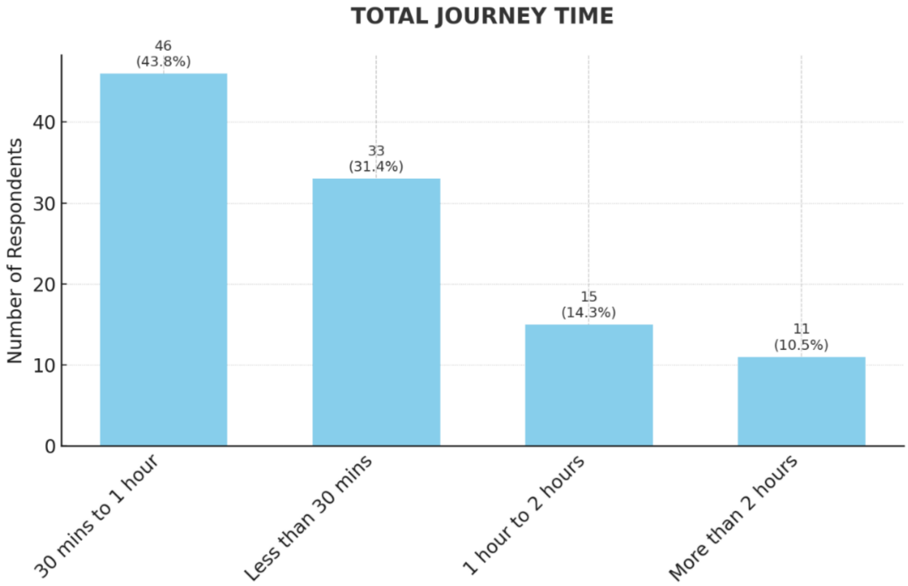
Journey Characteristics: The time taken for most journeys ranges from less than 30 minutes to an hour, with a significant number of respondents indicating the use of bicycles and buses. This suggests a reliance on personal and public transportation for relatively short commutes, which is typical for students travelling to educational institutions. However, the need for multiple transport connections is minimal, indicating direct routes or efficient transport links for the majority.

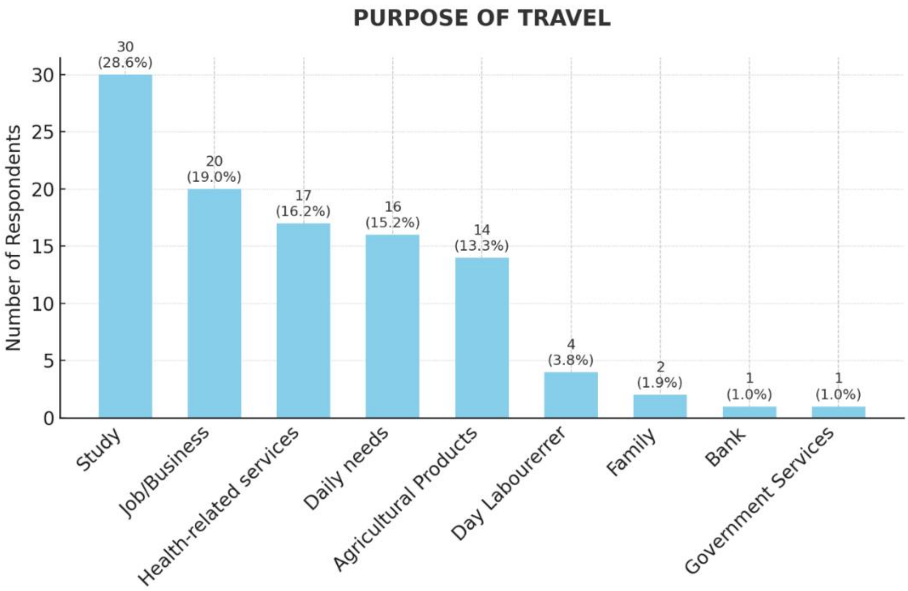
Challenges in Existing Transport Services: A prominent issue highlighted by respondents is the low frequency of buses and the unavailability of seats. These challenges point to overcrowding and inadequate scheduling, which can significantly impact the reliability and comfort of public transport. Moreover, some respondents reported the absence of bus services, suggesting gaps in the transportation network that need to be addressed.

Night Travel Patterns: Night travel appears less common; with many respondents indicating they do not travel at night. However, for those who do, health-related reasons are a primary motivator. Despite this, there is a strong interest in a night bus service, with a majority expressing willingness to use such a service if it were available. This highlights a latent demand for extended public transport services to cater to essential travel needs outside regular hours.

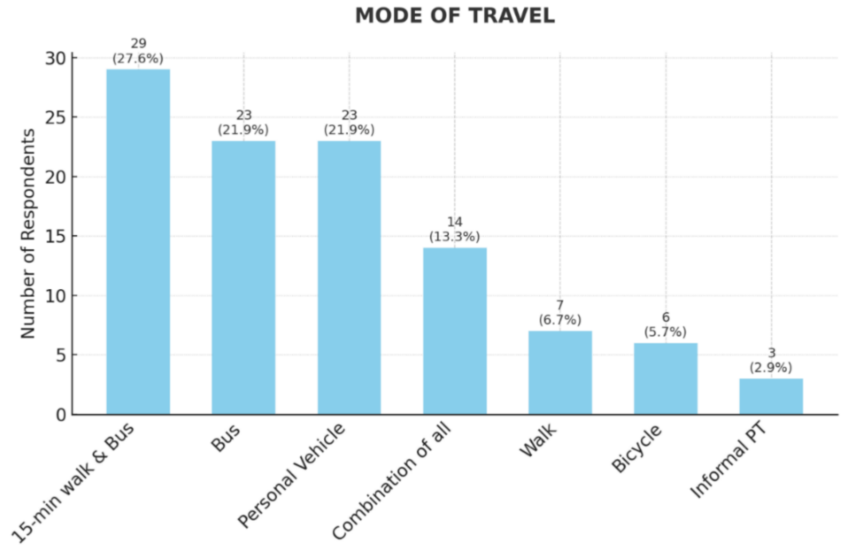
Walking and Waiting Times: A considerable number of respondents experience walking times over 15 minutes and waiting times exceeding 20 minutes, reflecting inefficiencies in last-mile connectivity and service punctuality. This further underscores the necessity for more frequent services and better coordination in transport scheduling to reduce waiting periods and enhance overall accessibility.

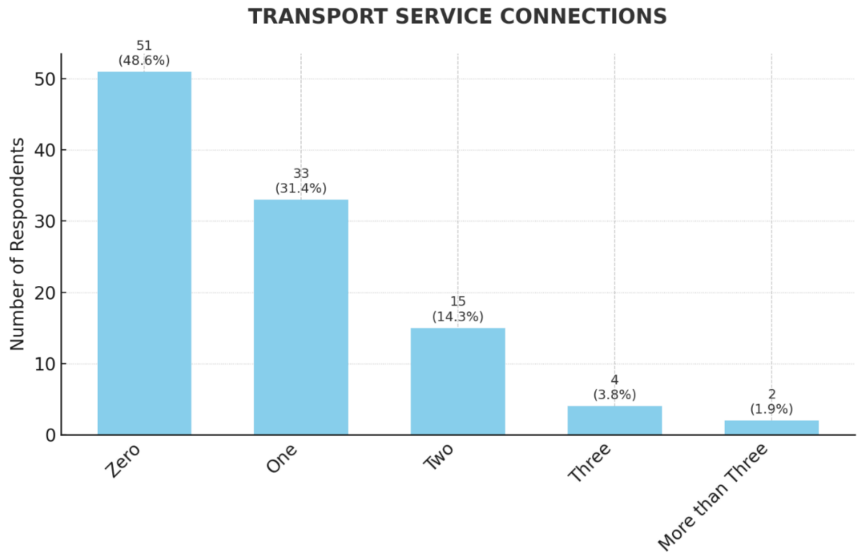
In conclusion, the survey data underscores critical areas needing improvement in the transportation infrastructure. The predominant reliance on bicycles and public buses for short journeys, coupled with significant issues of bus frequency and seat availability, calls for strategic interventions to enhance public transport reliability and comfort. The expressed interest in night bus services indicates a potential area for service expansion, particularly for essential travel. Addressing these challenges through targeted policies and improvements could significantly enhance the travel experience, particularly for the student demographic that forms the core user base in this survey.

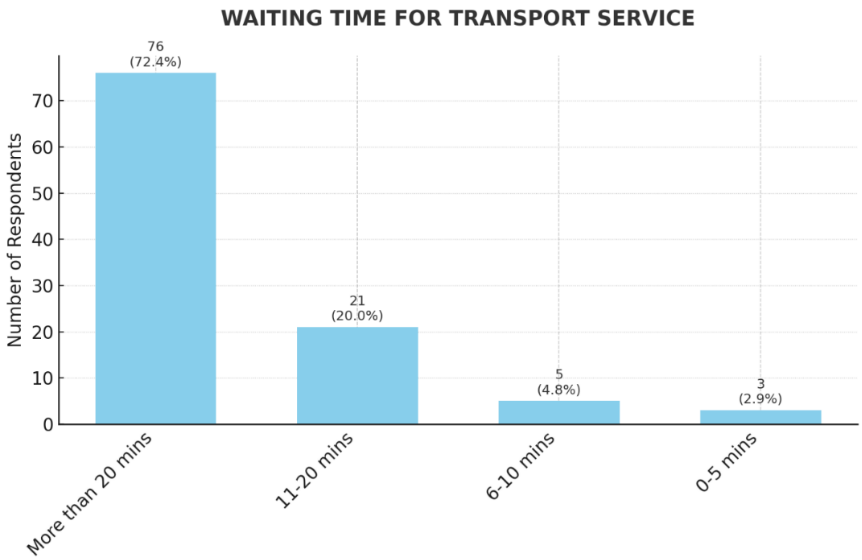




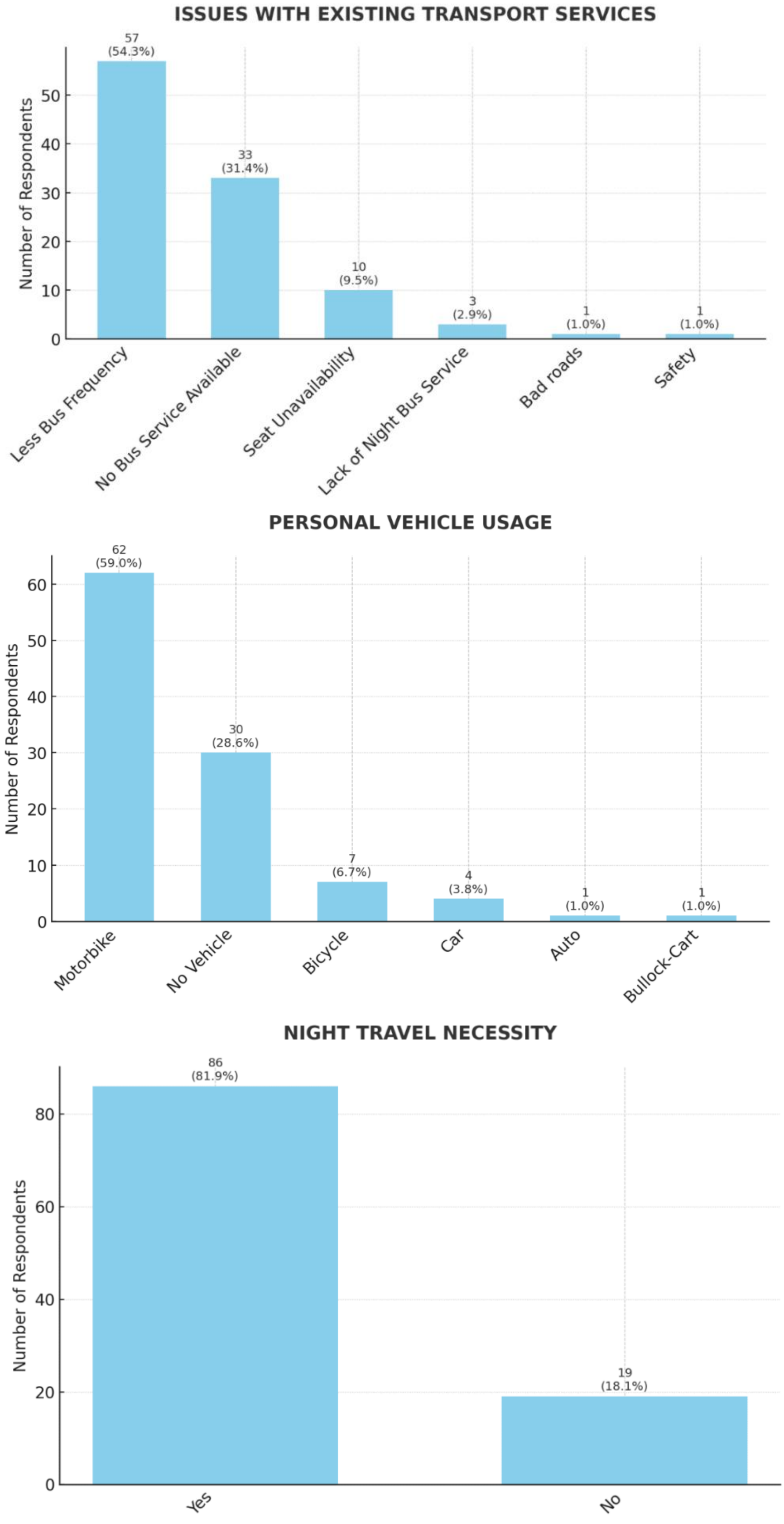
Graph 6-2 (Top) The graph shows the Journey time for the survey respondents. (Bottom) The graph describes the purpose the respondents make the Journey. ***N=106****. (Source: Graphs created by the Author)*



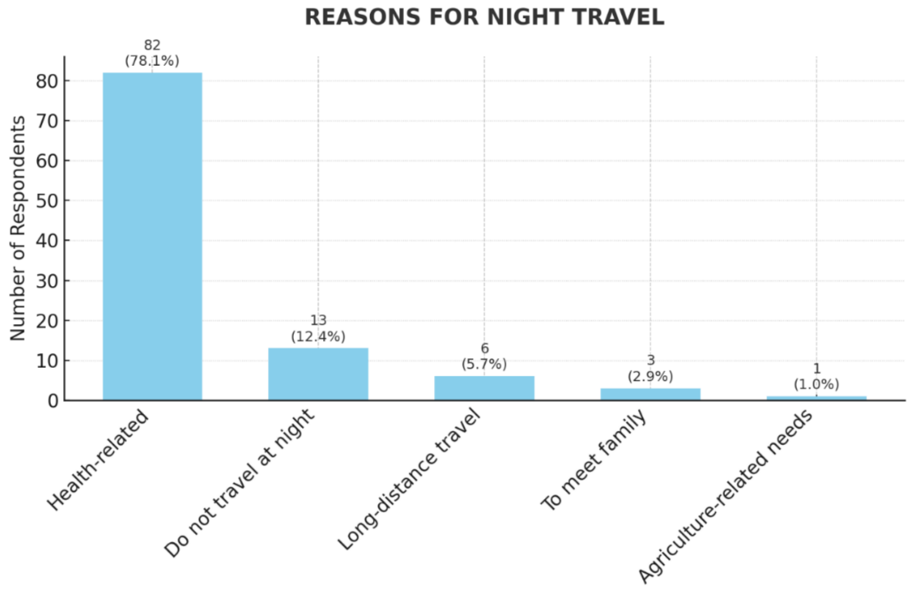




*Graph 6-3 (Top) The graph shows the mode of travel. (Middle) The graph suggests the number of connections respondents have to take to reach the destination. (Bottom) The graph shows the waiting time for public transport to arrive. **N=106**. (Source: Graphs created by the Author)*



Graph 6-4 (Top) The graph shows the issues respondents face. (Middle) The graph shows the type of personal vehicle respondents use. (Bottom) The graph shows the necessity of night trips. ***N=106****. (Source: Graphs created by the Author)*



Graph 6-5 The graph provides various reasons for respondent's night trips. ***N=106***. *Source: Graph created by the Author*

Perception of Demand-responsive Transport

Many people from the local community where the survey was conducted are unaware of DRT systems. The survey also asked them if they knew about app-based taxi services (such as Ola, and Uber) that operate in nearby cities. Only about 25 per cent of the respondents said they knew about them, and among those, only half understood how they functioned. This suggests that there is a need to raise awareness and educate the public about the availability and advantages of DRT systems, as well as to address the barriers and concerns that prevent them from using these options. Despite the rapid growth of technology and the low cost of mobile internet in India[7], many people still do not use a smartphone, especially young students, and older adults, due to economic or personal reasons. The survey reveals that 61 percent of the respondents own a smartphone whereas the remaining do not.

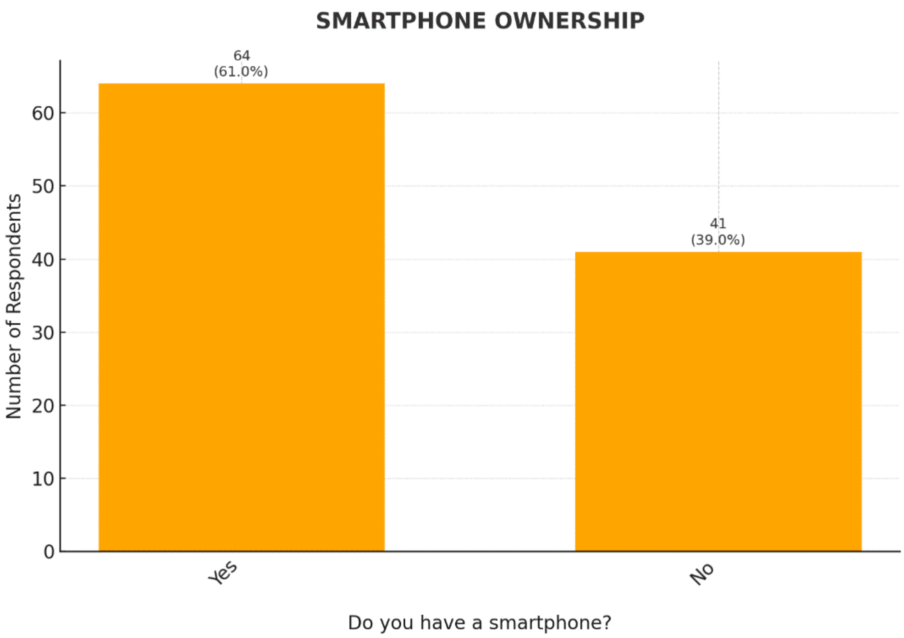
As we discussed before, the existing public transport system is inadequate and insufficient for the needs of the rural population. In the survey, a large majority of them, 93 per cent, expressed their desire for a bus service that would operate during the night as well. This would enable them to access emergency services or other facilities in case of urgent situations.

Many people in rural areas face the problem of infrequent bus services, which forces them to rely on personal transport or Informal PT in case of emergencies at night. For example, if they have a

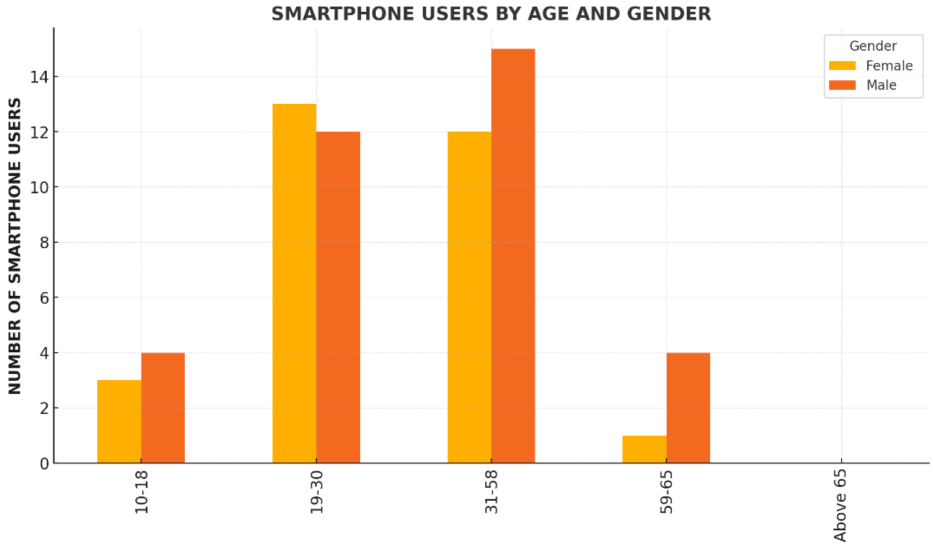
[7] https://www.cable.co.uk/mobiles/worldwide-data-pricing/

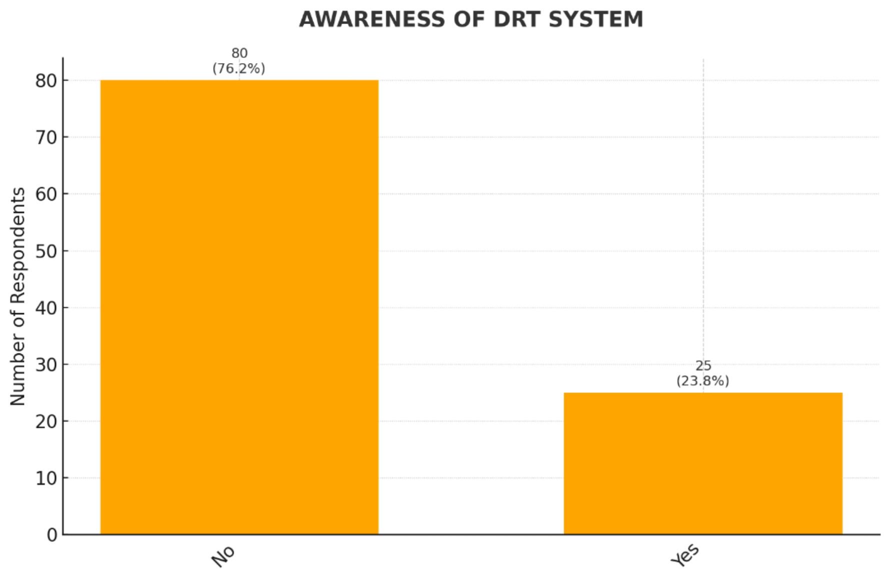
health emergency and need to visit the nearest clinic or hospital, they must pay 10 to 20 times more than the regular bus fare. The survey asked them if they would use a Demand-responsive Public Transport (DRT) system, which is a flexible and convenient mode of transport that can be booked on demand. A very high percentage of the respondents, 97 per cent, said they would use the DRT system if it were available. Moreover, 90 per cent of them were willing to pay a higher price for the DRT service than the normal bus service for the same route.

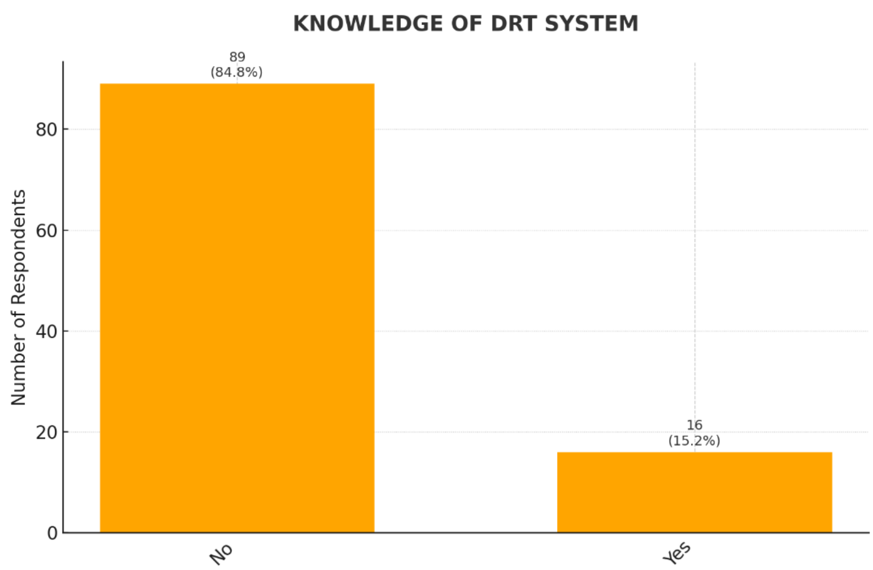
The part of survey aimed to understand the knowledge and interest of respondents in the Demand-responsive Transport (DRT) system in the Katol-Narkhed Sub-district rural area, and whether people would benefit from such a service. The survey results showed a very positive attitude towards the DRT system among the respondents. Based on the perceived benefits of DRT, more than 85% of respondents expressed that the service would be very helpful for them, especially in cases of medical emergencies, when they need to reach the nearest health facility quickly and safely. They also said that the service would save them a lot of time and hassle, as they would not have to wait for long hours for the regular bus service or travel long distances to access other modes of transport.



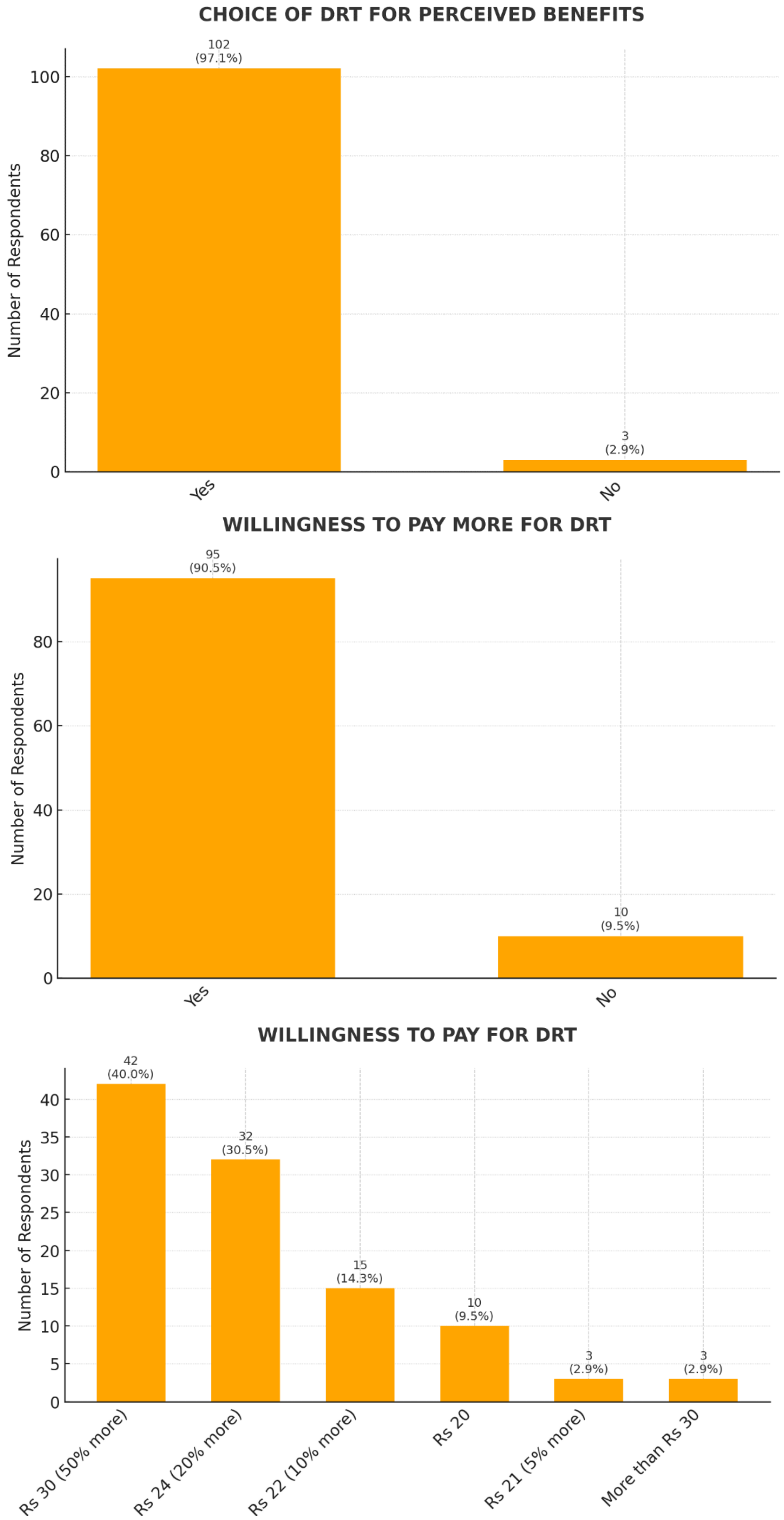
*Graph 6-6 Smartphone users. **N=106.** (Source: Graph created by the Author)*



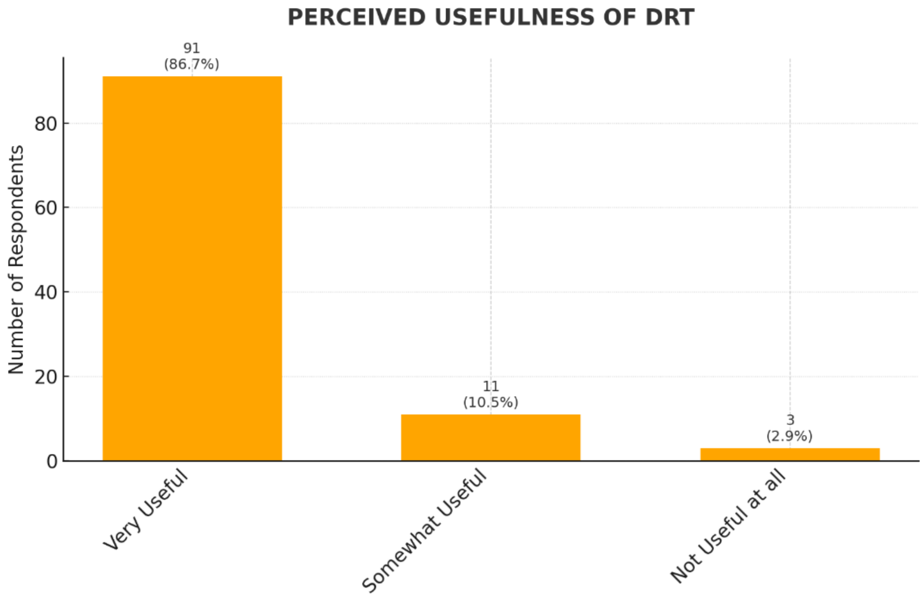


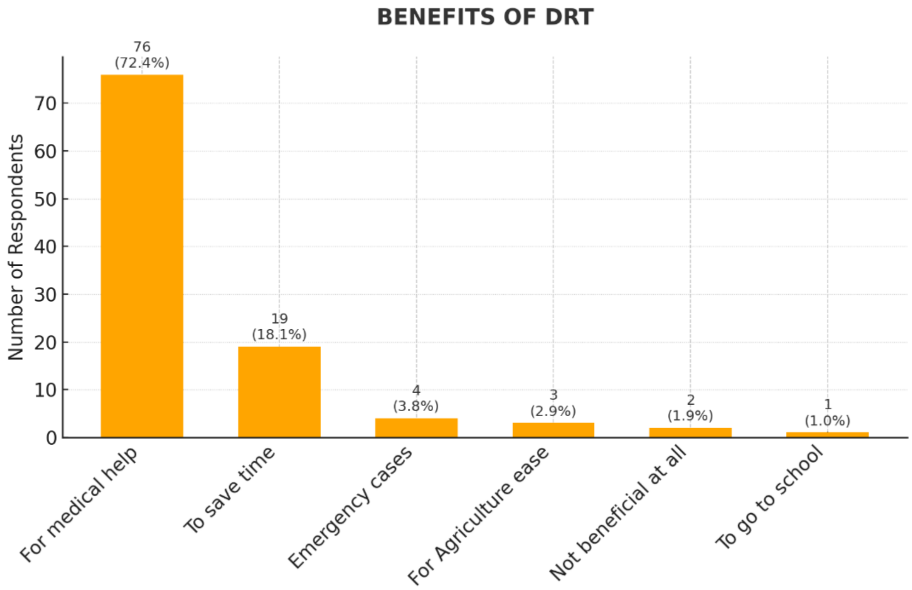


Graph 6-7 (Top) The graph shows gender and age based smartphone use. (Middle and Bottom) The graphs suggests awareness and knowledge about a DRT system. ***N=106.*** *(Source: Graphs created by the Author)*



Graph 6-8 (Top) The graph suggest respondents preference for DRT based on perceived befefits. (Middle) The graph indicates interest of respodents to pay higher for perceived benefits of the DRT. (Bottom) The graph shows inclination to pay more in %. Existing PT trip fare taken here is Rs 20. ***N=106****. (Source: Graphs created by the Author)*





Graph 6-9 (Top and Bottom) The graphs show perceived usefulness and benefits DRT can provide to the respondents. ***N=106****.*
(Source: Graphs created by the Author)

6.3. Spatial Analysis

The spatial analysis presents a comprehensive visual depiction of the services available, population distribution, and village locations within the selected areas of Katol and Narkhed Sub-districts. This examination is pivotal in elucidating the spatial dynamics and transportation requirements of the local populace relative to the existing facilities. By analysing these parameters, the study aims to provide an in-depth understanding of regional accessibility and the interaction between demographic characteristics and infrastructural provisions.

Data Acquisition

This study predominantly utilised population data from the 2011 Census of India[8], which is available in CSV format. This dataset records the population as of 2011 and projects demographic trends up to the year 2036. The information is disaggregated at the village level, with further classification into male and female categories. For geographic data concerning roads, railways, and other facilities, the study relied on shapefiles obtained from the Prime Minister Gram Sadak Yojana (PMGSY) National GIS portal[9], operated by the Ministry of Rural Development. However, it should be noted that this dataset is not regularly updated and lacks comprehensive details on many facilities. To enhance the dataset's utility for the spatial analysis required for this thesis, additional data were sourced through surveys and local contacts to integrate more comprehensive details about facilities and services. Moreover, the Maharashtra State Road Transport Corporation (MSRTC) bus timetables, essential for understanding regional transport dynamics, were procured directly from the bus terminuses at Katol, Kondhali and Sawargaon. Although these timetables were established in 2016, they continue to approximate current bus departure times and frequencies. The time isochrones data was gathered in QGIS 3.30 via the ORS plugin and API from openrouteservice.org.

Services and Facilities Mapping and Analysis

The maps identify essential services such as healthcare centres, educational institutions, markets, government offices, and other public services. By mapping these facilities, we can understand where essential services are located and how they are distributed across the region. This helps in identifying areas with adequate facilities and those that are underserved. The maps also illustrate the distribution of the population across the region alongside the services, indicating population density in various villages and rural areas. Understanding population

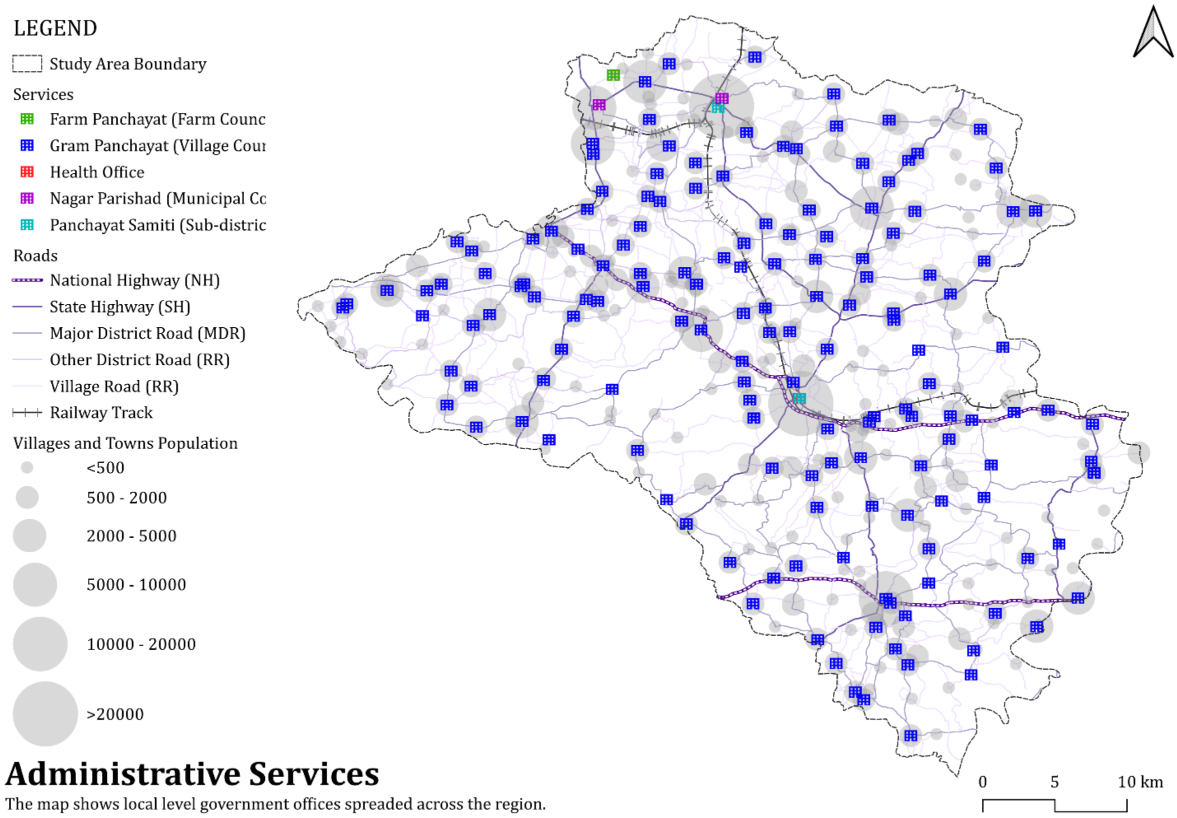
[8] Census tables | Government of India (censusindia.gov.in)
[9] PMGSY National GIS - Open Data PMGSY GeoSadak (geosadak-pmgsy.nic.in)

distribution is key to assessing the demand for transportation. Regions with higher population density have a greater need for efficient public transport systems.

The following Table 6-2 shows the categorisation of services offered by the area. By highlighting the locations of villages and rural areas, the maps provide insights into the living patterns of the local population. Some areas are more remote and less accessible, indicating a higher need for improved transportation solutions.

List of different groups of each facility and service			
Services/Facilities	**Sub-group**	**Count**	**Total**
Administrative	Gram Panchayat (Village Council)	155	162
	Farm Panchayat (Farm Council)	1	
	Nagar Parishad (Municipal Council)	3	
	Panchayat Samiti (Sub-district Council)	2	
	Health Office	1	
Agricultural	Agriculture Industry	8	36
	Mandi (Market)	27	
	Storage Facility	1	
Educational	Primary School	13	105
	Middle School	6	
	High School	77	
	College	9	
Other Essential	Bank	30	63
	Petrol Pump	17	
	Post Office	11	
	Police Station	5	
Healthcare	Government Hospital	16	43
	Private Hospital	13	
	Veterinary Hospital	14	
Transport	Bus Terminus	4	111
	Bus Stop	100	
	Railway Junction	2	
	Railway Station	5	

Table 6-2 Services and Facilities available in Katol-Narkhed Sub-district.
(Source: PMGSY National GIS portal and survey done by the author.)



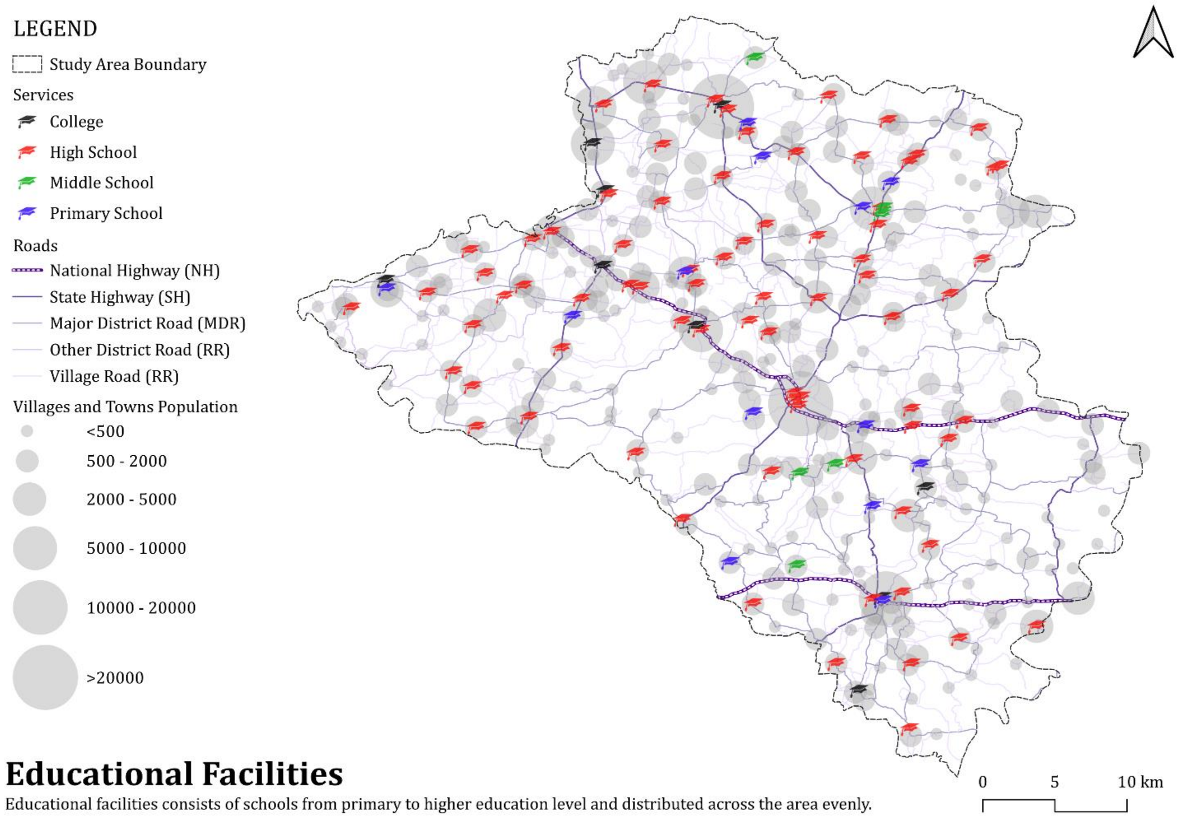
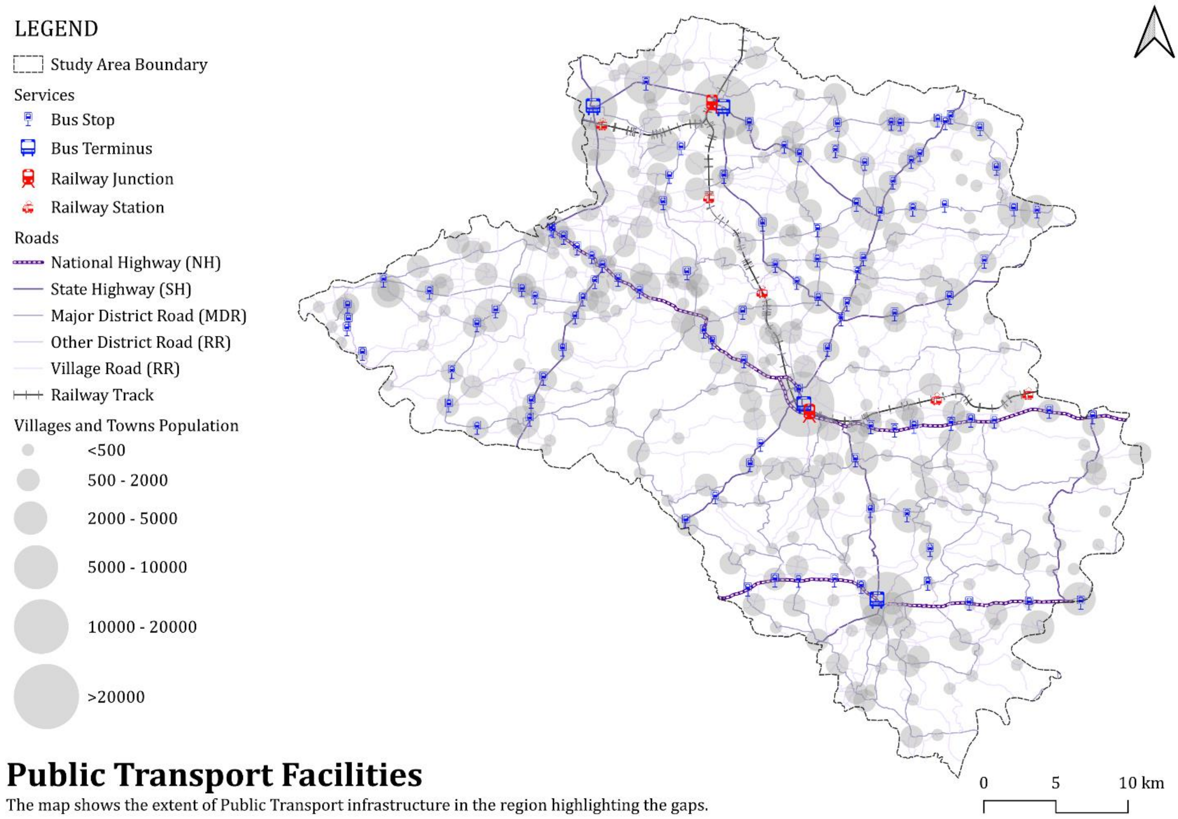


Figure 6-3 The maps show spatial distribution of administrative services (Top) and Educational Facilities (Bottom) in Katol-Narkhed subdistricts. They are mapped on the population count and road network to understand the distribution based on these factors.
(Maps illustrated by Author. Source: PMGSY national GIS portal, Census India 2011 and Survey by the author)



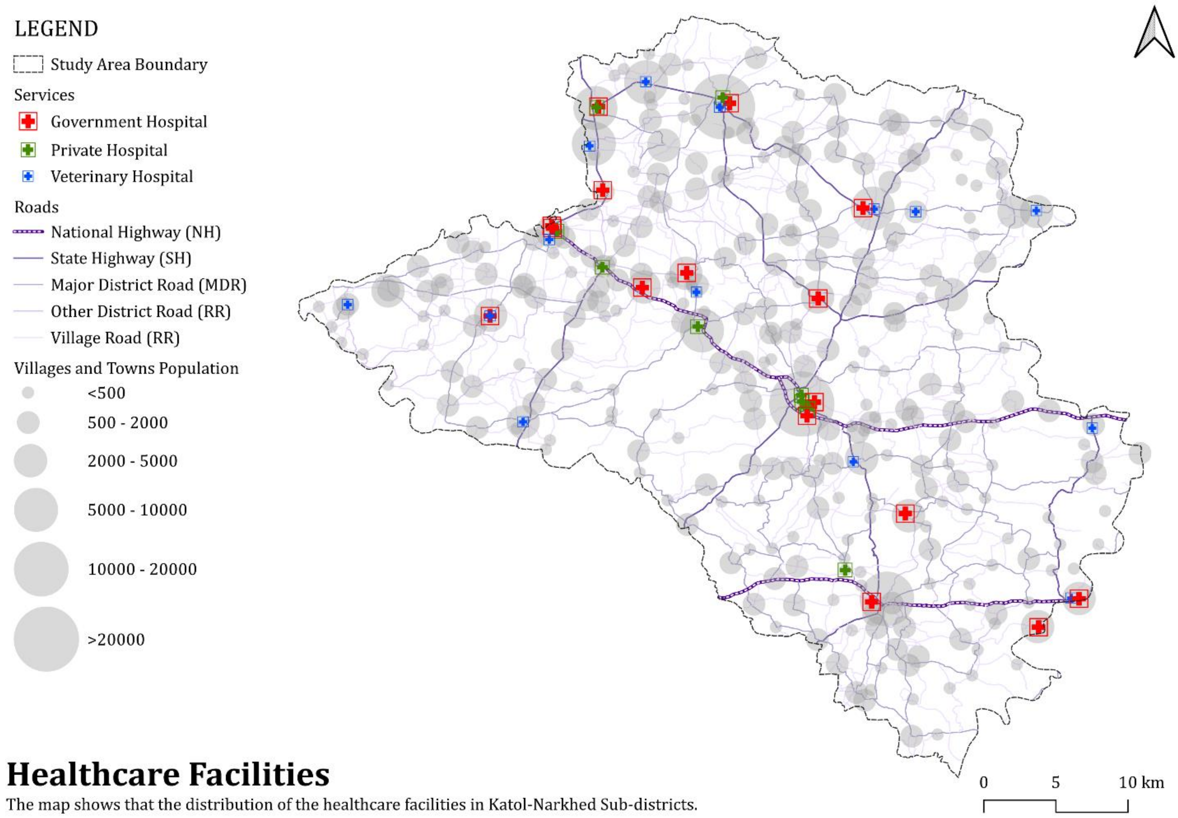
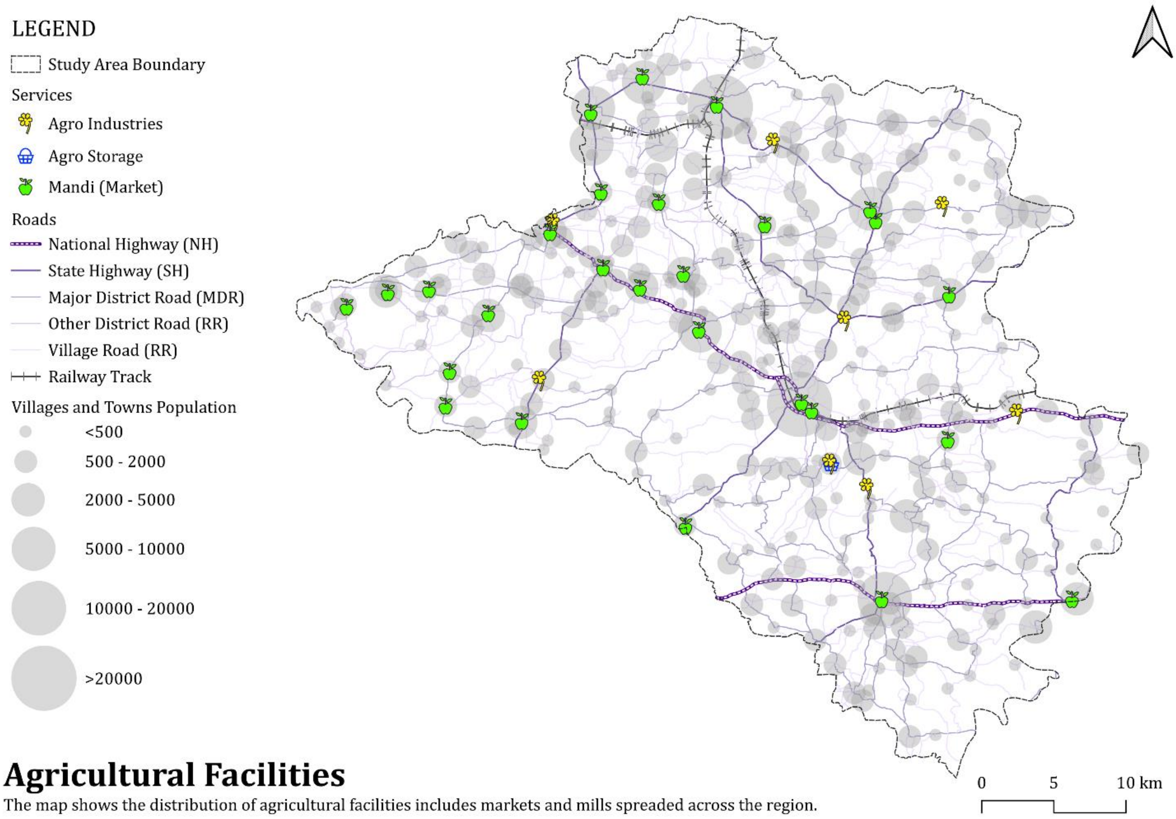
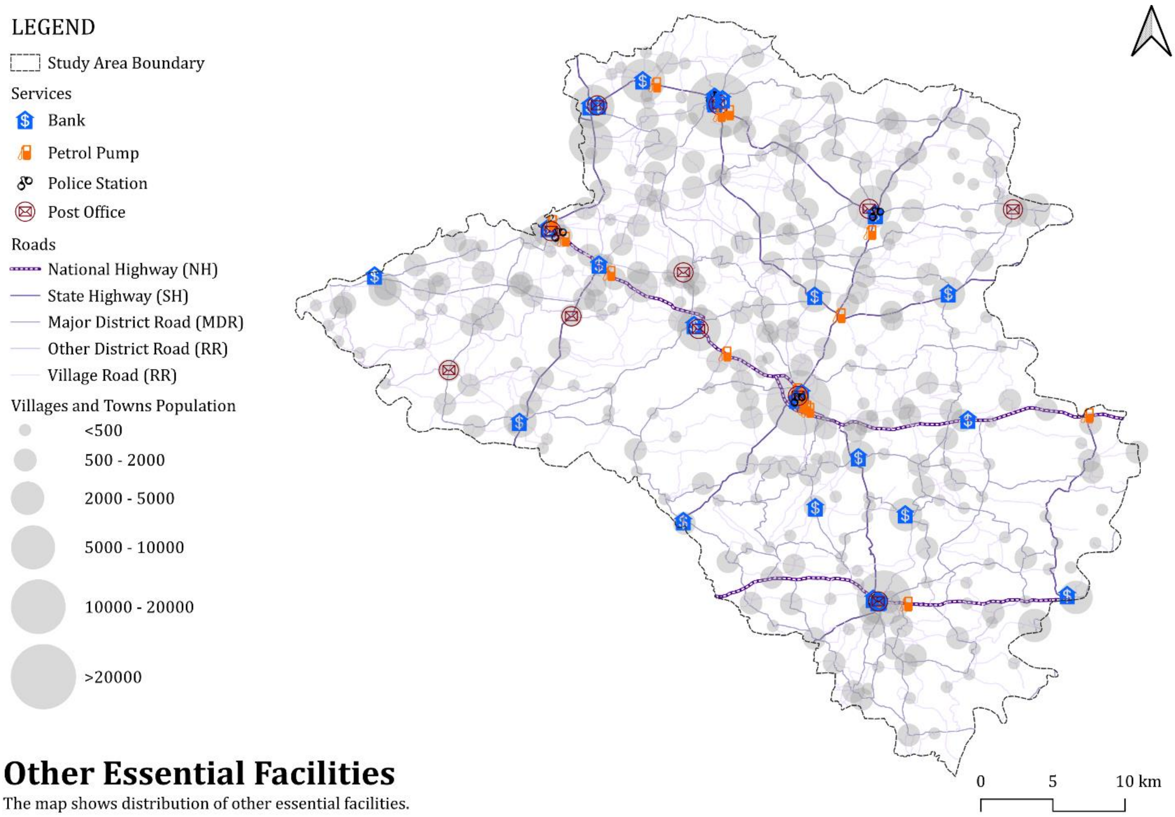


Figure 6-4 The maps show spatial distribution of public transport (Top) and Healthcare Facilities (Bottom) in Katol-Narkhed subdistricts. They are mapped on the population count and road network to understand the distribution based on these factors.
(Maps illustrated by Author. Source: PMGSY national GIS portal, Census India 2011 and Survey by the author)



Agricultural Facilities

The map shows the distribution of agricultural facilities includes markets and mills spreaded across the region.

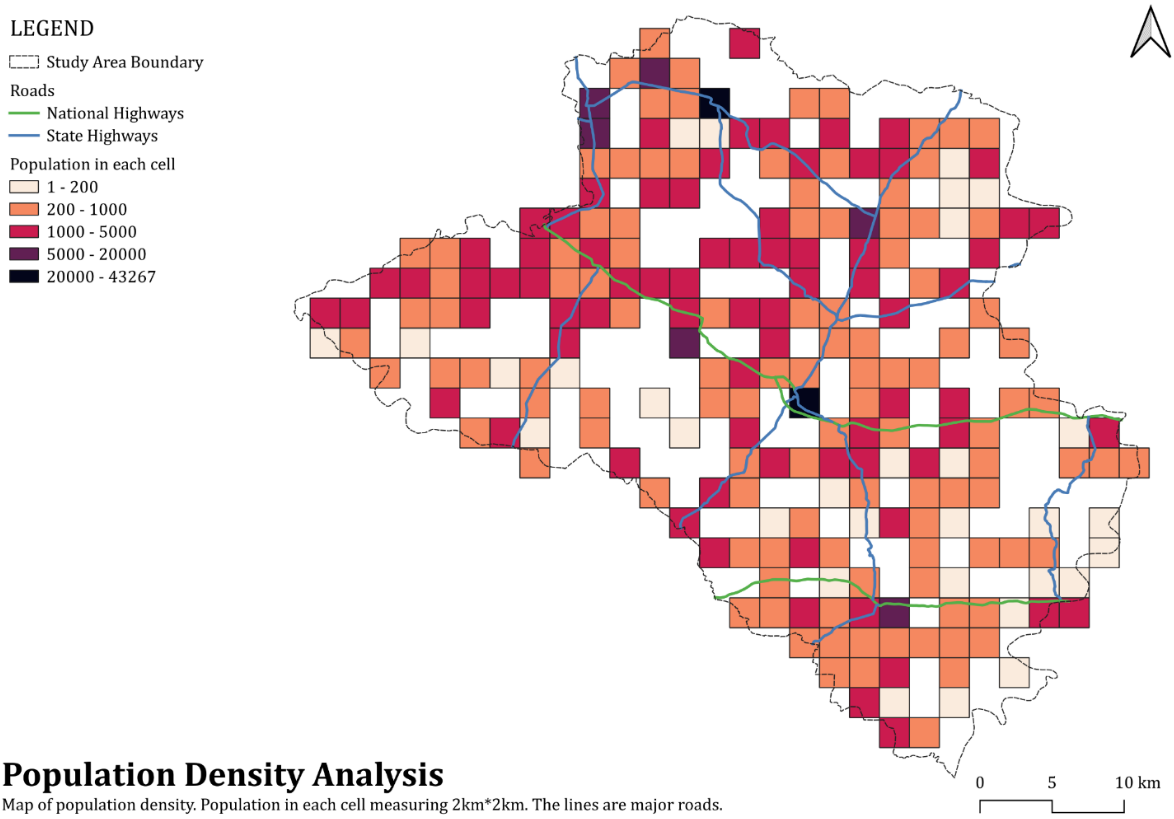


Other Essential Facilities

The map shows distribution of other essential facilities.

Figure 6-5 The maps show spatial distribution of agricultural (Top) and other essential Facilities (Bottom) in Katol-Narkhed subdistricts. They are mapped on the population count and road network to understand the distribution based on these factors.

(Maps illustrated by Author. Source: PMGSY national GIS portal, Census India 2011 and Survey by the author)



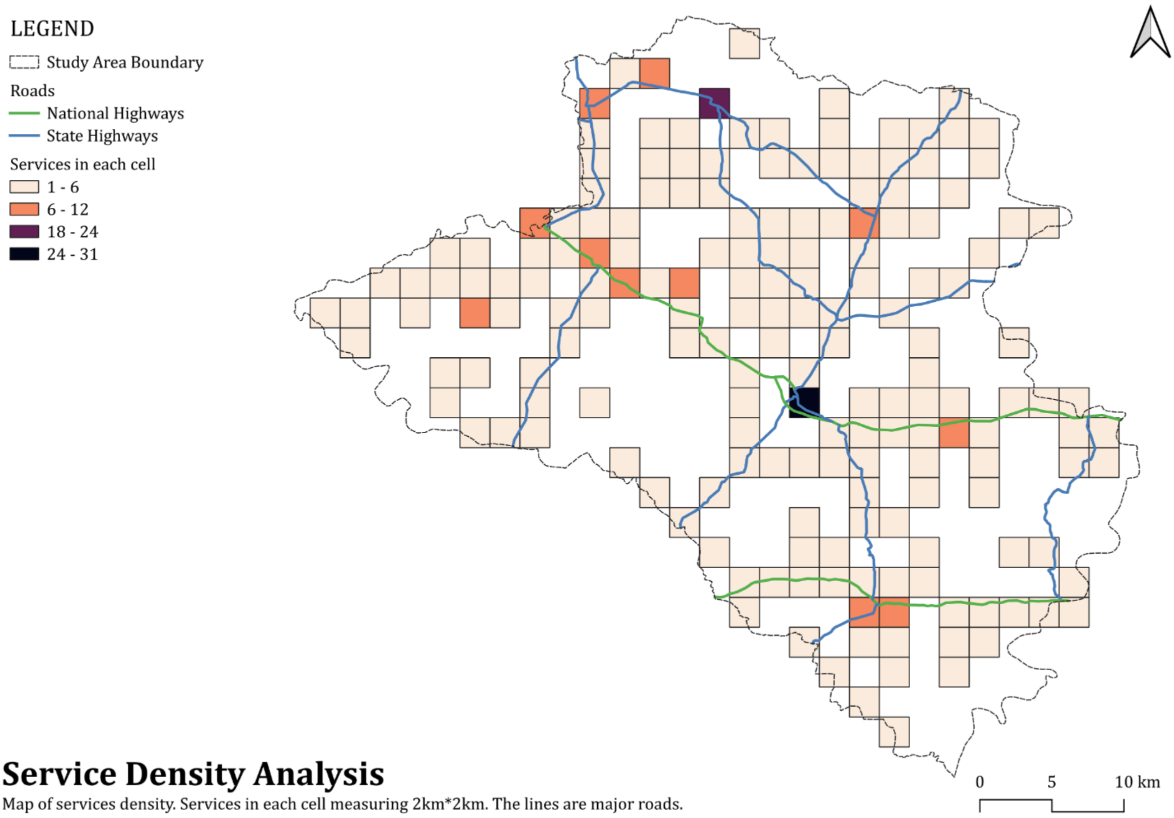


Figure 6-6 (Top) Map shows population in a 2 km by 2 km square and (Bottom) Map shows all available services and facilities combines in a 2 km by 2 km square.
(Maps illustrated by Author. Source: PMGSY National GIS portal, Census India 2011)

The above maps in Figure 6-6 are based on a grid system where each cell measures 2 kilometres by 2 kilometres. This consistent measurement allows for a detailed examination of how population and services are distributed across the area.

Previously we mapped available services and facilities on the map. In this passage use of Advanced spatial analysis techniques to examine population density and access to various services and facilities in the study area are visualised through a series of maps.

Kernel Density Estimation Analysis/Heatmaps

The heatmaps focus on the concentration of population and essential services like healthcare, education, and public transport. By mapping these elements, we can visually identify regions where there is either a high concentration of resources or significant gaps, indicating areas where services are lacking relative to the population.

Further analysis employs a technique called kernel density estimation (KDE). KDE is a statistical method used to produce a smooth estimate of the density of points (in this case, services) across the map. This approach helps in understanding areas with high or low service availability and is particularly useful in identifying clusters of services, which can be crucial for strategic planning and resource allocation.

Spatial Autocorrelation Analysis (Moran's I)

Moran's I is a tool used to measure how similar or different things are distributed across a geographic area. Imagine you have a map with various points, each representing a value, like the number of schools, hospitals, or pollution levels in different areas. Moran's I help understand if these points are clustered together, spread out, or randomly scattered.

- **Positive Moran's I (0 to +1):** Similar values are close to each other. For example, high-pollution areas are near other high-pollution areas.
- **Negative Moran's I (-1 to 0):** Dissimilar values are close to each other. For example, high-pollution areas are near low-pollution areas.
- **Around zero:** Values are randomly distributed with no clear pattern.

In this study, we use Moran's I to see how different types of facilities and services are distributed across a region. This helps us understand the spatial patterns and suggest improvements in facility planning, transportation planning and resource allocation.

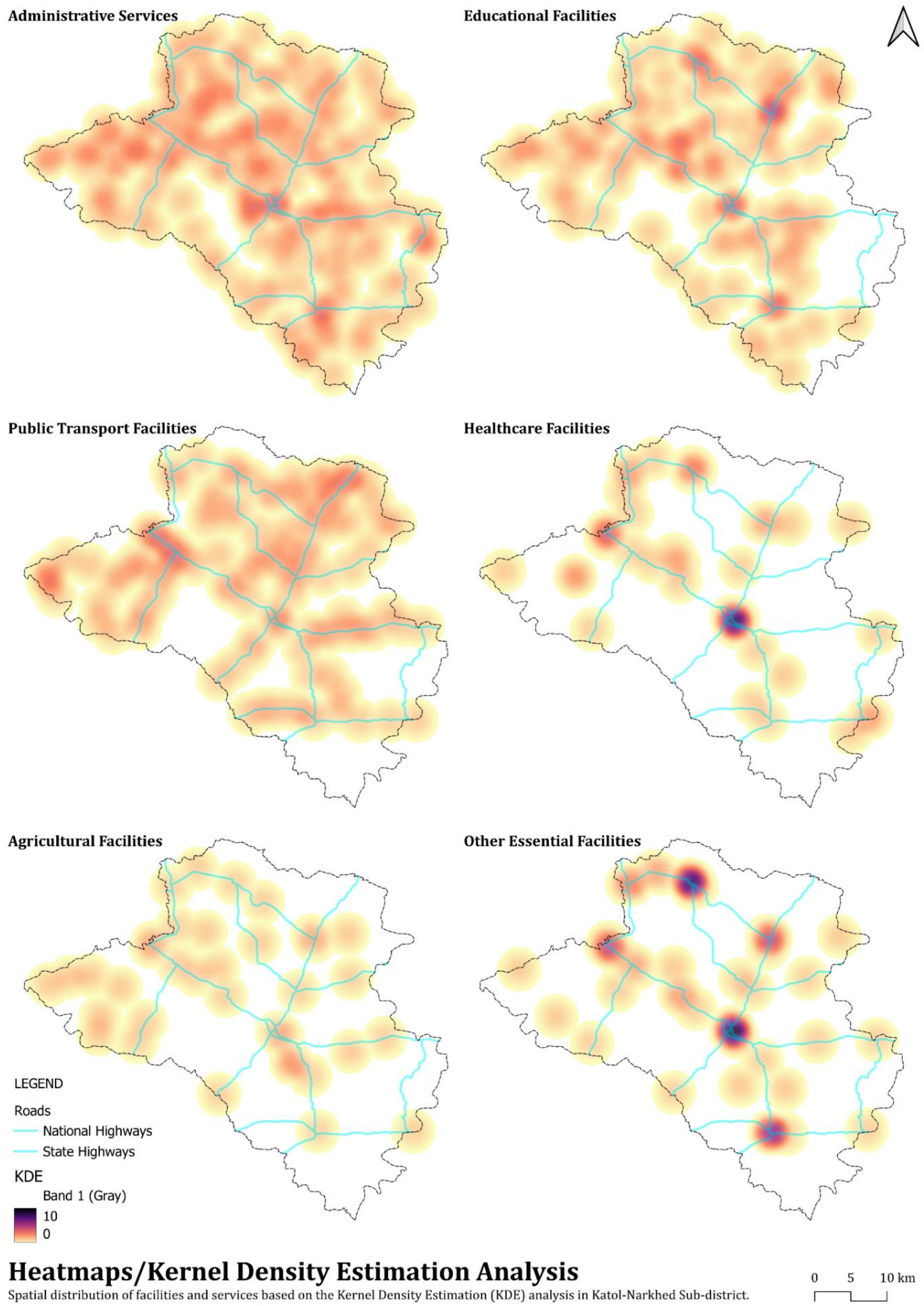


Figure 6-7 The heatmaps show various services and facilities concentrations indicating Healthcare and other essential facilities are concentrated along road intersections and nodes.
(Maps illustrated by Author. Data source: PMGSY National GIS portal, Census India 2011)

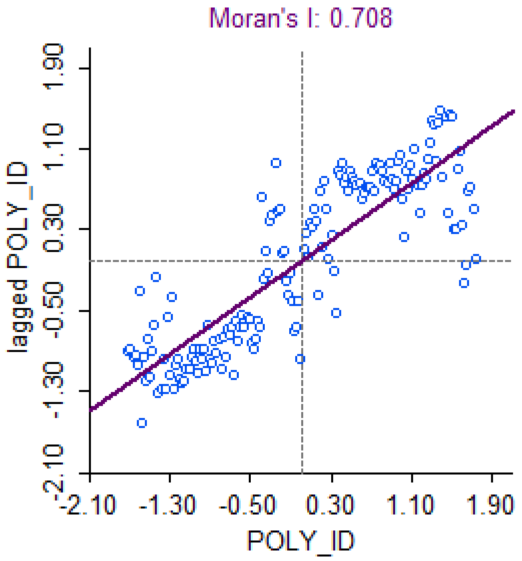


Figure 6-8 Moran's I: 0.708 indicates a very strong clustering of Administrative Facilities. The plot shows a very clear pattern of these facilities being close to each other.
(Source: Illustrated by Author in software GeoDa)

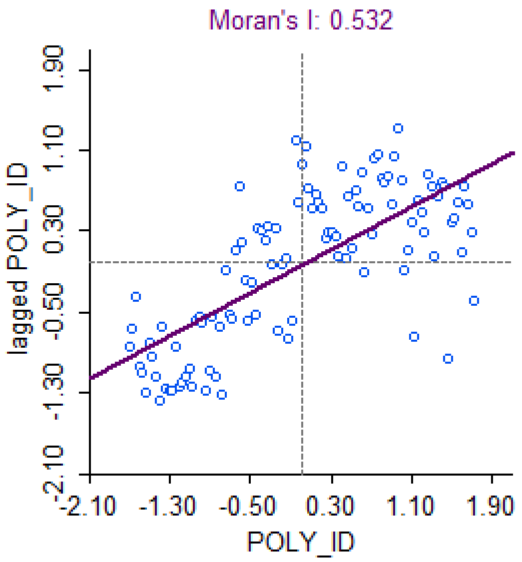


Figure 6-9 Moran's I: 0.532 indicates a strong clustering of Educational facilities. The plot shows a noticeable pattern of educational facilities being close to each other.
(Source: Illustrated by Author in software GeoDa)

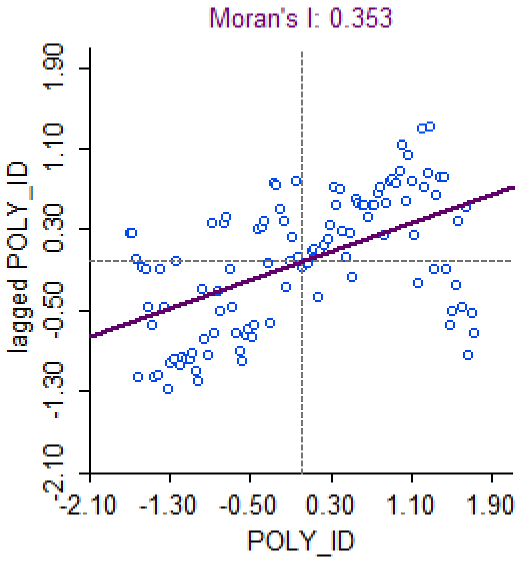


Figure 6-10 Moran's I: 0.353 means there's a moderate tendency for Public Transport Facilities to be located near each other. The plot shows some clustering of similar values but it's not very strong.
(Source: Illustrated by Author in software GeoDa)

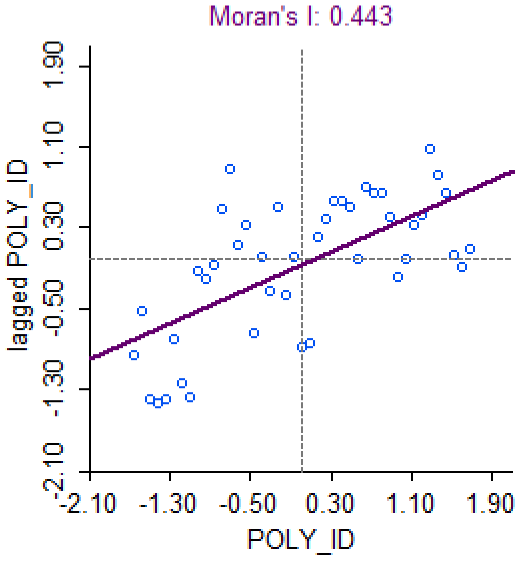


Figure 6-11 Moran's I: 0.443 indicates a stronger clustering of Healthcare Facilities. The plot shows a clearer pattern of healthcare facilities near other healthcare facilities.
(Source: Illustrated by Author in software GeoDa)

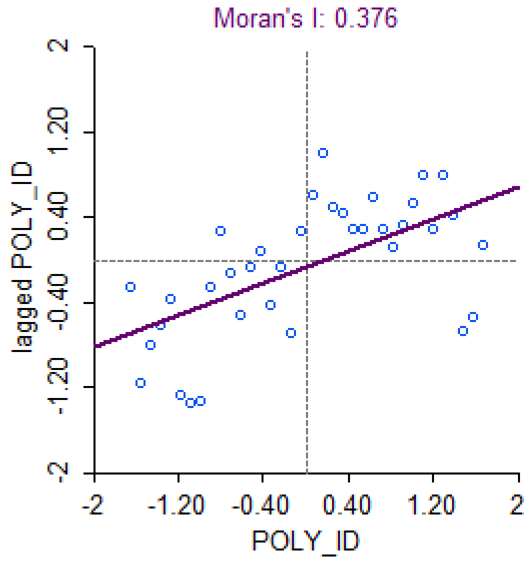


Figure 6-12 Moran's I: 0.376 means there's moderate clustering of Agricultural Facilities. The plot shows a moderate pattern of these facilities being near each other.
(Source: Illustrated by Author in software GeoDa)

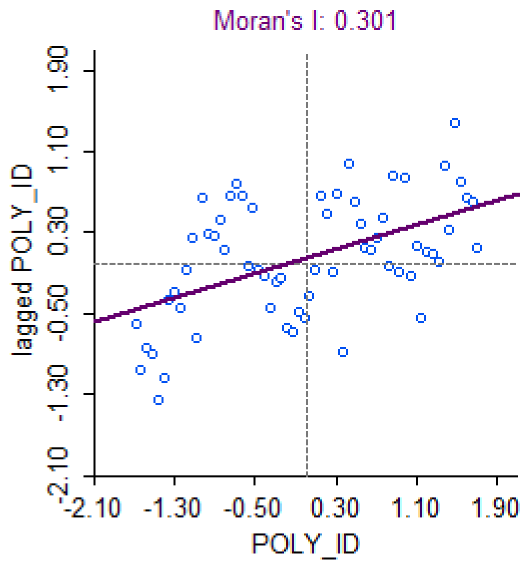


Figure 6-13 Moran's I: 0.301 means there's some clustering of Other Essential Facilities, but it's weaker compared to healthcare and public transport facilities. The plot shows a less clear clustering pattern.
(Source: Illustrated by Author in software GeoDa)

Time Isochrones

Time Isochrones maps explore the accessibility of these services by measuring the driving time required to reach them. These maps categorise driving times into 10 minutes to 45 minutes. This visualisation allows us to understand spatial inequalities in service access. By analysing the driving-time isochrones, we identified areas with insufficient access to essential services and prioritised infrastructure development to improve accessibility. The data suggests that while most facilities are well-distributed, some peripheral regions may require additional services to ensure equitable access for all residents.

1) Administrative Services

- The isochrones indicate that most administrative services are concentrated in central areas, with good coverage within a 30-minute drive.
- Areas on the periphery have less access, taking up to 45 minutes to reach administrative services.

2) Educational Facilities

- Educational facilities are more evenly distributed compared to administrative services.
- A significant portion of the study area can access educational facilities within 20 minutes, with some peripheral areas requiring up to 45 minutes.

3) Public Transport Facilities

- Public transport facilities show a similar distribution to educational facilities, providing good coverage within 20-30 minutes for most areas.
- Peripheral regions may need up to 45 minutes to access public transport hubs.

4) Healthcare Facilities

- Healthcare facilities are well-distributed across the study area, ensuring broad coverage.
- Most areas can reach healthcare services within 30 minutes, highlighting the importance of accessible healthcare.

5) Agricultural Facilities

- Agricultural facilities are mainly concentrated in specific zones, often aligned with the locations of national and state highways.
- Peripheral areas and less densely populated regions have longer driven times, extending up to 45 minutes.

6) Other Essential Facilities

- Essential facilities are strategically placed to ensure accessibility.
- The isochrones show that most areas can access these facilities within 30 minutes, with some areas requiring up to 45 minutes.

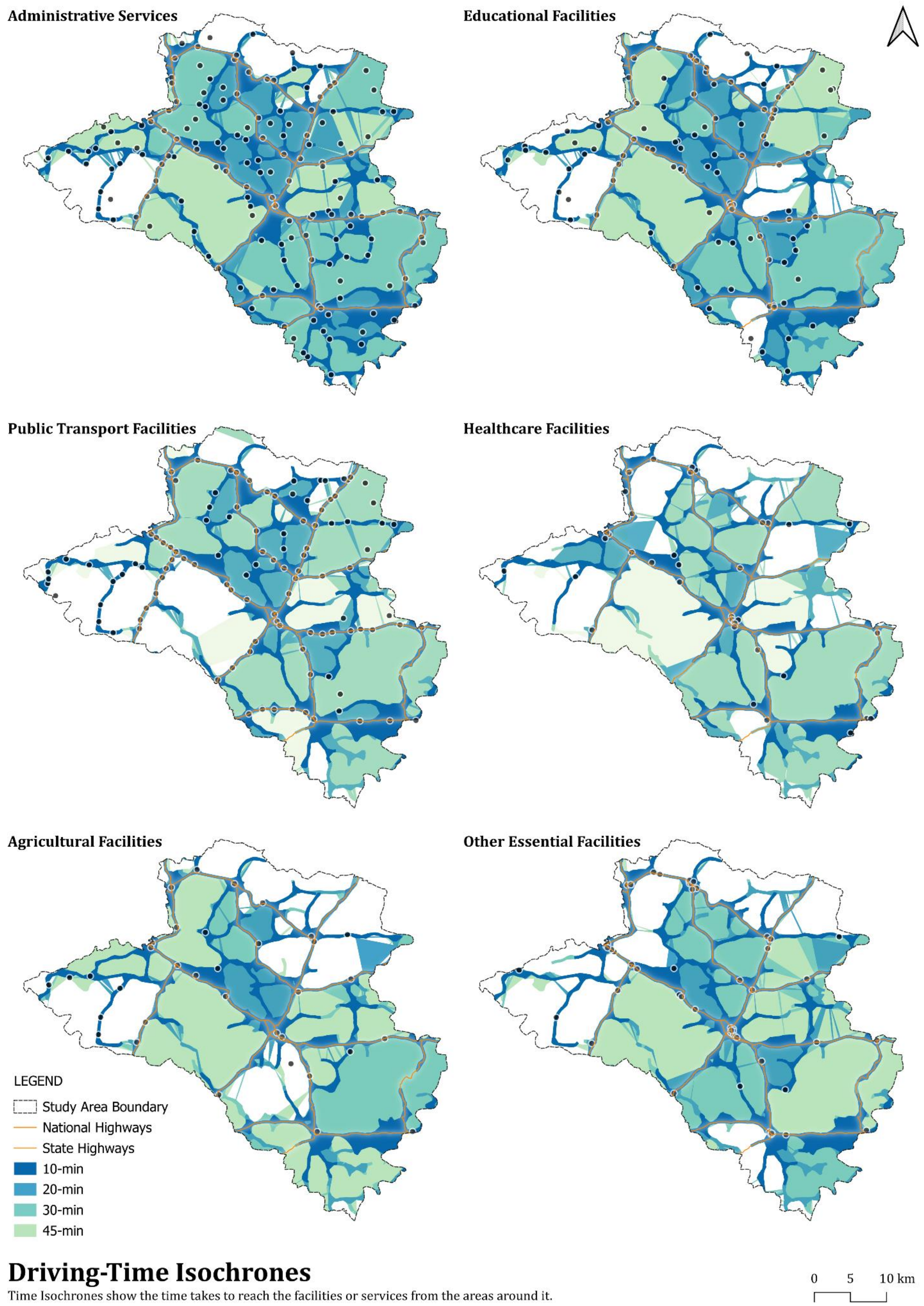


Figure 6-14 The time-isochrones map illustrates the time taken to reach various services and facilities. (Maps illustrated by Author. Data Source: Openrouteservice.org through QGIS plugin, PMGSY National GIS portal)

Public Transport Frequency Mapping and Analysis

The objective of mapping the bus network required comprehensive data collection on bus stops and bus timetable data from the Maharashtra State Road Transport Corporation (MSRTC). The timetable data, pivotal for understanding bus operational schedules, was sourced from the bus terminus in Katol and the bus stop at Sawargaon. Although this data dates to 2016, observational accounts from workers at the terminus suggest that the bus schedules and frequency have remained largely consistent, thus providing a reliable basis for current analyses.

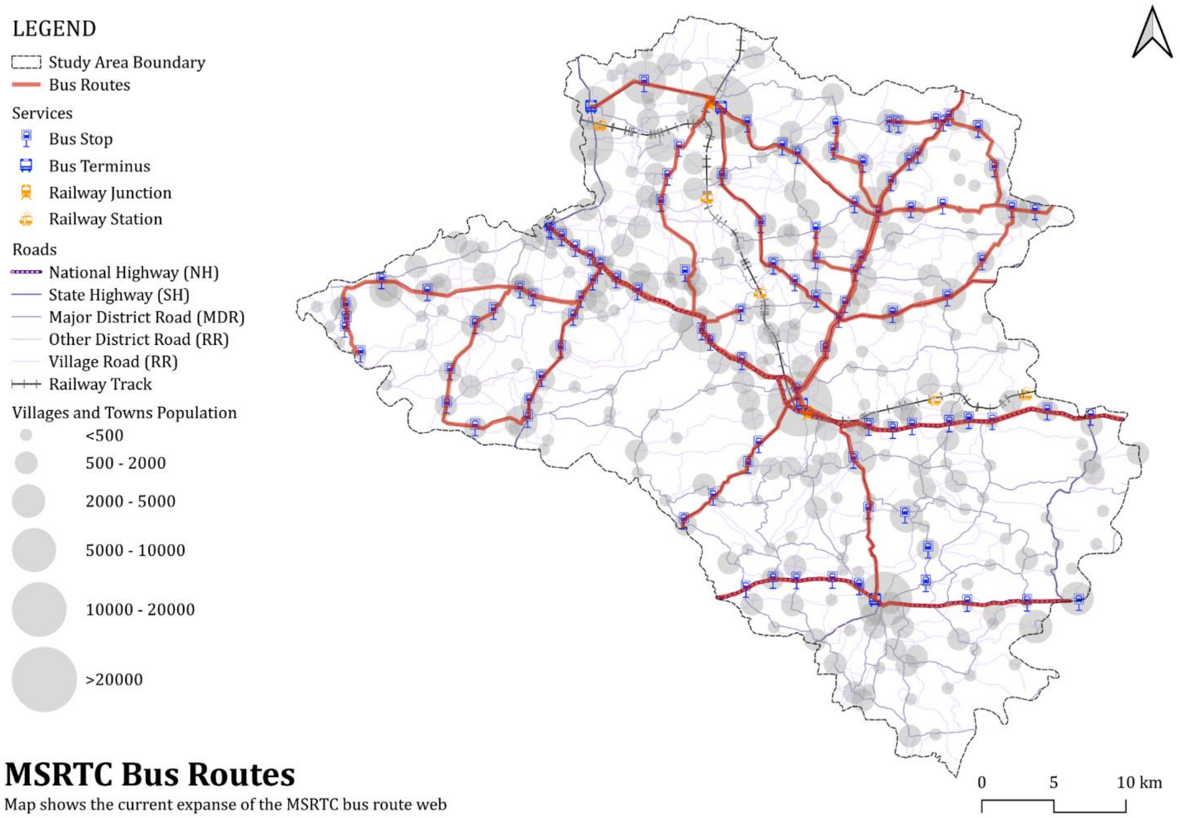
To compile the bus stop data, a combination of methods were used, incorporating but stop data from surveys, and leveraging local connections in areas where direct surveying was impractical. This approach ensured a thorough capture of the existing bus stop infrastructure across the selected regions. Out of 104 bus stops in the region, 86 bus stops were identified through the bus-time table acquired from Katol, Kondhali and Narkhed town bus stops and terminus. The remaining bus stops were identified through Google Maps and open street maps data and aerial imagery and confirmed with the locals during the survey.

The subsequent analysis of the mapped bus stops and frequency data revealed a distinct pattern: bus services predominantly utilise major roads, effectively connecting many towns and villages. However, this connectivity diminishes for remote or less populated villages. Discussions with residents during the survey phase illuminated specific challenges inhibiting bus service to these outlier areas, namely poor road conditions and insufficient demand, which in turn lead to lower revenue from these routes. Furthermore, the study's visual representation (Figure 4-1) delineates the conditions and widths of roads in areas devoid of bus service, reinforcing the connection between substandard road infrastructure and limited public transport availability.

Spatial variations in bus service frequency were also notable. Larger towns and villages located on major roads enjoy higher bus frequencies throughout most of the day, with the only notable reduction occurring during the late evening hours (20:00-24:00).

In stark contrast, villages situated away from primary roads experience significantly reduced bus services, with minimal to no service during the early morning (6:00 to 9:00) and late evening hours (after 18:00). This disparity highlights the critical impact of geographical positioning and road infrastructure on the accessibility and efficiency of public transport services in rural settings. This analysis underpins the necessity for targeted infrastructural improvements and strategic planning to enhance public transport connectivity and accessibility in underserved rural areas.

Figure 6-15 Existing village road (RR) conditions connecting villages away from major roads. Image Credit: Author



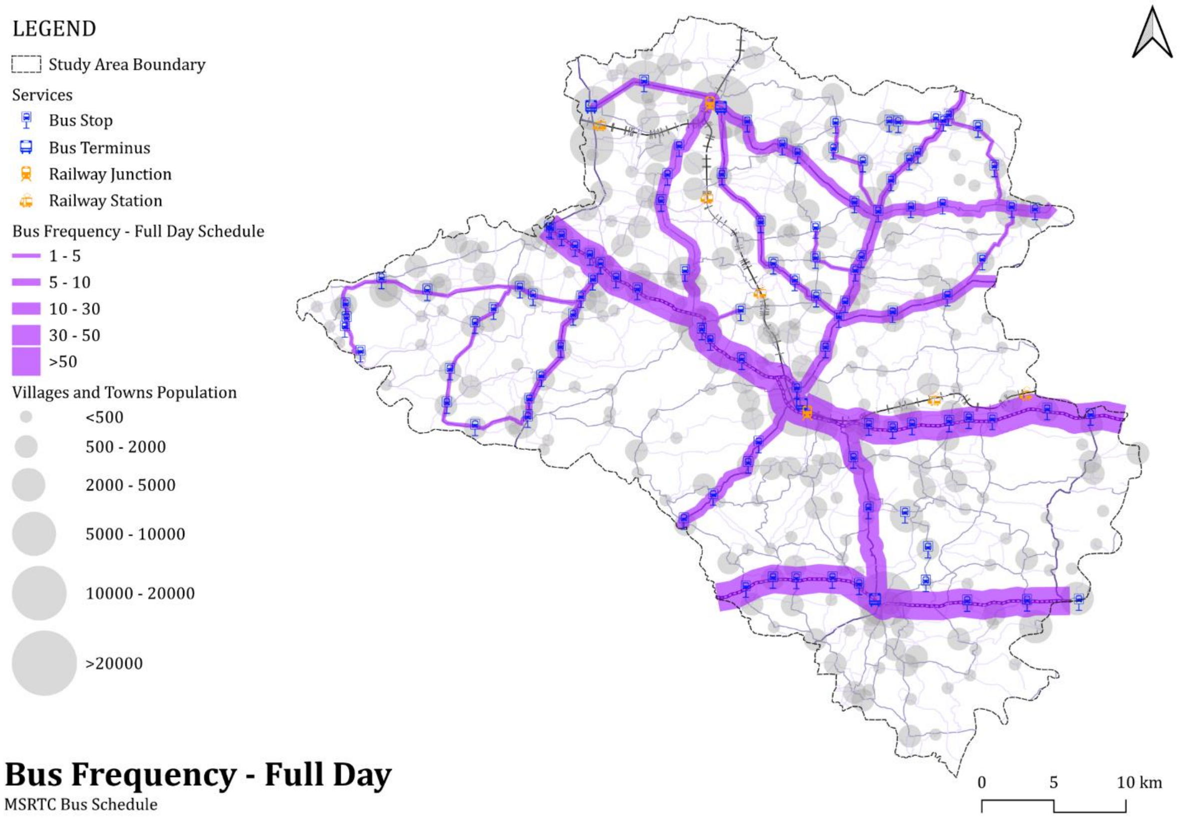
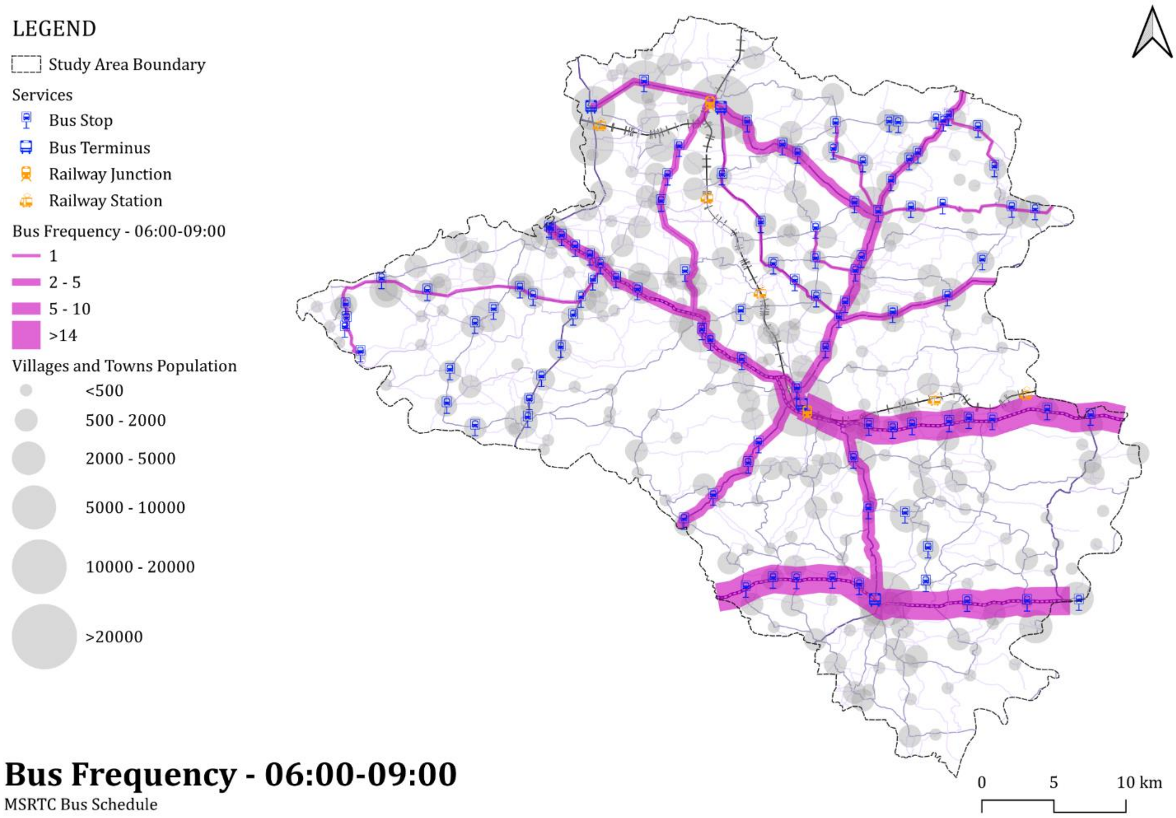


Figure 6-16 The (Top) map shows the current expanse of the existing Public Transport system operated by MSRTC. The (Bottom) map shows PT frequency on various routes.
(Maps Illustrated by Author. Data source: Timetable from MSRTC. Data layers from PMGSY National GIS portal)



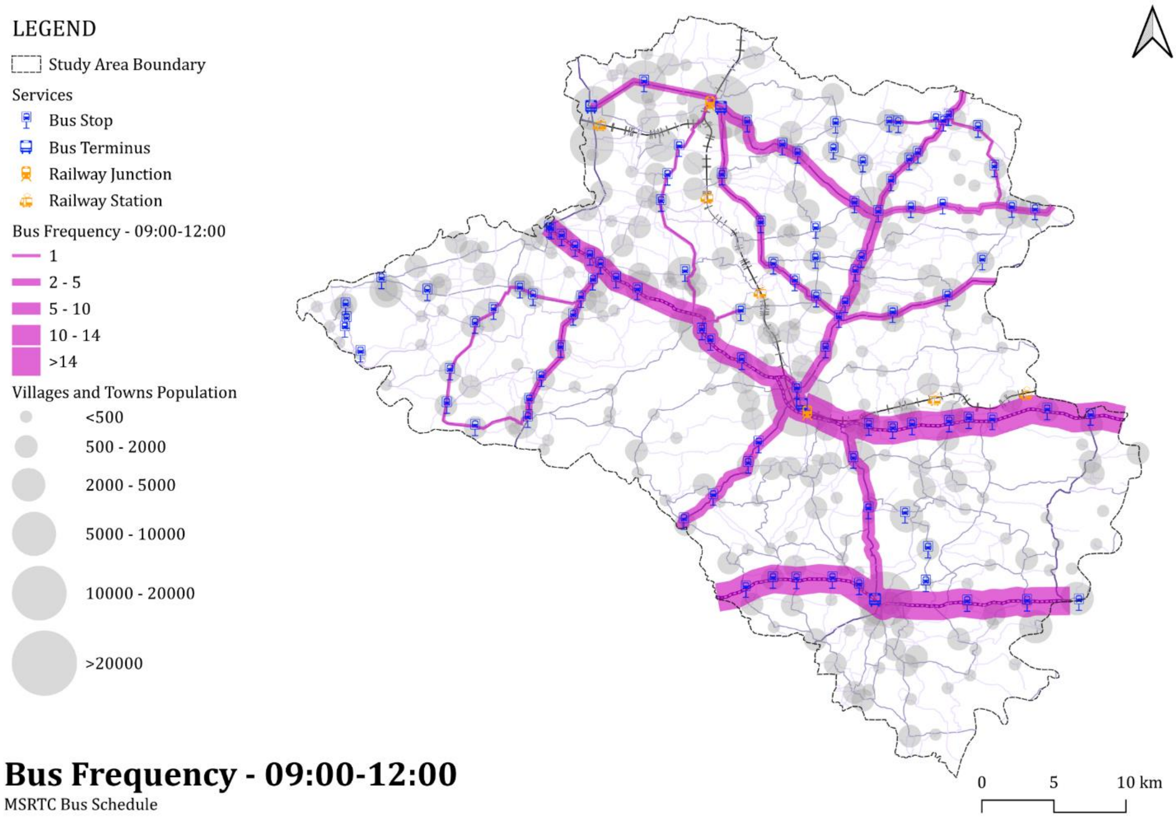
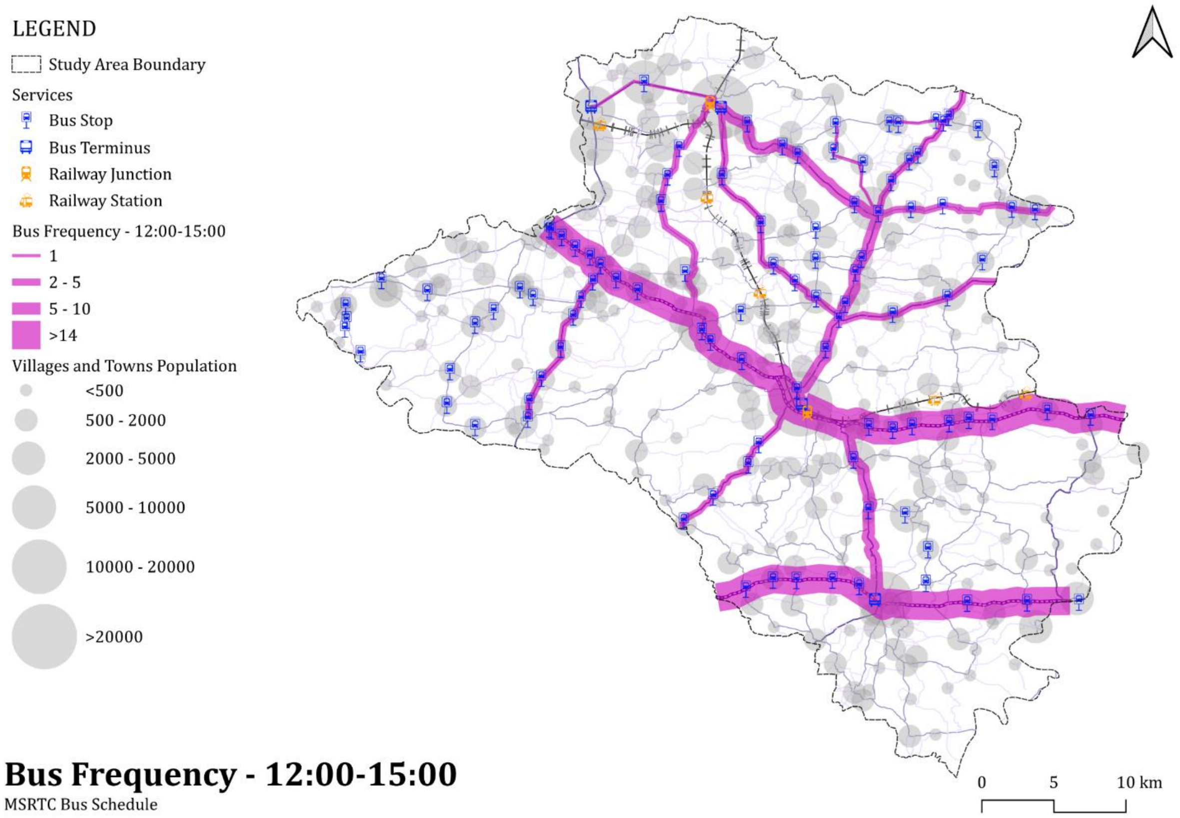


Figure 6-17 The maps show bus frequency on various lines in morning time intervals.
(Maps Illustrated by Author. Data source: Timetable from MSRTC. Data layers from PMGSY National GIS portal)



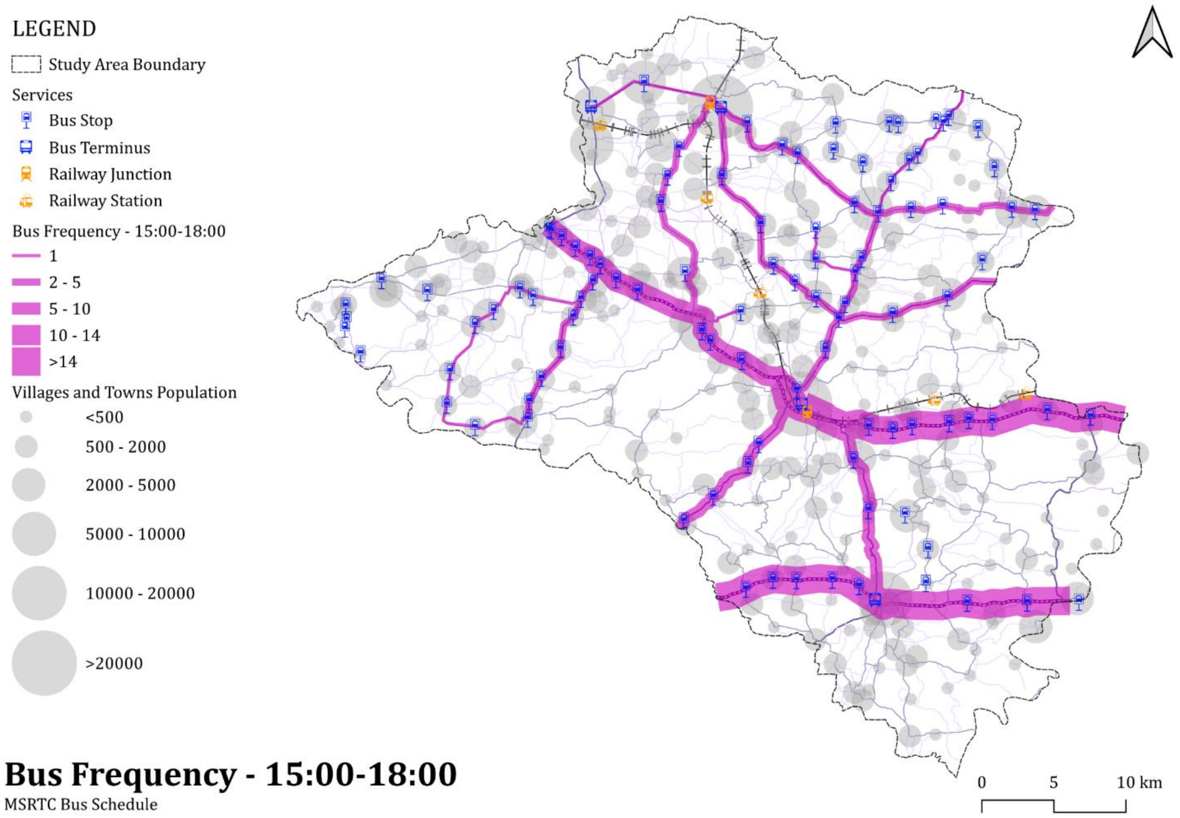
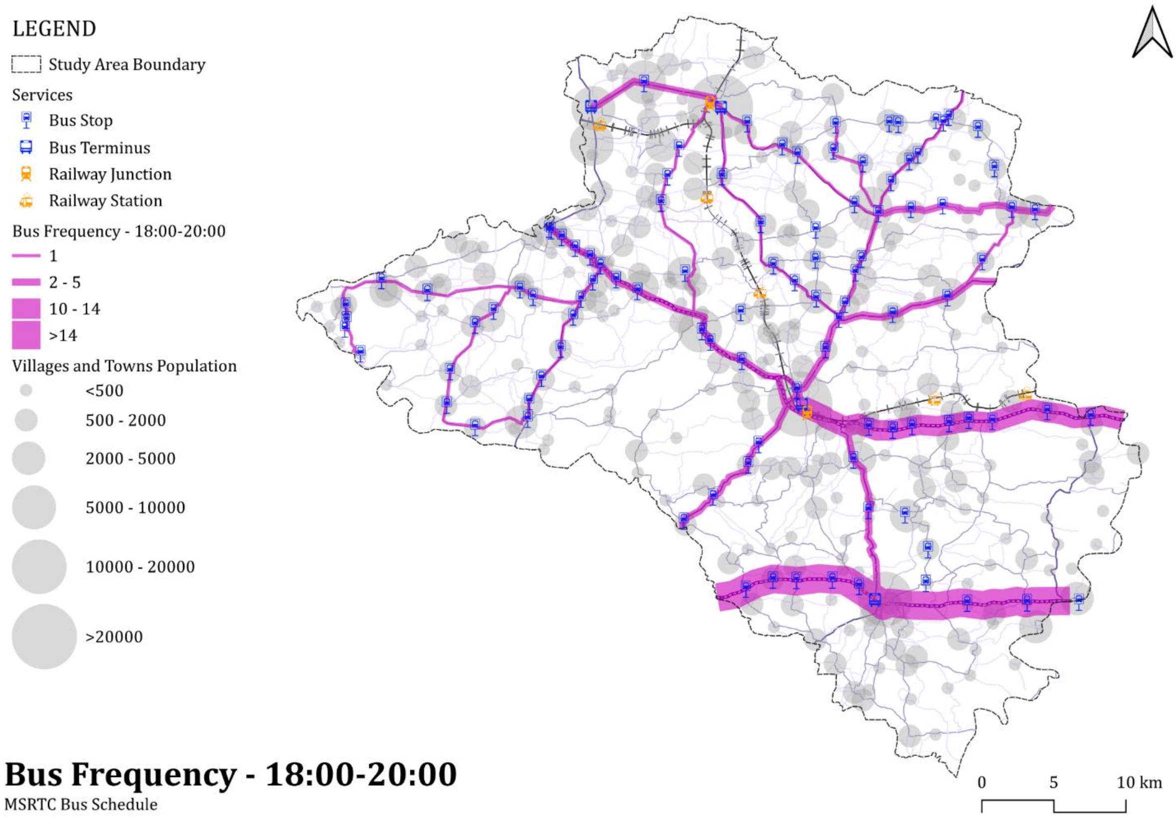


Figure 6-18 The maps show bus frequency on various lines in afternoon-early evening time intervals. (Maps Illustrated by Author. Data source: Timetable from MSRTC. Data layers from PMGSY National GIS portal)



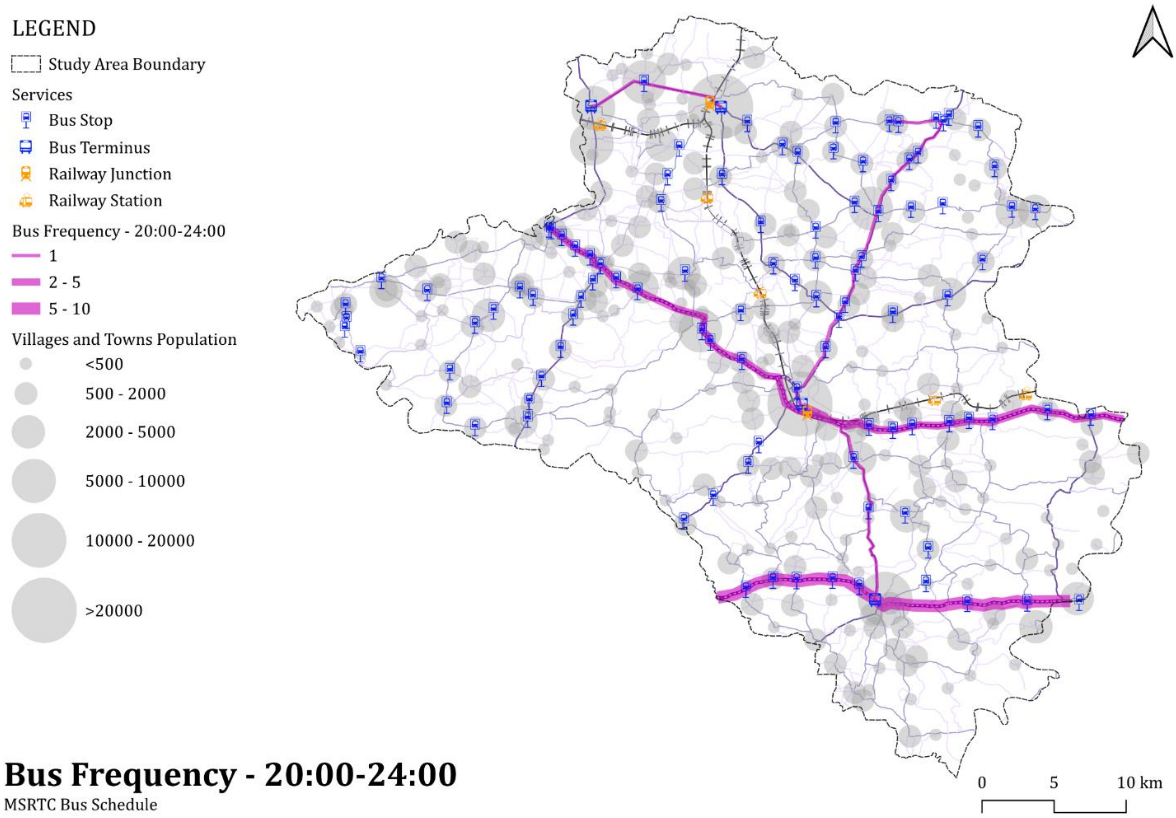


Figure 6-19 The maps show bus frequency on various lines in the evening and nigh time intervals.
(Maps Illustrated by Author. Data source: Timetable from MSRTC. Data layers from PMGSY National GIS portal)

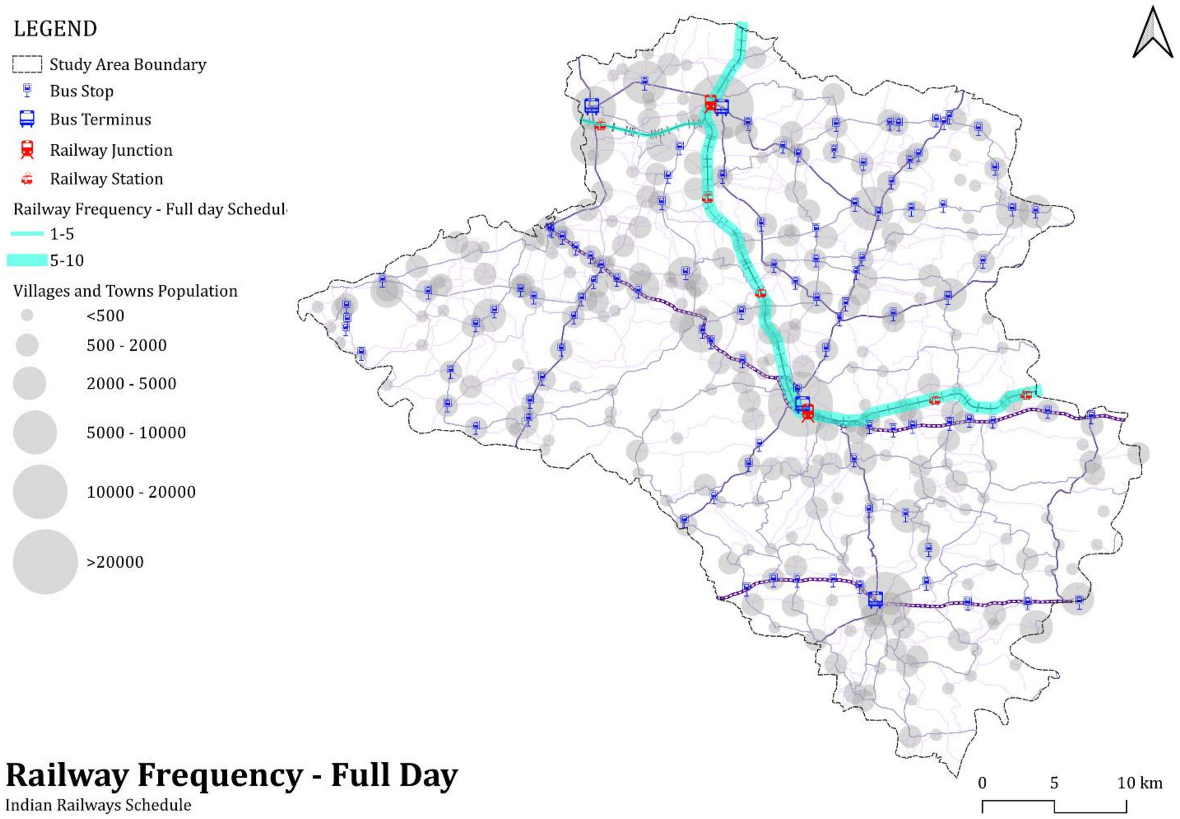


Figure 6-20 The maps show railway frequency during the day.
(Maps illustrated by Author, Data Source: Timetable from Indiarailinfo.com. Data layers from PMGSY National GIS portal)

6.4. Layered data approach

The layered data approach is a methodology used in this thesis to integrate and analyse multiple datasets simultaneously, which provides a comprehensive accessibility analysis of the study area. This approach involves superimposing service density, demographic, PT frequency and Time Isochrones data onto a common geographic framework, which in this case, is the H3 Spatial Index[10]. By combining these layers, complex interactions and patterns are visualised and understood more effectively for planning a Demand-responsive Transport system.

The resulting **Accessibility Assessment Map**, in Figure 6-21, depicts the performance of different hexagonal cells (i) through an Accessibility Score (ASi) based on values of service density, public transport frequency, population, time isochrones and road categories. The following paragraph explains the resulting map.

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[10] H3 Spatial Index - H3 | H3 (h3geo.org)

Score Range

The Accessibility Score (ASi) ranges from 0 to 0.71, where higher scores indicate better overall accessibility in terms of service density, public transport frequency, and proximity to major roads.

Observations

The analysis of accessibility scores reveals distinct spatial patterns across various regions. The highest scores, ranging from 0.7 to 0.71, are concentrated in small clusters primarily located along major transportation routes and central areas. These regions benefit from high service density and frequent public transport, indicating excellent accessibility. High scores, between 0.5 and 0.7, are distributed along secondary transport routes and near suburban centres, reflecting good accessibility with a balanced mix of services and infrastructure. Medium scores, ranging from 0.3 to 0.5, are more widespread and indicative of moderate accessibility, likely characterizing suburban or semi-urban areas with an average level of service availability and public transport options. Low scores, from 0.15 to 0.3, are found in more remote or less developed regions, denoting relatively poor accessibility with less frequent public transport and fewer available services. The lowest scores, between 0 and 0.15, are predominantly in rural or peripheral areas, highlighting the poorest accessibility due to sparse service availability, infrequent public transport, and longer travel times to access necessary facilities.

How Demand-Responsive Transport (DRT) can be beneficial

Improving overall accessibility through Demand-Responsive Transport (DRT) can significantly benefit low-scoring and medium-scoring areas. For low-scoring areas, with scores ranging from 0 to 0.15 and 0.15 to 0.3, DRT can provide flexible and on-demand transport services. This approach offers residents access to essential services such as healthcare, education, and administrative facilities that are otherwise difficult to reach. Additionally, by offering tailored transport solutions, DRT can bridge the accessibility gap for communities lacking immediate access to frequent public transport or major road networks. For medium-scoring areas, with scores between 0.3 and 0.5, DRT can enhance connectivity by linking these moderately accessible areas with highly accessible regions. This connectivity facilitates better access to a wider range of services and reduces travel times. Furthermore, implementing DRT as a first-mile/last-mile solution can improve the overall efficiency and convenience of the transport network by serving as a feeder service to existing public transport systems.

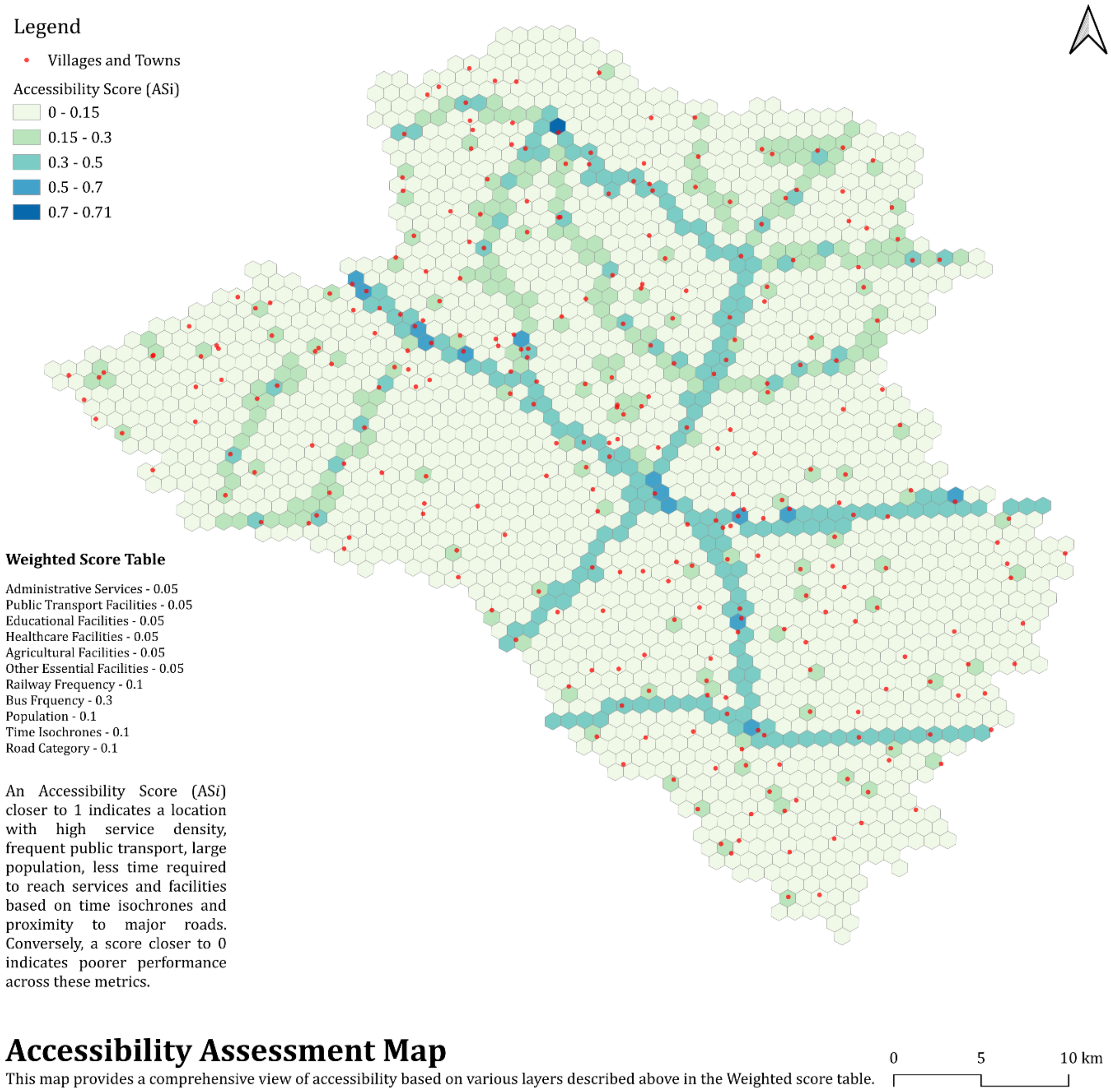


Figure 6-21 The result of the layered data approach sums up into Accessibility Assessment Map. (Source: Illustrated by Author)

Comparing Accessibility Assessment maps for different facilities

Figure 6-22 illustrates variations in accessibility scores for healthcare, agriculture, education, and other essential facilities. The weighting of these scores is informed by survey analysis, which indicated that respondents most frequently travel for healthcare, agricultural, and educational purposes. At first glance, the maps appear similar; however, closer examination reveals subtle differences. This variation arises because not all facilities are in the same places, resulting in different accessibility scores for villages based on the input matrices. These Accessibility Assessment maps highlight the stark contrast in accessibility between villages and towns along major roads and those located further away from these roads.

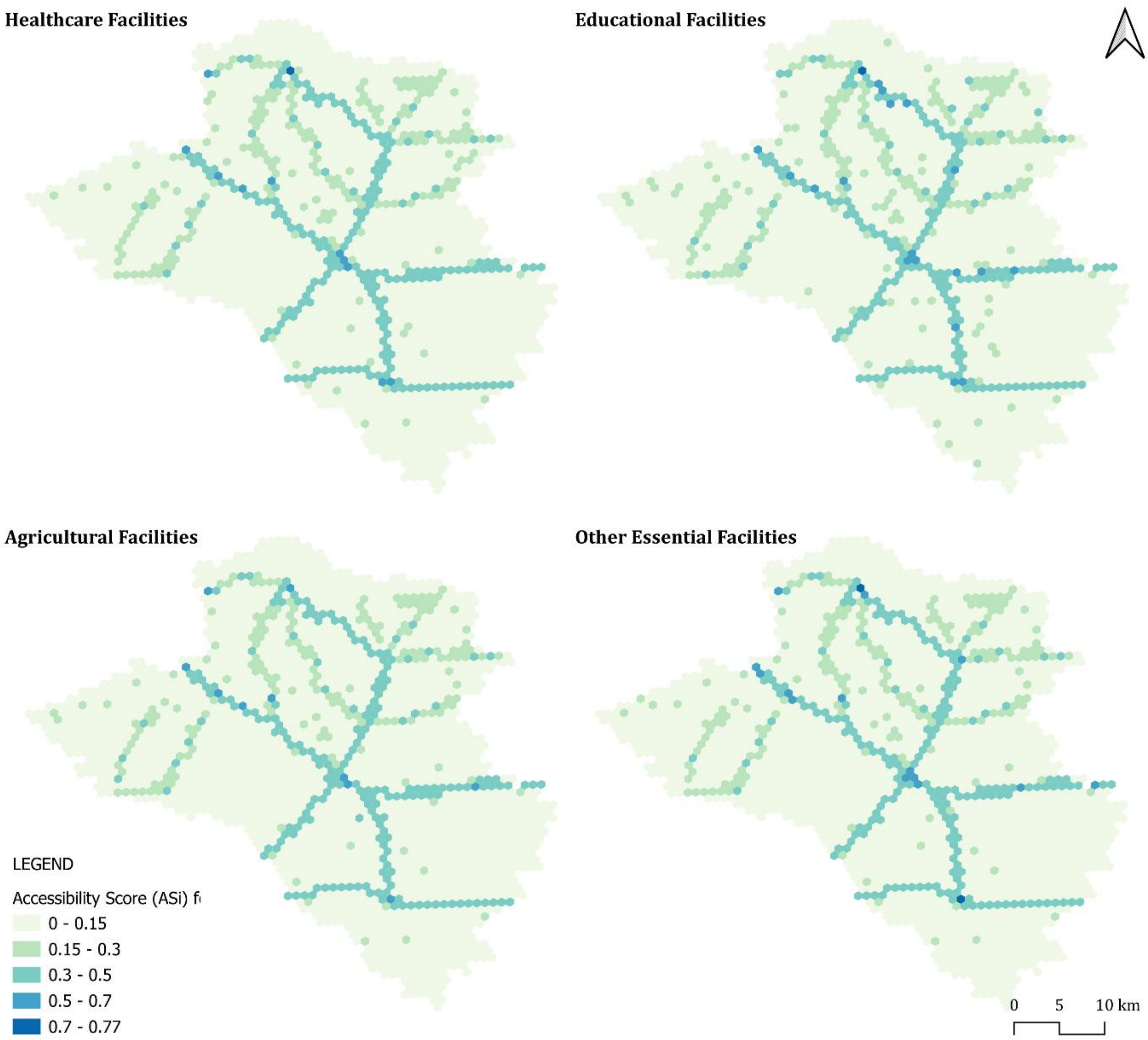


Figure 6-22 These maps illustrate accessibility for different facilities and services. (Source: Illustrated by Author)

How Demand-Responsive Transport (DRT) can be beneficial to access various facilities

Improving access to healthcare through Demand-Responsive Transport (DRT) can have a transformative impact on communities, particularly in low-accessibility areas. By integrating DRT with emergency healthcare services, rapid response and transportation to healthcare facilities can be ensured, which is crucial in emergencies. Additionally, offering reliable transport options for regular medical check-ups and treatments can significantly improve overall health outcomes for residents in underserved regions.

Facilitating market access through DRT can enhance the economic viability of rural areas. For farmers, DRT can provide efficient transportation of produce to markets or agricultural service centres, thereby reducing post-harvest losses and improving market access. Furthermore, DRT can ensure the timely delivery of agricultural inputs such as seeds, fertilizers, and equipment, thus enhancing productivity and supporting rural economies.

Enhancing student mobility through DRT can play a critical role in improving educational outcomes. In regions with low educational facility scores, DRT can help students reach schools and educational institutions that are otherwise inaccessible due to distance or lack of public transport. Additionally, DRT can support access to after-school programs, extracurricular activities, and educational resources, promoting the holistic development of students.

Other Interpretations and usefulness of Accessibility Assessment Map

Using the weighted scoring system, the overall analysis provides a comprehensive spatial assessment of the study area by integrating service density, public transport frequency, demographic data, road categories, and time isochrones. The results of this analysis offer the following insights:

1) **Detection of Service Gaps:** The analysis reveals areas with low combined scores, indicating potential service gaps. These areas may lack sufficient services and public transport options or have less favourable demographic conditions. Identifying these gaps can help in planning and prioritising interventions to improve service delivery and infrastructure.
2) **Data-Driven Decision Making:** The integration of multiple data layers into a single score facilitates data-driven decision-making. Stakeholders can rely on quantitative assessments rather than subjective judgments, leading to more objective and effective planning.
3) **Improved Resource Allocation:** Urban planners and policymakers can use the results to decide where to allocate resources, build new infrastructure, or enhance existing services. For example, areas with low service density but high population density might be prioritised for new service facilities.
4) **Strategic Location for New Services and Infrastructure:** Businesses and service providers can use the analysis to identify optimal locations for new branches or facilities. High combined scores indicate areas with good accessibility and a potential customer base, making them attractive for new investments.
5) **Balanced Development:** The results guide efforts towards balanced development by identifying areas that need more attention versus those that are already well-served. This can help achieve equitable distribution of services and infrastructure across the region.

7. DRT design and service specification

Demand-responsive Transport (DRT) systems offer a flexible and adaptive approach to public transportation, designed to address the dynamic needs of both urban and rural communities. By conducting a spatial analysis of the study area, we identified service gaps in transport frequency, spread and clustering of available services and facilities, and the time required to access those areas. The result was visualised using accessibility assessment maps created with a layered data approach in the H3 spatial index. Unlike traditional fixed-route services, DRT systems provide on-demand transit solutions, optimising routes and schedules based on real-time passenger requests. This innovative model aims to enhance accessibility, reduce congestion, and deliver a more efficient, user-centric transport service. The growing interest in DRT systems is driven by their potential to overcome the limitations of conventional public transport, particularly in areas with low population density or irregular travel patterns (Mulley & Nelson, 2009); (Davison et al., 2014).

The successful design and implementation of a DRT system require careful planning and consideration of various factors, including service coverage, operational logistics, and technological infrastructure. Effective DRT systems can make significant contributions to sustainable urban mobility by incorporating advanced dispatch and routing technologies, ensuring accessibility for diverse user groups, and promoting environmentally friendly transport options (Papanikolaou et al., 2017). This chapter presents comprehensive steps for designing DRT systems based on the previous analysis and findings, focusing on defining service objectives, establishing coverage areas, determining stops, and improving overall PT accessibility.

Service Objectives

The spatial analysis revealed significant gaps in public transport coverage, indicating that it does not serve the entire population or cover the entire territory. The primary objective is to ensure that every village and town in the Katol-Narkhed sub-districts receive adequate public transport service. The second objective is to reduce waiting times for public transport arrivals. The third objective focuses on enhancing connectivity to services and facilities by offering Demand-Responsive Transport (DRT) services during non-peak hours and nighttime.

Following are the guideline steps for designing a DRT system based on the Analysis results:

1) Select High-Value Towns

- Based on the Spatial Assessment map, shortlist the High Value Towns.

- These High-Value Towns have better connectivity, high public transport frequency and many services which generate demand.

2) Establish Coverage Areas

- Analyse the spatial assessment map and identify clustering of low-value areas.
- Define the geographical boundaries of the DRT service area based on the proximity of the HVTs and natural cut-off points, e.g. administrative boundaries, major roads, natural borders, etc.

3) Determine Stops and Pickup Points

- Strategically locate stops to maximise accessibility and improve connectivity, ensuring safety and convenience.
- Based on the population density, choose villages that will use fixed stops or flexible pickup points.

4) Select the Type of DRT

- Based on the overall analysis and the stop locations and route, select an appropriate combination of Models for DRT

7.1. Selecting High-Value Towns

Based on the analysis of the Accessibility Assessment Maps, several high-value Towns (HVTs) have been identified within the region. These HVTs correspond to towns that exhibit superior connectivity, frequent transportation options, high service density, and a significant creation of demand. The Accessibility score (ASi) depicted on the map highlights these areas as being of particular interest. According to survey analysis, these HVTs are frequented by individuals for a variety of needs and reasons, indicating their importance as regional hubs. The spatial distribution of higher ASi values often concentrated around the HVTs, suggests that these towns serve as central points of activity and services. This frequent travel and utilisation underscore the critical role these areas play in meeting the demands of the population. Figure 7-1 utilises a gradient colour scheme to effectively convey the variations in ASi, with darker shades indicating higher values. This visual representation allows for a clear identification of the spatial patterns and the relative significance of different areas within the region. The network-like patterns observed, potentially following major roads or other infrastructural features, further reinforce the connectivity and accessibility of these HVTs.

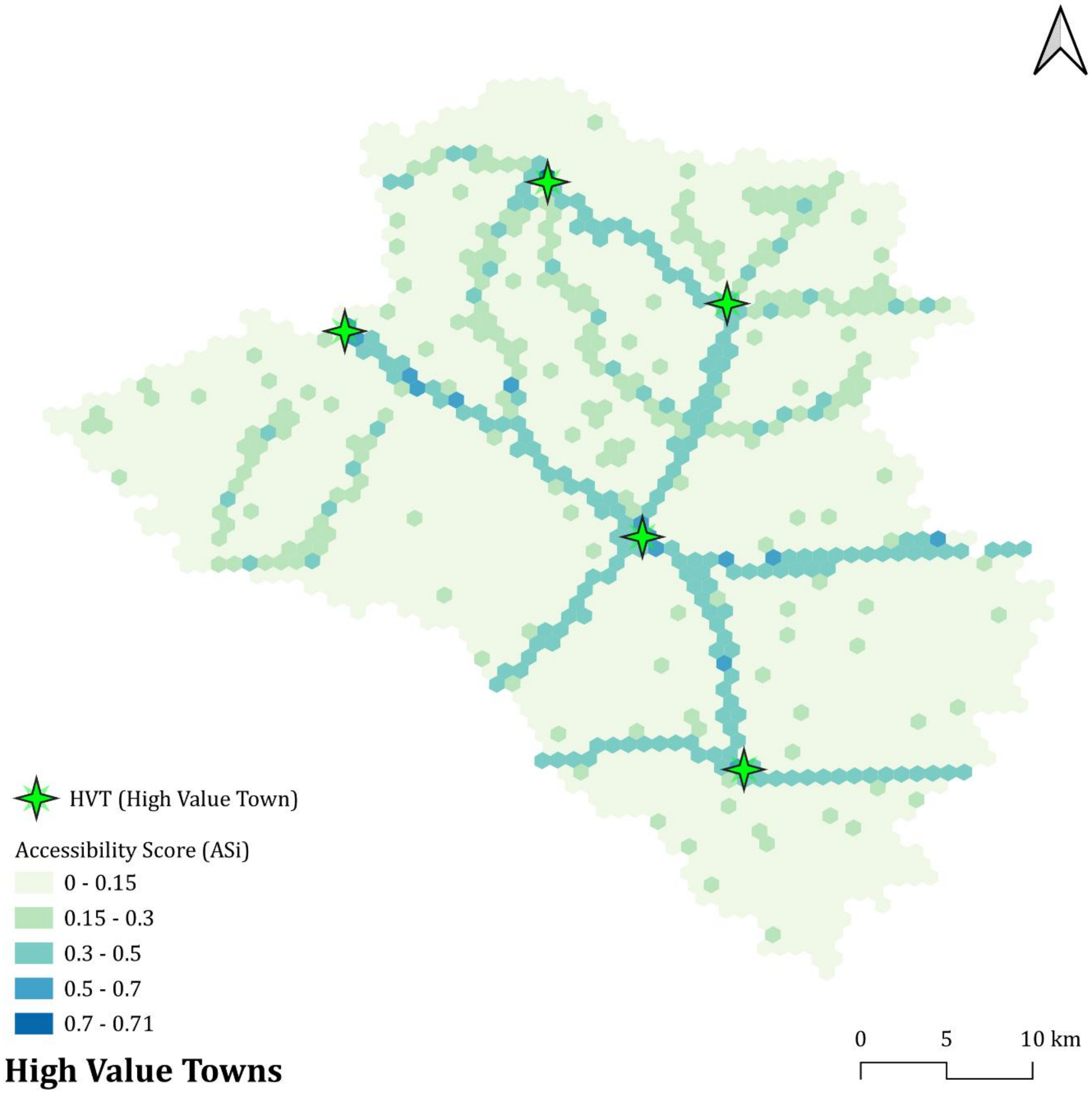


Figure 7-1 The map visualises High-Value Towns based on the clustering of high accessibility score hexagons. (Source: Illustrated by Author)

7.2. Establishing Coverage Area

These High-Value Towns (HVTs) are strategically located along major roads and frequent transportation routes, making them high-demand areas for neighbouring villages. Given their connectivity and the population distribution across the region, these HVTs, along with the major roads, are utilised as territorial boundaries for defining coverage areas for Demand Responsive Transport (DRT) services. Consequently, each coverage area is designed to connect one or more HVTs, ensuring efficient and effective transport solutions as shown in Figure 7-2.

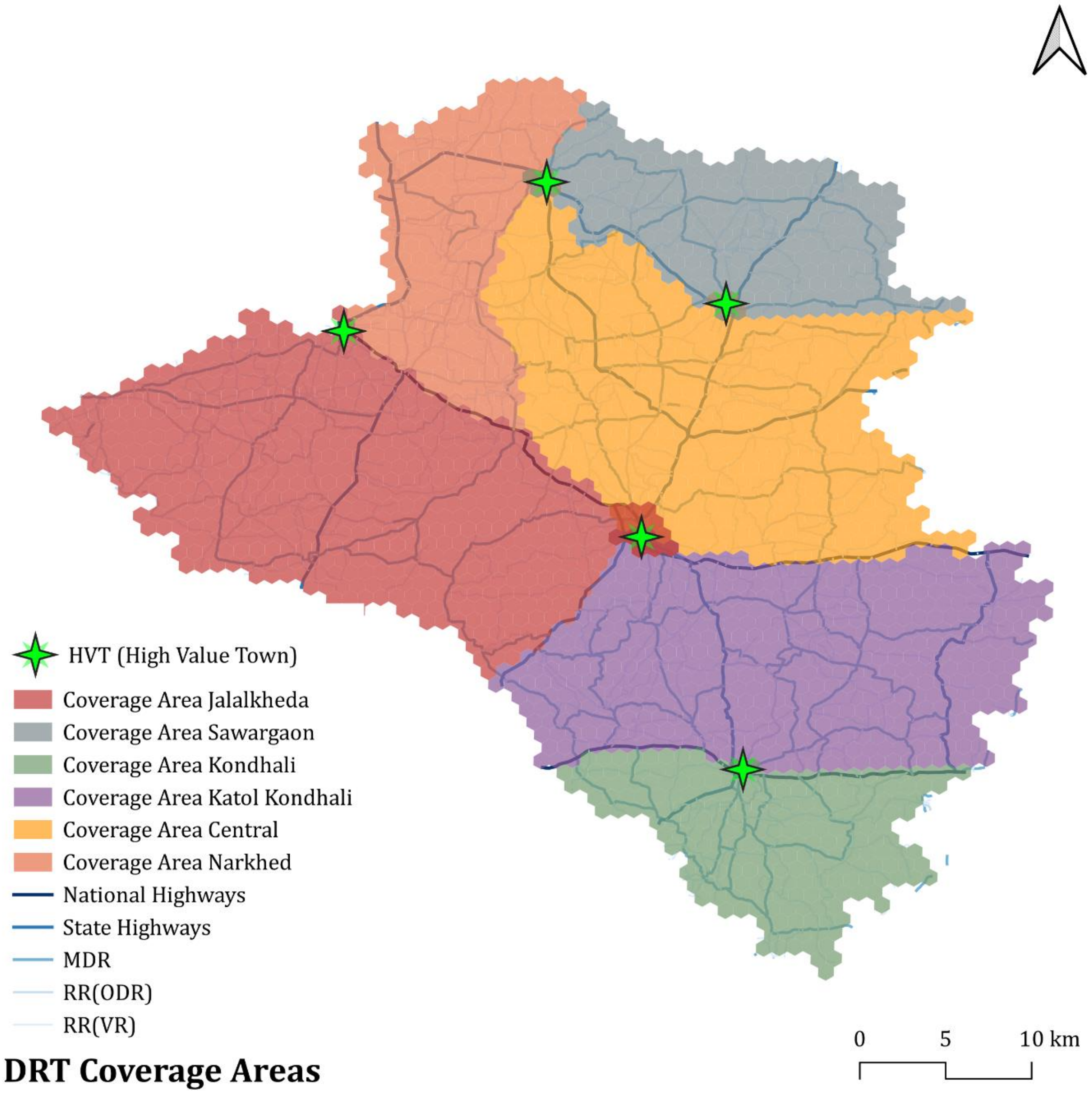


Figure 7-2 The map defines the coverage areas for the DRT service.
(Source: Illustrated by Author)

The spatial arrangement of these HVTs facilitates the creation of well-defined service zones, optimising the reach and accessibility of DRT services. By aligning the coverage areas with the major roads and the HVTs, the transport network can better accommodate the travel patterns and service needs of the population. This approach not only enhances the connectivity of remote villages to the HVTs but also supports the overall mobility and economic activity within the region.

7.3. Determining stops

Selecting appropriate stops within the designated study area for demand-responsive transport (DRT) systems emerges as a relatively straightforward process, particularly due to the conspicuous absence of conventional bus services in villages distanced from major thoroughfares. This gap in accessibility makes the inclusion of such villages imperative; they are systematically integrated into the DRT stops list, ensuring coverage of areas otherwise neglected by existing transport infrastructures.

In addition to addressing the transportation void in remote villages, the placement strategy for DRT stops also emphasizes inclusion in High-Value Towns (HVTs). These towns, characterized by their significant socio-economic importance or higher population densities, are provided with multiple stops. This approach not only facilitates access to essential services and facilities for residents of HVTs but also extends connectivity to adjacent, less accessible areas, thereby enhancing the overall utility and reach of the DRT system.

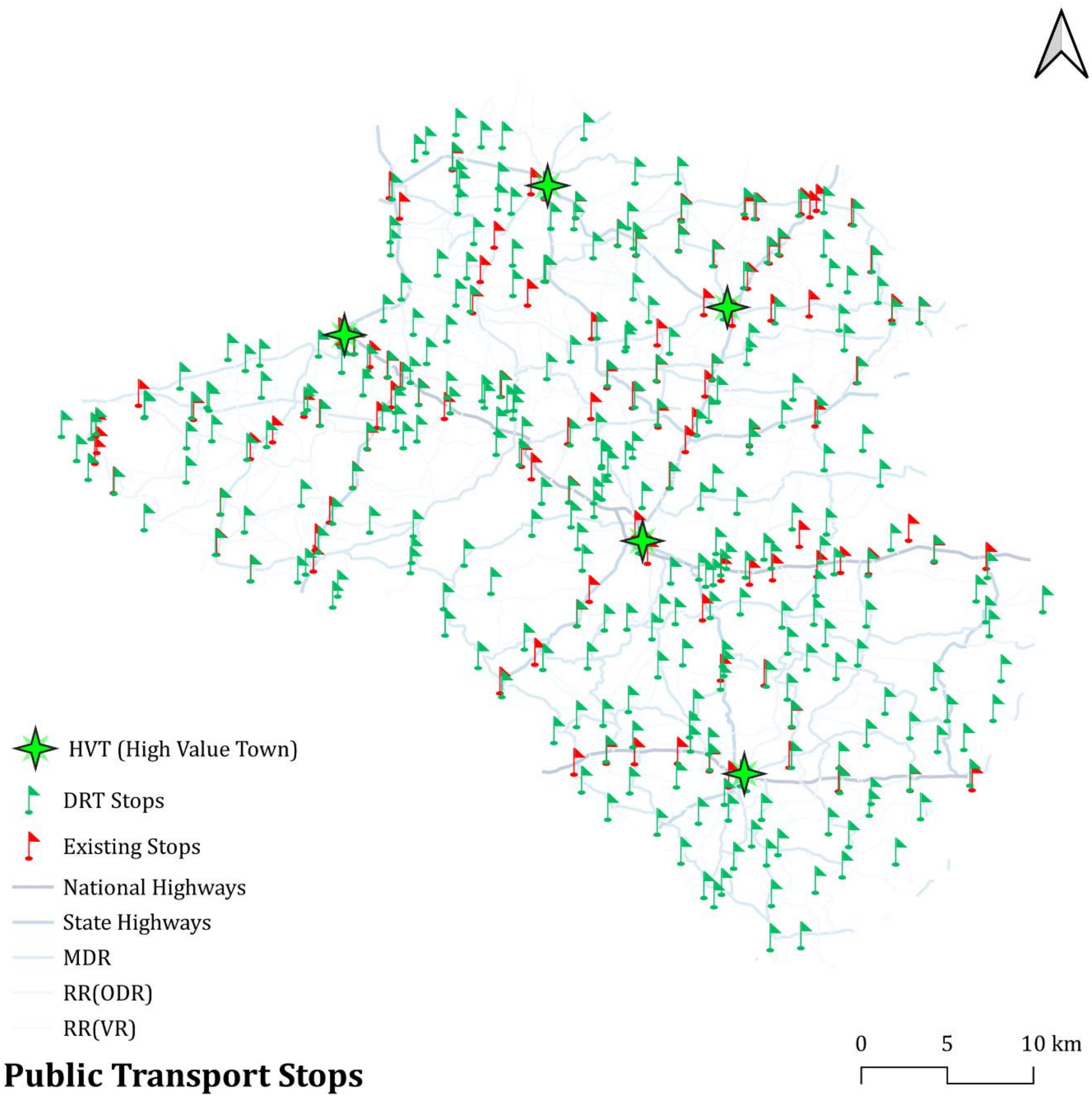


Figure 7-3 Updated public transport stops.
(Source: Illustrated by Author)

Comparative analysis of the existing transport system underscores the expansiveness of the proposed DRT framework. The current setup comprises 111 stops, which include both bus and railway stations. This number, while adequate for a conventional fixed-route system, is markedly insufficient for comprehensive area coverage, particularly in rural or underserved regions. In contrast, the proposed DRT scheme dramatically increases the number of stops to 300. This enhancement not only promises improved access for all villages within the study area but also reflects a strategic commitment to inclusive transport planning. By more than doubling the number of stops, the DRT initiative aims to deliver a robust solution to mobility challenges in the region, fostering greater socio-economic integration and accessibility.

7.4. Selection of Type of DRT

The implementation of Demand Responsive Transport (DRT) services aims to provide last-mile connectivity accessible to all individuals. To achieve this, a hybrid service model has been selected, combining the extension of traditional services with the detour of scheduled services. The extension of traditional services involves lengthening existing routes with predefined schedules to cover underserved or unserved areas, thus improving accessibility and connectivity for remote or isolated regions. This method ensures reliable and regular transportation options for a broader population. In addition, the detour of scheduled services introduces flexibility by allowing deviations from predefined routes to accommodate real-time passenger pick-ups and drop-offs. This responsive approach ensures that the transport service

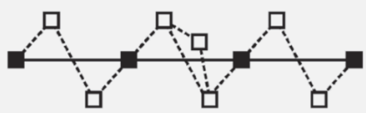
Selected DRT Models for Implementation in the Study Area		
	**Extension of a traditional service with a predefined route and schedule**	Stops and routes are known. Some extension stops can be served on demand. The feasibility of such a service is limited because the extension route may lead to severe delays on the non-demand route.
	**Detour of a scheduled service along predefined routes**	The detour leads to increased direct route times, so seeking the right balance between detour and default route is essential. Users must be informed about delay margins on fixed service stops.
Legend	■ Predefined stop, always served, with scheduling □ Predefined stop, with scheduling, served only on request	

Table 7-1 Selected DRT models

can dynamically adjust to meet the varying travel demands of the population, offering a more personalised and efficient service.

By integrating these two service types described in Table 7-1, the DRT model provides comprehensive coverage and enhances the transport network's adaptability. This strategy ensures that last-mile connectivity is both reliable and flexible, meeting the diverse transportation needs of all residents in the study area and improving overall mobility and quality of life.

In the study area, the integration of two Demand-Responsive Transport (DRT) models has led to an updated stop selection, categorizing stops into three distinct types. The first category includes stops on already high-frequency lines, which are marked in red, indicating their existing high-

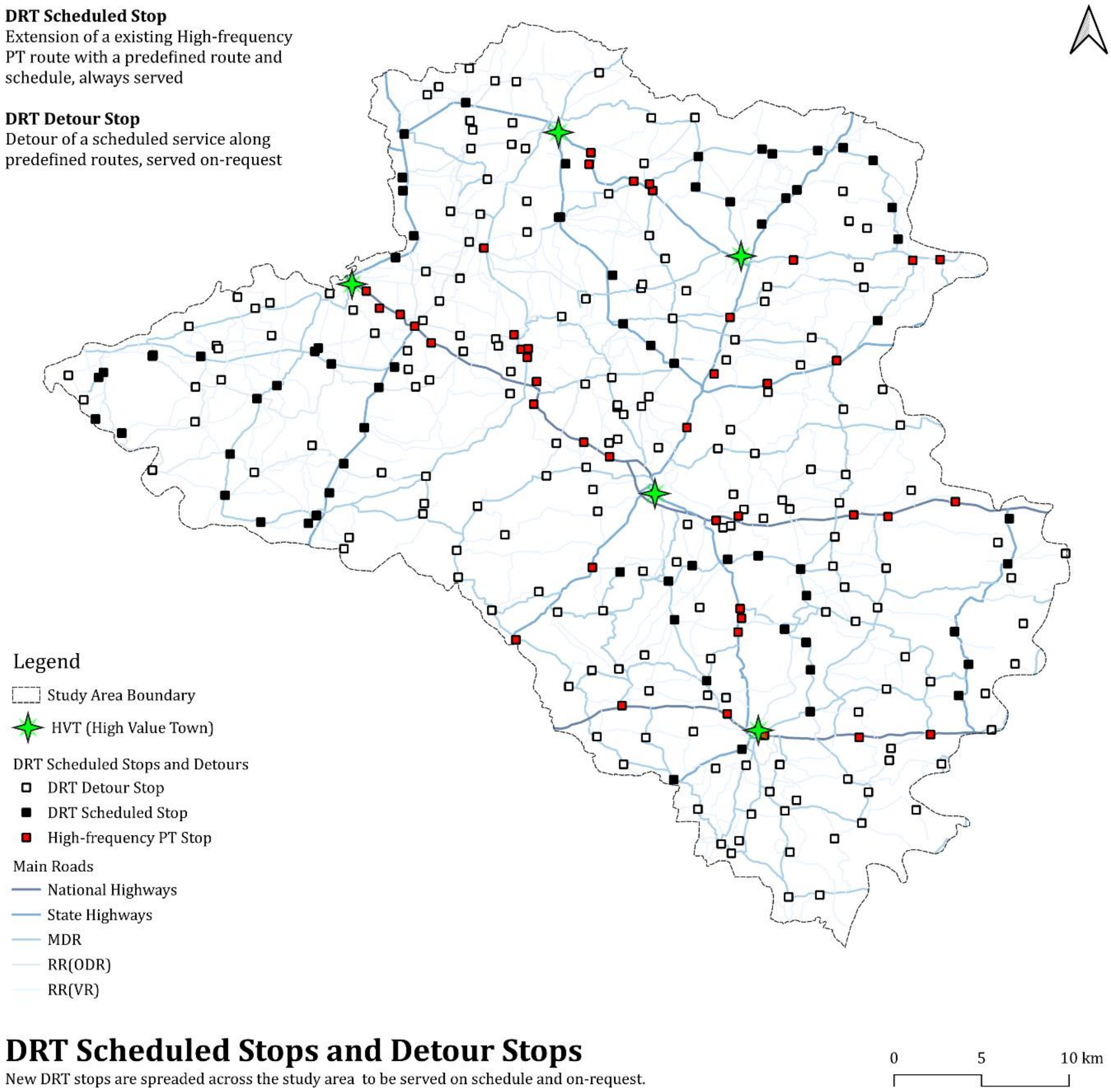


Figure 7-4 DRT Scheduled and Detour stops.
(Source: Illustrated by Author)

frequency public transport (PT) connectivity. The second category consists of medium and low-frequency stops that have been converted to DRT scheduled stops. These stops will be served by medium-sized vehicles on a predefined schedule, consistently extending the high-frequency PT network. The third category comprises stops that were previously unserved by the existing PT system. These are designated as DRT detour stops, which will be served on request. These detour stops are strategically located near DRT scheduled stops to minimise waiting times. The categorization and visual representation of these stops are illustrated in Figure 7-4.

7.5. Accessibility Assessment Map with DRT

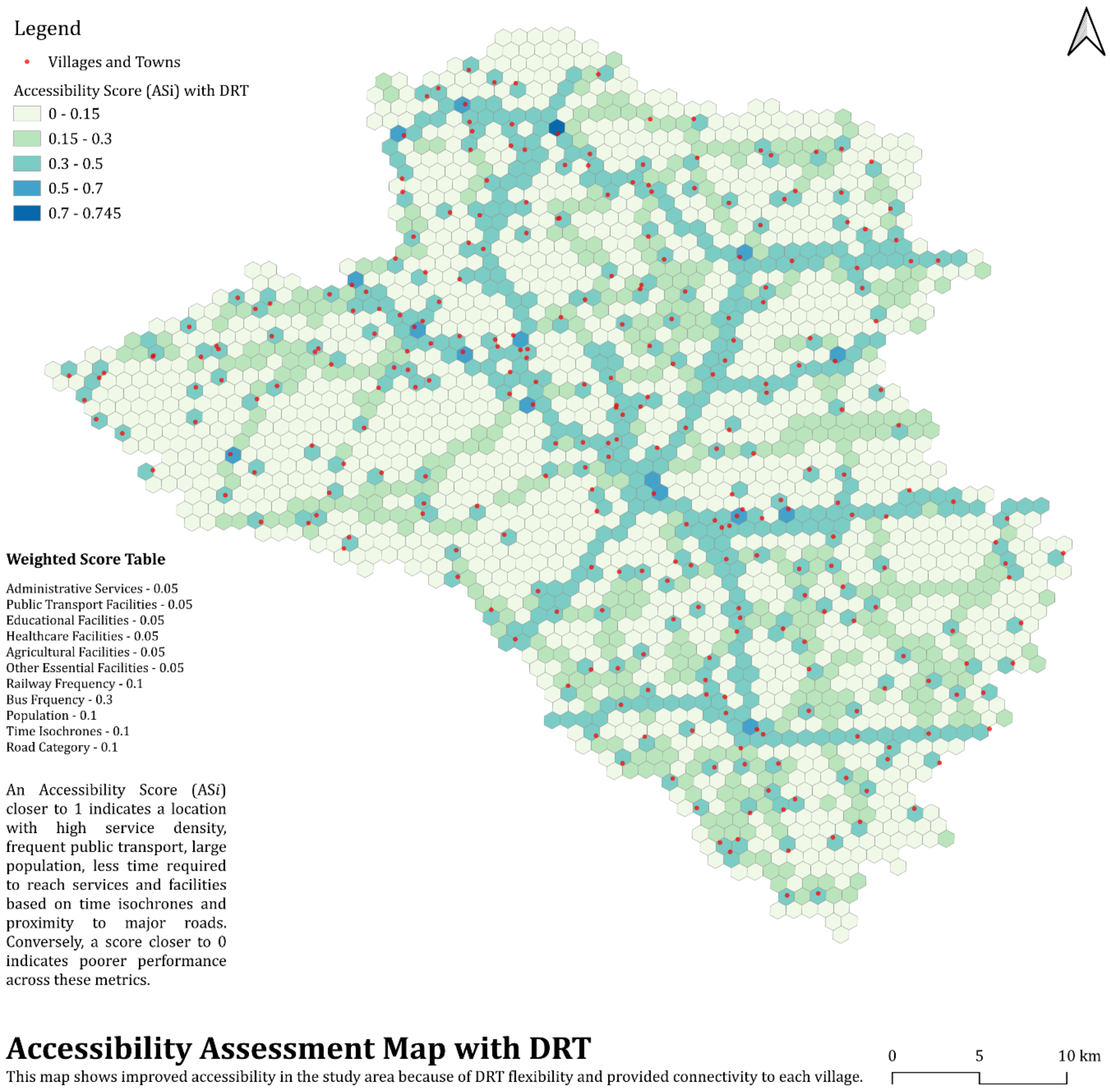


Figure 7-5 Accessibility Map together with villages show Improved Accessibility score for each village. (Source: Illustrated by Author)

The accessibility map with DRT in Figure 7-5, demonstrates, that enhancing public transport connectivity across all villages significantly boosts the overall accessibility score. This visualisation underscores the substantial benefits that Demand-Responsive Transport (DRT) offers, particularly for underserved and vulnerable communities. By effectively bridging gaps in the existing transport network, DRT plays a pivotal role in ensuring equitable access to essential services and opportunities.

7.6. Comparative Visual Analysis Results

The comparative visual analysis between accessibility with existing PT and accessibility with DRT analyses the maps based on colour and hexagonal cells identifying the overall change.

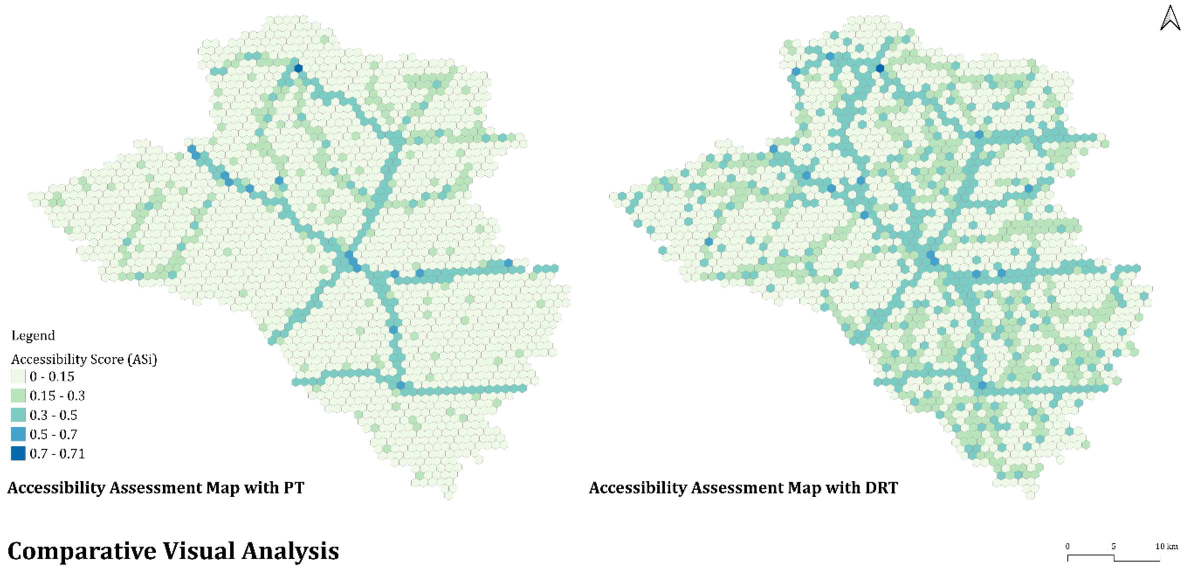


Figure 7-6 Comparative Visual Analysis
(Source: Illustrated by Author)

Table 7-2 Change Comparison Table Total hexagons – 2218. (Source: Author)

Accessibility Assessment Map (With PT)			**Accessibility Assessment Map (With DRT)**		
ASi	**No. of Hexagons**	**% of Hexagons**	**ASi**	**No. of Hexagons**	**% of Hexagons**
0 - 0.15	1767 hexagons	79.7%	0 - 0.15	1273 hexagons	57.4%
0.15 - 0.3	220 hexagons	9.9%	0.15 - 0.3	449 hexagons	20.2%
0.3 - 0.5	213 hexagons	9.6%	0.3 - 0.5	479 hexagons	21.6%
0.5 - 0.7	17 hexagons	0.8%	0.5 - 0.7	16 hexagons	0.7%
0.7 - 0.71	1 hexagon	0.05%	0.7 - 0.745	1 hexagon	0.05%

These results shown in Table 7-2 indicate that the introduction of DRT has improved overall accessibility in the Katol-Narkhed subdistricts, increasing the percentage of hexagons with medium to high accessibility scores and reducing the percentage of hexagons with low accessibility scores.

8. Conclusions

This study has revealed critical insights into the state of rural transportation and the potential for Demand-Responsive Transport (DRT) systems to address these challenges. Analysing transport-related policies since 1950 indicates a significant gap in the focus on rural transport innovation. Despite numerous policies aimed at improving road infrastructure, encouraging private transportation innovations, and electrifying vehicles, there has been a notable absence of policies dedicated to developing new transport services specifically for rural areas. The current public transportation system, particularly in rural regions, remains inadequate and is further strained by financial burdens. This lack of targeted policy attention has resulted in a transportation infrastructure that fails to meet the needs of rural populations effectively.

The survey conducted among residents of the Katol and Narkhed sub-districts highlighted a profound distrust in the existing public transport system. Key issues identified included infrequent service, long waiting times, and the need for multiple connections to reach destinations. Notably, 97% of respondents expressed a willingness to use a DRT system, and 90% of respondents were willing to pay a higher fare compared to traditional bus services. Additionally, 40% of respondents were willing to pay 50% more than the current fare for improved services. The primary reasons for preferring DRT included the convenience, flexibility, and improved accessibility it offers. These findings underscore the high demand for reliable and efficient transportation solutions in rural areas.

The spatial analysis provided a comprehensive view of the existing transport infrastructure and service availability. Bus frequency analysis revealed a high frequency of bus services along National and State highways, with a significant drop in frequency on other roads, particularly in the afternoon and nighttime. GIS mapping demonstrated a high concentration of services and facilities along major highways, leaving many rural areas underserved. Kernel Density Estimation (KDE) indicated significant clustering of administrative (Moran's I: 0.708), educational, healthcare, and agricultural facilities, suggesting strong service concentration in specific areas. Isochrones Analysis identified underserved regions with poor accessibility and long travel times to essential services, highlighting critical areas needing improved transport solutions.

The spatial assessment using the Accessibility Score (ASi) revealed that 56% of the total population resides in areas with medium to high combined scores, indicating better proximity to and accessibility of facilities and services. The remaining 44% live in areas with low combined scores, reflecting inadequate transportation and limited access to essential services. These lower-scoring areas are primarily located away from major roads, exacerbating the accessibility issues for nearly half of the rural population. This suggests that almost half of the population have less proximity to facilities and services, low accessibility to facilities and services, and face inadequate transportation. Most medium to high Accessibility score (ASi) areas are located along or in the proximity of major roads.

The findings collectively highlight the urgent need for innovative mobility solutions tailored to the specific needs of rural areas in India. The current policy framework has not adequately addressed the unique challenges of rural transportation, resulting in significant accessibility and service gaps. The positive response to the DRT system from the survey participants, combined with the detailed spatial analysis, provides a strong case for the implementation of DRT services as a viable solution to enhance rural mobility.

The implementation of a Demand Responsive Transport system presents a promising opportunity to significantly improve the existing public transport infrastructure and enhance last-mile connectivity. The DRT promisingly improved the score for areas previously scoring low accessibility scores (ASi). This conclusion is based on a preliminary analysis of the study area. The DRT system is designed to extend high-frequency existing public transport lines and act as a feeder service, thereby connecting villages and remote locations to high-value town (HVT) services. The analysis indicates a substantial increase in the overall public transport coverage area, as it serves the whole territory based on demand. The comprehensive spatial analysis and survey results indicate that DRT is a viable solution to promote sustainable mobility in rural and remote areas, not merely limited to urban settings. By addressing these transportation challenges through targeted policies and innovative service models, it is possible to significantly improve the quality of life for rural residents and foster more equitable socio-economic development.

In conclusion, the study posits that the implementation of a DRT system can significantly enhance the existing public transport framework and improve accessibility for underserved populations. However, as gleaned from the literature review, further analysis and in-depth studies are imperative for the successful deployment of DRT systems. It is crucial to ensure that these systems meet the specific needs and contexts of the areas they are designed to serve. By addressing these requirements, DRT systems can facilitate a more inclusive and efficient public transport network, thereby contributing to sustainable mobility solutions across diverse geographic regions.

8.1. Policy Recommendations

The following table outlines the critical issues identified in rural transportation, along with proposed approaches and detailed policy recommendations aimed at addressing these challenges. The recommendations are based on a comprehensive analysis of historical transport policies, spatial analysis, and survey data, highlighting the urgent need for innovative solutions tailored to the unique needs of rural populations. The table describes each policy recommendation, identifying the key beneficiaries and offering a strategic approach to improving rural mobility and accessibility.

Table 8-1 Rural transport policy recommendations

	Problem/Issue	Approach	Policy Recommendation	Beneficiaries
A	**Need for comprehensive rural transport policy**	A historical review of policies shows a lack of focus on rural transport innovation and inadequate public transport in rural areas.	Develop targeted policies to foster rural transport innovations and address the unique challenges faced by rural populations, moving beyond infrastructure improvements to include service-based solutions.	Everyday transport users, Local communities, Business communities, Transport service providers, Tourists
B	**Lack of innovative rural transport solutions and inadequate existing public transport**	The Demand-Responsive Transport (DRT) system can enhance rural mobility, providing convenience, flexibility, and improved accessibility for rural populations.	Develop and implement policies promoting DRT systems specifically for rural areas, focusing on improving frequency, reducing waiting times, and enhancing overall service coverage through public-private partnerships.	Everyday transport users, Local communities, Business communities, Students, Senior Citizens, Healthcare workers and vulnerable populations.
C	**Significant gaps in infrastructure and accessibility**	Utilising spatial analysis to identify underserved regions and improve last-mile connectivity.	Invest in infrastructure, including increased bus frequency on non-highway roads and enhanced service and facilities coverage for rural areas.	Everyday transport users, Local communities, Business communities, educational institutions, Healthcare facilities and Agricultural sectors.

8.2. Limitations

The current investigation faced several important constraints. The survey's coverage was limited by time and budget, affecting the generalisability of the results. Specifically, the lack of detailed data on rural areas, including incomplete bus timetable data at the time of thesis research taken place for Sawargaon, Kondhali, and Narkhed bus stations, incomplete information about bus routes, outdated facilities and services layers, and lack of actual travel demand data hindered a thorough assessment of service availability, frequency, and accessibility. This prevented a comprehensive evaluation of rural transportation needs. Additionally, relying on publicly available open-source datasets limited the depth and breadth of analysis in these rural contexts. The study also lacked sufficient expertise in feasibility assessment, resulting in an incomplete exploration of demand-responsive transport (DRT), particularly concerning fleet size, platform selection, and cost-benefit analysis. Future research should address these gaps and build upon the findings of this study to improve the understanding and implementation of DRT systems.

8.3. Future Use

Future work extending this study should include a detailed feasibility analysis of Demand-Responsive Transport (DRT), encompassing a comprehensive cost-benefit analysis, identification of funding opportunities, and a thorough examination of implementation approaches. This analysis should also involve assessing the operational logistics, evaluating potential market demand through a comprehensive survey of Katol-Narkhed sub-districts, conducting an in-depth stakeholder analysis, and considering regulatory and policy frameworks. Such an in-depth study would provide critical insights into the economic viability, potential sources of financial support, and practical strategies for deploying DRT systems effectively. By addressing these aspects, future research can offer actionable recommendations to enhance the adoption and success of DRT in various contexts, thereby improving transport solutions for underserved regions.

Given the scalable nature of the methodology employed, particularly the use of the Hexagonal Hierarchical Spatial Index (H3), this approach holds significant potential for application in other geographical areas and contexts. The methodology could be adapted for studies on adopting transportation electrification, decision-making for charging station locations, and other critical aspects of modern transport infrastructure.

An exciting extension of this research would be the development of a user-friendly interactive web service. This platform would enable the visualisation and analysis of transportation data on a larger scale, potentially at district and state levels. Such a tool would aid in planning and decision-making and engage stakeholders dynamically and informally. Through this service, residents could visualise transport data and provide feedback on services, fostering community involvement in transport planning. This engagement would ensure that development efforts align with the needs and preferences of local populations.

Moreover, the platform could serve as a crucial tool for evaluating the environmental impacts of various transport strategies and promoting sustainable mobility solutions. By analysing different scenarios and their potential effects on the environment, the service would assist policymakers and planners in making informed decisions to reduce carbon footprints and improve overall environmental health.

These enhancements would expand the applicability of the research findings and ensure their relevance and value for ongoing transport planning and decision-making, bridging the gap between theoretical research and practical, impactful implementations. This integrated approach would advance our understanding of transport systems and contribute significantly to the sustainable development of transportation infrastructures globally.

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Appendix

Survey Questionnaires

Transport users survey to understand the problems of public transport service (ST bus) of Katol-Narkhed talukas (Sub-districts) and to create awareness about demand-response transport (DRT) system

नमस्कार! मी प्रतीक लटवे, पॉलिटेक्निको डी टोरिनो, इटली येथे पदव्युत्तर पदवी विद्यार्थी आहे. काटोल-नरखेड तालुक्याच्या ग्रामीण भागात भविष्यात 'प्रवासाचा हक्क' म्हणून प्रत्येकाला अत्यावश्यक, शेवटच्या मैलाची सेवा देण्यासाठी आणि सामाजिक समावेशकता वाढवण्यासाठी नवीन परिवहन सेवेचा माझा प्रबंध विषय म्हणून मी संशोधन करत आहे. नवीन सार्वजनिक वाहतूक सेवेच्या संभाव्य अंमलबजावणीची गरज समजून घेण्यासाठी कृपया मला ही प्रश्नावली भरण्यास मदत करा. (प्रश्नावली 12 मिनिटांपेक्षा कमी वेळ घेईल आणि एकूण 33 प्रश्न असतील)

Hello! I am Pratik Latwe, Master's degree student at Politecnico di Torino, Italy. I am researching the new transport service as my thesis topic that can be implemented in future in the rural area of Katol-Narkhed Taluka to provide essential, last-mile service to everyone as a 'Right to Travel' and increase social inclusion. Please help me fill out this Questionnaire to understand the need for the possible implementation of the new public transport service. (The questionnaire will take less than 12 mins and has total 33 questions)

* 1. Where do you live? तुम्ही कुठे राहता?

* 2. What's your age? तुमचं वय काय आहे?
  - 10-18
  - 19-30
  - 31-58
  - 59-65
  - Above 65

* 3. What's your gender? तुमचे लिंग काय आहे?
  - Male पुरुष
  - Female महिला
  - Others इतर

* 4. What do you do? तुम्ही काय करता?
  - Student विद्यार्थी
  - Teacher शिक्षक
  - Business Person/Shop Owner व्यावसायिक व्यक्ती / दुकान मालक
  - Farmer शेतकरी
  - Day Labour दिवसमजूर
  - Homemaker गृहिणी
  - Government Employee सरकारी कर्मचारी
  - Private Job/Employee खाजगी नोकरी / कर्मचारी
  - Other इतर (please specify कृपया निर्दिष्ट करा)

* 5. Do you often travel to other villages? तुम्ही अनेकदा इतर गावी जाता का?
  - Yes हो
  - No नाही

* 6. Which village do you start your journey from? कुठल्या गावातून प्रवासाला सुरुवात करता?

* 7. What's your destination in your journey? आपल्या प्रवासातील शेवटचे स्थान काय आहे?

* 8. How much time the total journey takes? एकूण प्रवासाला किती वेळ लागतो?
  - Less than 30 mins ३० मिनिटांपेक्षा कमी
  - 30 mins to 1 hour ३० मिनिटे ते १ तास
  - 1 hour to 2 hours १ तास ते २ तास
  - More than 2 hours २ तासांपेक्षा जास्त

* 9. How often do you take this journey? हा प्रवास तुम्ही किती वेळा करता?
  - Everyday दररोज
  - 4-5 times a week आठवड्यातून ४-५ वेळा
  - 1-2 times in a week आठवड्यातून १-२ वेळा
  - 2-3 times a month महिन्यातून २-३ वेळा

* 10. When do you usually travel: आपण सहसा कधी प्रवास करता:
  - In weekdays सोमवार ते शुक्रवार
  - During weekends शनिवार रविवार
  - Any day कोणत्याही दिवशी

* 11. At what time do you start your journey? आपण आपला प्रवास किती वाजता सुरू करता?
  - 6AM-9AM
  - 9AM-12PM
  - 12PM-3PM
  - 3PM-6PM
  - 6PM-8PM
  - 8PM-12AM

* 12. For what purpose do you generally travel to your destination? आपण आपल्या अंतिमस्थानापर्यंत साधारणपणे कोणत्या उद्देशाने प्रवास करता?
  - Study शिकणे
  - Groceries/Daily Utilities/Vegetable Markets किराणा माल/दैनंदिन जीवनावश्यक वस्तू/भाजी मंडई
  - Agricultural Products कृषी उत्पादने
  - Health-related services आरोग्याशी संबंधित सेवा
  - Long-distance Travels लांब पल्ल्याचा प्रवास
  - Job/Business नोकरी/व्यवसाय
  - Day Labourer दिवसमजूर
  - Other इतर (please specify कृपया निर्दिष्ट करा)

* 13. What time do you return back to the place of start? सुरुवातीच्या ठिकाणी किती वाजता परत येता?
  - 6AM-9AM
  - 9AM-12PM
  - 12PM-3PM
  - 3PM-6PM
  - 6PM-8PM
  - 8PM-12AM

* 14. How do you make this journey? आपण हा प्रवास कसा करता?
  - ST Bus एसटी बससह
  - Other transport modes (Jeep, Auto) इतर वाहतुकीच्या साधनांसह
  - Walking चालत चालत
  - Bicycle सायकलसह
  - ST Bus + Walking एसटी बससह + चालत चालत
  - Other transport modes (Jeep, Auto) + Walking इतर वाहतूक साधने (जीप, ऑटो) + चालत चालत
  - Private Transport (Motorbike, Car) खाजगी वाहतूक (मोटारसायकल, कार)
  - with mix of all सर्वांच्या मिश्रणाने

* 15. What are other Public Transport options available other than ST Bus? बस व्यतिरिक्त इतर सार्वजनिक वाहतुकीचे पर्याय काय आहेत?
  - Jeep (12 seater Shared-taxi)
  - Auto (3-wheeled vehicle)
  - Private Bus Service खाजगी बस सेवा
  - Not Available at all अजिबात उपलब्ध नाही
  - Other इतर (please specify कृपया निर्दिष्ट करा)

* 16. How many transport service connections do you change to reach your destination? आपल्या अंतिमस्थानापर्यंत पोहोचण्यासाठी आपण किती परिवहन सेवा बदलता?
  - Zero शून्य
  - One एक
  - Two दोन
  - Three तीन
  - More than three तीनपेक्षा जास्त

* 17. Does your journey include more than 15 minutes of walking when taking the bus? आपल्या प्रवासात बस पकडताना 15 मिनिटांपेक्षा जास्त चालण्याचा समावेश आहे का?
  - Yes हो
  - No नाही

* 18. How much time do you wait for the Bus/Taxi/Auto to arrive? बस/टॅक्सी/ऑटो येण्याची किती वेळ वाट पहावी?
  - 0-5 mins
  - 6-10 mins
  - 11-20 mins
  - More than 20 mins

* 19. Which time of the day is the most difficult to get the Bus/Taxi/Auto? बस / टॅक्सी / ऑटो मिळविणे दिवसाच्या कोणत्या वेळेस सर्वात कठीण आहे?

- ◯ 6AM-9AM
- ◯ 9AM-12PM
- ◯ 12PM-3PM
- ◯ 3PM-6PM
- ◯ 6PM-8PM
- ◯ 8PM-12AM

* 20. What are the issues you find in the existing transport service? सध्याच्या परिवहन सेवेत कोणत्या अडचणी आढळतात?

- ◯ No Bus Service Available बस सेवा उपलब्ध नाही
- ◯ Less Bus Frequency बसची वारंवारता कमी
- ◯ Seat Unavailability जागेची अनुपलब्धता
- ◯ Safety सुरक्षितता
- ◯ Lack of Night Bus Service रात्रीच्या बससेवेचा अभाव
- ◯ Other इतर (please specify कृपया निर्दिष्ट करा)

* 21. Other than the different Public transport modes, do you also have to use your personal vehicle to go to other villages? वेगवेगळ्या सार्वजनिक वाहतुकीच्या साधनांव्यतिरिक्त, इतर गावांमध्ये जाण्यासाठी आपल्याला स्वतःच्या वाहनाचा वापर करावा लागतो का?

- ◯ Yes हो
- ◯ No नाही

* 22. What Personal Vehicle do you use? आपण कोणते वैयक्तिक वाहन वापरता?

- ◯ Motorbike मोटारसायकल
- ◯ Bicycle सायकल
- ◯ Car कार
- ◯ Bullock-Cart बैलगाडी
- ◯ No Vehicle वाहन नाही
- ◯ Other इतर (please specify कृपया निर्दिष्ट करा)

* 23. Have you ever needed to go to other Villages at night? तुम्हाला कधी रात्री च्या वेळी इतर गावी जाण्याची गरज पडली आहे का?

- ◯ Yes हो
- ◯ No नाही

* 24. For what reasons do you have to travel during night? कोणत्या कारणास्तव रात्रीच्या वेळी प्रवास करावा लागतो?

- ☐ Health-related needs आरोग्याशी संबंधित गरजा
- ☐ Long-distance travel needs लांब पल्ल्याच्या प्रवासाची गरज
- ☐ Other इतर (please specify कृपया निर्दिष्ट करा)

* 25. Would you use a night bus service (between 8PM-12AM) connecting to Katol, Narkhed, Health Facilities or Railway Stations? काटोल, नरखेड, आरोग्य सुविधा किंवा रेल्वे स्थानकांना जोडणारी रात्रीची बससेवा (रात्री ८ ते सकाळी १२ वाजेपर्यंत) वापराल का?

- ◯ Yes हो
- ◯ No नाही

* 26. Do you have a smartphone? तुमच्याकडे स्मार्टफोन आहे का?

- ◯ Yes हो
- ◯ No नाही

* 27. Have you heard of the Demand-responsive Transport (DRT) system before? (for example Ola, Uber) मागणी-प्रतिसाद वाहतूक (डीआरटी) सेवेबद्दल आपण आधी ऐकले आहे? (उदाहरणार्थ ओला, उबर)

- ◯ Yes हो
- ◯ No नाही

* 28. Do you know how Demand-responsive Transport (DRT) works? मागणी-प्रतिसाद वाहतूक (डीआरटी) कसे कार्य करते हे आपल्याला माहित आहे का?

- ◯ Yes हो
- ◯ No नाही

What is Demand-responsive Transport (DRT) system?
Demand-responsive Transport (DRT) is a type of transport service that provides shared transport to users who specify their desired location and time of pick-up and drop-off.

मागणी-प्रतिसाद वाहतूक (डीआरटी) सेवा म्हणजे काय?
मागणी-प्रतिसाद वाहतूक (डीआरटी) ही एक प्रकारची घरपोच वाहतूक सेवा आहे जी वापरकर्त्यांना सामायिक वाहतूक प्रदान करते जे त्यांचे इच्छित स्थान आणि पहिला थांबा आणि अंतिमस्थानाची वेळ निर्दिष्ट करतात आणि वापरकर्त्यांना अंतिमस्थानी सोडून देतात.

* 29. Would you choose a bus service (DRT) for villages and rural areas that picks you up at your house and drops you at or near your destination? आपण गावे आणि ग्रामीण भागासाठी अशी बस सेवा (डीआरटी) निवडाल जी आपल्याला आपल्या घरी उचलते आणि आपल्या अंतिमस्थानावर किंवा जवळ सोडते?

- ◯ Yes हो
- ◯ No नाही

* 30. If such a service is available, would you pay more for your daily journey than usual? जर अशी सेवा उपलब्ध असेल तर आपण आपल्या दैनंदिन प्रवासासाठी नेहमीपेक्षा जास्त पैसे द्याल का?

- ◯ Yes हो
- ◯ No नाही

* 31. How much more will you pay than the original fair? For example, if you pay Rs 20 for your everyday journey, how much will you pay for the new service? मूळ जत्रेपेक्षा किती जास्त पैसे द्याल? उदाहरणार्थ, जर आपण आपल्या दैनंदिन प्रवासासाठी 20 रुपये देत असाल तर नवीन सेवेसाठी आपण किती पैसे द्याल?

- ◯ Rs 20
- ◯ Rs 21 (5% more)
- ◯ Rs 22 (10% more)
- ◯ Rs 24 (20% more)
- ◯ Rs 30 (50% more)
- ◯ More than Rs 30

* 32. According to you, how useful will be the DRT system when implemented? तुमच्या मते डीआरटी प्रणाली लागू केल्यास कितपत उपयुक्त ठरेल?

Not Useful at all अजिबात उपयोगी नाही	Moderately Useful मध्यम उपयुक्त	Very Useful अतिशय उपयुक्त
◯	◯	◯

* 33. In which cases/instances, the DRT system will be most useful? कोणत्या प्रकरणांमध्ये/ घटनांमध्ये, डीआरटी प्रणाली सर्वात उपयुक्त ठरेल?

- ☐ For immediate Medical Help त्वरित वैद्यकीय मदतीसाठी
- ☐ In other emergency cases इतर आणीबाणीच्या प्रकरणांमध्ये
- ☐ For ease of Business व्यवसाय सुलभतेसाठी
- ☐ To save time वेळेची बचत करण्यासाठी
- ☐ For ease of Agriculture शेतीच्या सुलभतेसाठी
- ☐ To go to School शाळेत जाण्यासाठी
- ☐ Other इतर (please specify कृपया निर्दिष्ट करा)

QGIS SQL Statements

The following **QGIS** Field Calculator formula SQL statements are used to calculate the Variable Score (VSi) for each data layer and Combined Score (CSi) in the layered data approach:

Bus Frequency ($PTBusF_i$)	**Total Population (TP_i)**
CASE WHEN "Bus frequency"< 3 THEN 0.1 WHEN "Bus frequency">= 3 AND "Bus frequency"< 5 THEN 0.3 WHEN "Bus frequency">= 5 AND "Bus frequency"< 10 THEN 0.5 WHEN "Bus frequency">= 10 AND "Bus frequency"< 20 THEN 0.7 WHEN "Bus frequency">= 20 AND "Bus frequency"< 30 THEN 0.9 WHEN "Bus frequency">= 30 THEN 1 ELSE 0 END	CASE WHEN "Total Population"< 500 THEN 0.5 WHEN "Total Population">= 500 AND " Total Population "< 2000 THEN 0.6 WHEN "Total Population">= 2000 AND "Total Population"< 5000 THEN 0.7 WHEN "Total Population">=5000 AND "Total Population"< 10000 THEN 0.8 WHEN "Total Population">=10000 AND "Total Population"< 20000 THEN 0.9 WHEN " Total Population " >= 20000 THEN 1 ELSE 0 END
Railway Frequency ($PTRailF_i$)	**Time Isochrones (TI_i)**
CASE WHEN "Railway Frequency layer"< 2 THEN 0.1 WHEN "Railway Frequency">= 2 AND "Railway Frequency "< 5 THEN 0.3 WHEN "Railway Frequency">= 5 AND "Railway Frequency "< 10 THEN 0.5 ELSE 0 END	CASE WHEN "Time Isochrone layer" = 10 THEN 1 WHEN " Time Isochrone layer" = 20 THEN 0.7 WHEN " Time Isochrone layer" = 30 THEN 0.4 WHEN " Time Isochrone layer" = 45 THEN 0.1 ELSE 0 END
Service Density (SD_i) for each service category	**Road Categories (RC_i)**
CASE WHEN "Services Count Layers" < 2 THEN 0.5 WHEN " Services Count Layers ">= 2 AND " Services Count Layers " < 4 THEN 0.7 WHEN " Services Count Layers " >= 4 AND " Services Count Layers " < 6 THEN 0.9 WHEN " Services Count Layers " >= 6 THEN 1 ELSE 0 END	CASE WHEN "Road Category" = 'NH' THEN 0.9 WHEN "Road Category" = 'SH' THEN 0.8 WHEN "Road Category" = 'MDR' THEN 0.7 WHEN "Road Category" = 'RR(ODR)' THEN 0.6 WHEN "Road Category" = 'RR(VR)' THEN 0.5 ELSE 0 END

Bus Timetables from Katol and Sawargaon Bus stations