

Clean Air Initiatives for Indore's Public Transit: Planning for Infrastructure and Operations

Bachelor of Planning

Shubh Shrivastava
2211002101



Department of Architecture and Planning
Maulana Azad National Institute of Technology, Bhopal
462003

May 2026

CLEAN AIR INITIATIVES FOR INDORE'S PUBLIC TRANSIT: PLANNING FOR INFRASTRUCTURE AND OPERATIONS

BACHELOR OF PLANNING

SHUBH SHRIVASTAVA

2211002101



Department of Architecture and Planning
Maulana Azad National Institute of Technology, Bhopal
462003
May 2026

CLEAN AIR INITIATIVES FOR INDORE'S PUBLIC TRANSIT: PLANNING FOR INFRASTRUCTURE AND OPERATIONS

A Thesis Project

*submitted in partial fulfillment of the requirements for the
award of the degree of*

Bachelor of Planning

By

SHUBH SHRIVASTAVA

2211002101

Under the Guidance of

Dr. Rahul Tiwari



**Department of Architecture and Planning
Maulana Azad National Institute of Technology, Bhopal**

May, 2026

CANDIDATE'S DECLARATION

I Shubh Shrivastava, Scholar No. 2211002101 hereby declare that the Thesis Project "Clean Air Initiative for Indore's Public Transit: Planning for Infrastructure and Operations", submitted by me in partial fulfilment of the requirement for the award of degree of Bachelor of Planning at the Department of Architecture and Planning, Maulana Azad National Institute of Technology, Bhopal, India, is a record of Bonafide the work carried out by me. The matter/result embodied in this project has not been submitted to any other University or Institute for the award of any degree or diploma.

If, in future, it is found that the above statement is false, then I have no objection in withdrawal of Bachelor of Planning Degree awarded to me by the Institute.

Signature of the Student

Date:

CERTIFICATE

This is to certify that the declaration of Shubh Shrivastava is true to the best of my knowledge and that the student has worked under my guidance for one semester in preparing this thesis.

RECOMMENDATION

Signature of the Guide

ACCEPTED

Signature of
Head, Department of
Architecture and Planning
Date: _____
Place: _____

Space
for
Official
Seal

Signature of
Thesis Coordinator for Year of
2025-26
Date: _____
Place: _____

सारांश

भारत भर में शहर तेजी से बढ़ रहे हैं, और उस विकास के साथ गतिशीलता संबंधी चुनौतियाँ भी आती हैं जिन्हें नजरअंदाज नहीं किया जा सकता है। इंदौर, मध्य प्रदेश की वाणिज्यिक राजधानी और मध्य भारत के सबसे गतिशील शहरी केंद्रों में से एक, इसी चौराहे पर खड़ा है। पिछले दशक में, शहर में महत्वपूर्ण आर्थिक विस्तार, जनसंख्या वृद्धि और बाहरी शहरी फैलाव देखा गया है, इन सभी ने सामूहिक रूप से यात्रा की मांग को बढ़ाया है, यातायात की भीड़ को बदतर बना दिया है, और हवा की गुणवत्ता में लगातार गिरावट में योगदान दिया है। जबकि शहर ने मुख्य रूप से एआईसीटीएसएल बस सेवाओं और अब बंद हो चुके बीआरटीएस कॉरिडोर के माध्यम से एक संरचित सार्वजनिक परिवहन ढांचे के निर्माण के लिए सार्थक प्रयास किए हैं, यह प्रणाली कई महत्वपूर्ण क्षेत्रों में कमजोर बनी हुई है। असमान सेवा वितरण, रूट ओवरलैप, अपर्याप्त परिधीय कनेक्टिविटी, अनियमित शेड्यूलिंग और एकीकृत बुनियादी ढांचे की कमी ने सार्वजनिक परिवहन के आकर्षण को कम कर दिया है, जिससे अधिक निवासियों को निजी वाहनों की ओर धकेल दिया गया है और शहर की पर्यावरण और गतिशीलता चुनौतियां गहरी हो गई हैं।

"इंदौर के सार्वजनिक पारगमन के लिए स्वच्छ वायु पहल: बुनियादी ढांचे और संचालन के लिए योजना" शीर्षक वाली यह थीसिस सीधे तौर पर इन चुनौतियों का सामना करती है। इसका उद्देश्य इंदौर की जीवाश्म ईंधन आधारित सार्वजनिक परिवहन प्रणाली की वर्तमान सीमाओं को समझना और मूल्यांकन करना है कि इलेक्ट्रिक बसें कैसे स्वच्छ, अधिक कुशल और टिकाऊ विकल्प प्रदान कर सकती हैं। महत्वपूर्ण रूप से, अध्ययन इस परिवर्तन को एक साधारण वाहन अदला-बदली के रूप में नहीं, बल्कि एक व्यापक योजना प्रक्रिया के रूप में मानता है, जिसमें बुनियादी ढांचे की तैयारी, परिचालन पुनर्गठन और राष्ट्रीय और राज्य-स्तरीय नीति ढांचे के साथ संरेखण को संबोधित किया जाना चाहिए।

अध्ययन पांच परस्पर जुड़े चरणों के आसपास निर्मित एक संरचित, अनुक्रमिक पद्धति को अपनाता है। यह मौजूदा सार्वजनिक परिवहन प्रणाली के गहन आधारभूत विश्लेषण के साथ शुरू होता है, जिसमें भीड़भाड़ वाले गलियारों में प्राथमिक अवलोकन क्षेत्र सर्वेक्षण, ड्राइवरो और यात्रियों के साथ अनौपचारिक बातचीत, और बस स्टॉप और डिपो स्थितियों के प्रत्यक्ष मूल्यांकन के साथ-साथ एआईसीटीएसएल परिचालन रिपोर्ट, जीआईएस-आधारित मैपिंग, भूमि-उपयोग दस्तावेज़ और यातायात अध्ययन से माध्यमिक डेटा शामिल है। यह फाउंडेशन एक ऐसे नेटवर्क का खुलासा करता है जो अत्यधिक केंद्रीकृत, गलियारे पर निर्भर और रेडियल रूप से संरचित है, जिसके मार्ग एबी रोड, रिंग रोड और एमजी रोड जैसे प्रमुख मार्गों के साथ शहर के केंद्र की ओर मिलते हैं। हालांकि ये गलियारे महत्वपूर्ण यात्री भार को संभालते हैं, लेकिन शहर के परिधीय और नए विकासशील क्षेत्र विरल बस स्टॉप, लंबे रास्ते और खराब अंतिम-मील कनेक्टिविटी के कारण वंचित रहते हैं।

इस आधार रेखा पर निर्माण करते हुए, अध्ययन वर्तमान प्रणाली में अंतर्निहित प्रमुख परिचालन और पर्यावरणीय चुनौतियों की पहचान करता है। सुबह, दोपहर और शाम-रात की अवधि में सवारियों की संख्या के विश्लेषण से प्रमुख गलियारों के साथ तेजी से दिशात्मक पीक-आवर प्रवाह का पता चलता है, दोपहर के दौरान मध्यम और बिखरी हुई यात्रा होती है और रात में विशेष रूप से परिधीय क्षेत्रों में मांग में धीरे-धीरे गिरावट आती है जहां सुरक्षा चिंताएं और सीमित-सेवा आवृत्ति सवारियों को हतोत्साहित करती है। कंजेशन मैपिंग सरवटे बस स्टैंड, विजय नगर स्कायर और राजवाड़ा जैसे प्रमुख चौराहों के साथ-साथ एबी रोड और एमआर -10 सहित गलियारों पर महत्वपूर्ण दबाव बिंदुओं को उजागर करती है, जहां उच्च यातायात मात्रा, मिश्रित भूमि उपयोग और पूरे दिन निरंतर गतिविधि लगातार बाधाएं पैदा करती है जिससे बस संचालन में देरी होती है। शेड्यूलिंग विश्लेषण आगे नियोजित समय सारिणी और वास्तविक संचालन के बीच एक बेमेल को उजागर करता है, पीक-आवर सेवाएं अपेक्षाकृत पर्याप्त हैं लेकिन ऑफ-पीक सेवाएं सिस्टम की विश्वसनीयता और समग्र उपयोगकर्ता विश्वास को काफी कम कर देती हैं।

पारंपरिक डीजल बसों के मुकाबले इलेक्ट्रिक बसों का तुलनात्मक मूल्यांकन अध्ययन का विश्लेषणात्मक मूल है। प्रति दिन तय की गई दूरी, ऊर्जा खपत, परिचालन लागत, उत्सर्जन आउटपुट और सेवा अनुकूलनशीलता सहित मापदंडों के आधार पर मूल्यांकन किया जाए तो इलेक्ट्रिक बसें इंदौर के विशिष्ट संदर्भ के लिए स्पष्ट रूप से बेहतर विकल्प के रूप में उभरती हैं। वे ग्रीनहाउस गैस उत्सर्जन में मापनीय कटौती, कम ध्वनि प्रदूषण, बेहतर ऊर्जा दक्षता और दीर्घकालिक रखरखाव लागत में कमी की पेशकश करते हैं। हालाँकि, अध्ययन यह स्वीकार करने में सावधानी बरतता है कि उनकी सफल तैनाती कई सक्षम स्थितियों पर निर्भर करती है, विशेष रूप से उपयुक्त डिपो सुविधाओं की उपलब्धता, पर्याप्त चार्जिंग बुनियादी ढांचे, ग्रिड की तैयारी और मार्ग-स्तरीय अनुकूलता।

इस विश्लेषण से सूचित होकर, थीसिस एकीकृत योजना प्रस्तावों का एक सेट विकसित करती है। पहला मार्ग अनुकूलन को संबोधित करता है, मौजूदा नेटवर्क को अधिक तार्किक, नोड-आधारित प्रणाली में पुनर्गठित करता है जो अतिरेक को कम करता है, क्रॉस-परिधीय कनेक्टिविटी में सुधार करता है, और कोर और बाहरी क्षेत्रों के बीच सेवा वितरण को संतुलित करता है। दूसरा परिचालन सुधार, अनुकूलित शेड्यूलिंग, पीक अवधि के दौरान कम प्रगति, बेहतर बेड़े आवंटन और दैनिक संचालन में पूर्वानुमान और स्थिरता लाने के लिए वास्तविक समय निगरानी उपकरणों की शुरूआत पर केंद्रित है। डिपो योजना प्रस्ताव का तीसरा स्तंभ है: इलेक्ट्रिक बस डिपो के लिए उपयुक्त स्थानों की पहचान भूमि की उपलब्धता, स्थानिक पहुंच और चार्जिंग बुनियादी ढांचे की आवश्यकताओं के आधार पर की जाती है, जिससे कुशल बेड़े प्रबंधन, न्यूनतम माइलेज और

दीर्घकालिक परिचालन विश्वसनीयता सुनिश्चित होती है। अंत में, एक डेटा-संचालित किराया संरचना प्रस्तावित है, जो ऊर्जा खपत के आंकड़ों, यात्री क्षमता डेटा और परिचालन लागत विश्लेषण से प्राप्त होती है, जो पारगमन एजेंसी के लिए उपयोगकर्ता सामर्थ्य और वित्तीय स्थिरता के बीच संतुलन बनाती है।

पूरे अध्ययन में, राष्ट्रीय नीति उपकरणों विशेष रूप से राष्ट्रीय इलेक्ट्रिक मोबिलिटी मिशन योजना (एनईएमएमपी), फेम-द्वितीय योजना और राष्ट्रीय शहरी परिवहन नीति, 2006 के साथ संरेखण को एक आवश्यक प्रवर्तक के रूप में जोर दिया गया है। ये ढाँचे न केवल इलेक्ट्रिक बसों में परिवर्तन के लिए वित्तीय प्रोत्साहन और बुनियादी ढाँचा सहायता प्रदान करते हैं, बल्कि शहरी योजनाकारों, परिवहन एजेंसियों और नीति निर्माताओं के बीच समन्वित कार्रवाई के लिए एक संस्थागत आधार भी प्रदान करते हैं। अध्ययन स्वीकार करता है कि इंदौर जैसे टियर-2 शहर के लिए, जो सीमित बुनियादी ढाँचे की क्षमता और लगातार बदलते यात्रा व्यवहार की विशिष्ट बाधाओं के तहत काम कर रहा है, स्थानीय स्तर पर अनुरूप और संदर्भ-विशिष्ट योजना दृष्टिकोण अपरिहार्य है।

निष्कर्ष सामूहिक रूप से स्थापित करते हैं कि इंदौर की सार्वजनिक परिवहन प्रणाली कार्यात्मक है, लेकिन अपर्याप्त रूप से एकीकृत है, संचालन में असमान है, और जानबूझकर हस्तक्षेप के बिना विद्युतीकरण के लिए संरचनात्मक रूप से तैयार नहीं है। प्रस्तावित रूपरेखा दर्शाती है कि एक सुनियोजित विद्युत पारगमन प्रणाली सार्थक रूप से सेवा की गुणवत्ता में सुधार कर सकती है, भीड़भाड़ को कम कर सकती है और विशेष रूप से शहर के वंचित परिधीय समुदायों के लिए पहुंच बढ़ा सकती है। अधिक व्यापक रूप से, थीसिस इस परिवर्तन को एक परिभाषित योजना चुनौती के रूप में प्रस्तुत करती है: जिसे सफल होने के लिए तकनीकी कठोरता, स्थानिक बुद्धिमत्ता और नीति समन्वय के समान उपायों की आवश्यकता होती है।

निष्कर्ष में, यह अध्ययन इंदौर को स्वच्छ, कुशल और भविष्य के लिए तैयार सार्वजनिक गतिशीलता की दिशा में आगे बढ़ाने के लिए एक व्यावहारिक, स्केलेबल और साक्ष्य-आधारित ढाँचे में योगदान देता है। यह अन्य मध्यम आकार के भारतीय शहरों के लिए टिकाऊ शहरी पारगमन की दिशा में एक समान यात्रा के लिए हस्तांतरणीय अंतर्दृष्टि भी प्रदान करता है, जो इस बात की पुष्टि करता है कि विद्युतीकरण, जब व्यापक योजना पर आधारित होता है, न केवल एक पर्यावरणीय अनिवार्यता है, बल्कि शहरी जीवन की गुणवत्ता के लिए एक वास्तविक छलांग है।

Abstract

Cities across India are growing rapidly, and with that growth comes a set of mobility challenges that cannot be ignored. Indore, the commercial capital of Madhya Pradesh and one of central India's most dynamic urban centres, stands at this very crossroads. Over the past decade, the city has witnessed significant economic expansion, population growth, and outward urban sprawl, all of which have collectively intensified travel demand, worsened traffic congestion, and contributed to a steady decline in air quality. While the city has made meaningful efforts to build a structured public transport framework primarily through the AICTSL bus services and the now-discontinued BRTS corridor, the system continues to fall short in several critical areas. Uneven service distribution, route overlaps, inadequate peripheral connectivity, irregular scheduling, and a lack of integrated infrastructure have reduced public transport's attractiveness, pushing more residents toward private vehicles and deepening the city's environmental and mobility challenges.

This thesis, titled "Clean Air Initiatives for Indore's Public Transit: Planning for Infrastructure and Operations," directly confronts these challenges. It aims to understand the current limitations of Indore's fossil fuel-based public transit system and evaluate how electric buses can offer a cleaner, more efficient, and sustainable alternative. Crucially, the study treats this transition not as a simple vehicle swap, but as a comprehensive planning process that must address infrastructure readiness, operational restructuring, and alignment with national and state-level policy frameworks.

The study adopts a structured, sequential methodology built around five interconnected steps. It begins with a thorough baseline analysis of the existing public transport system, drawing on both primary observations field surveys across congested corridors, informal interactions with drivers and commuters, and direct assessment of bus stops and depot conditions as well as secondary data from AICTSL operational reports, GIS-based mapping, land-use documents, and traffic studies. This foundation reveals a network that is heavily centralized, corridor-dependent, and radially structured, with routes converging toward the city centre along major arterials such as AB Road, Ring Road, and MG Road. While these corridors handle significant passenger loads, the peripheral and newly developing areas of the city remain underserved, with sparse bus stops, longer headways, and poor last-mile connectivity.

Building on this baseline, the study identifies the key operational and environmental challenges embedded in the current system. Ridership analysis across morning, afternoon, and evening-night periods reveals sharply directional peak-hour flows along dominant corridors, with moderate and dispersed travel during afternoons and a gradual decline in demand at night particularly in peripheral

areas where safety concerns and limited-service frequency further discourage ridership. Congestion mapping highlights critical pressure points at major intersections such as Sarwate Bus Stand, Vijay Nagar Square, and Rajwada, as well as along corridors including AB Road and MR-10, where high traffic volumes, mixed land use, and continuous activity throughout the day create persistent bottlenecks that delay bus operations. Scheduling analysis further exposes a mismatch between planned timetables and actual operations, with peak-hour services relatively adequate but off-peak services significantly reduced undermining the system's reliability and overall user confidence.

A comparative evaluation of electric buses against conventional diesel buses forms the analytical core of the study. Assessed across parameters including distance travelled per day, energy consumption, operational costs, emission output, and service adaptability, electric buses emerge as a clearly superior alternative for Indore's specific context. They offer measurable reductions in greenhouse gas emissions, lower noise pollution, improved energy efficiency, and reduced long-term maintenance costs. However, the study is careful to acknowledge that their successful deployment hinges on several enabling conditions specifically the availability of suitable depot facilities, adequate charging infrastructure, grid readiness, and route-level compatibility.

Informed by this analysis, the thesis develops a set of integrated planning proposals. The first addresses route optimization, restructuring the existing network into a more logical, node-based system that reduces redundancy, improves cross-peripheral connectivity, and balances service distribution between core and outer areas. The second focuses on operational improvements optimized scheduling, reduced headways during peak periods, better fleet allocation, and the introduction of real-time monitoring tools to bring predictability and consistency to daily operations. Depot planning forms the third pillar of the proposal: suitable locations for electric bus depots are identified based on land availability, spatial accessibility, and charging infrastructure requirements, ensuring efficient fleet management, minimized dead mileage, and long-term operational reliability. Finally, a data-driven fare structure is proposed, derived from energy consumption figures, passenger capacity data, and operational cost analysis, striking a balance between user affordability and financial sustainability for the transit agency.

Throughout the study, alignment with national policy instruments particularly the National Electric Mobility Mission Plan (NEMMP), the FAME-II scheme, and the National Urban Transport Policy, 2006 is emphasized as an essential enabler. These frameworks not only provide financial incentives and infrastructure support for transitioning to electric buses but also offer an institutional basis for

coordinated action between urban planners, transport agencies, and policymakers. The study

acknowledges that for a Tier-2 city like Indore, operating under distinct constraints of limited infrastructure capacity and continuously shifting travel behaviour, a locally tailored and context-specific planning approach is indispensable.

The findings collectively establish that Indore's public transport system is functional but insufficiently integrated, operationally uneven, and structurally unprepared for electrification without deliberate intervention. The proposed framework demonstrates that a well-planned electric transit system can meaningfully improve service quality, reduce congestion, and enhance accessibility particularly for the city's underserved peripheral communities. More broadly, the thesis positions this transition as a defining planning challenge: one that requires equal measures of technical rigour, spatial intelligence, and policy coordination to succeed.

In conclusion, this study contributes a practical, scalable, and evidence-based framework for advancing Indore's transition toward clean, efficient, and future-ready public mobility. It also offers transferable insights for other mid-sized Indian cities navigating a similar journey toward sustainable urban transit affirming that electrification, when grounded in comprehensive planning, is not just an environmental imperative but a genuine leap forward for urban quality of life.

Keywords: Electric Public Transit, Urban Mobility, Sustainable Transport, Electric Buses, Route Optimization, Public Transport Planning, Urban Infrastructure, Transit Operations, Fare Structure, Depot Planning, Traffic Congestion, Clean Mobility, Indore City, Sustainable Urban development

Acknowledgement

I express my sincere gratitude to Department of Architecture and Planning, Manit Bhopal for providing me with the opportunity to undertake this research on “Clean Air initiatives For Indore Public Transit: Planning for Infrastructure and Operations”

I am deeply grateful to my thesis supervisor, Dr. Rahul Tiwari, for their invaluable guidance, encouragement, and constructive feedback throughout this research. Their insightful suggestions and continuous support have played a crucial role in shaping this work.

I would also like to extend my heartfelt thanks to the thesis coordinator, Dr. Preeti Onkar and Dr. Premjeet Das Gupta faculty members and HOD of Architecture and Planning Department, Dr. Nakul Dhagat, and their support and knowledge-sharing, which have greatly contributed to my academic growth.

I acknowledge the cooperation and assistance of various government agencies, urban Transit stakeholders, who provided crucial data and insights essential for this research. Their inputs have been instrumental in understanding the challenges and opportunities related to Electric Public Transit in Indore.

A special note of appreciation goes to my family and friends for their unwavering support, patience, and motivation during this journey. Their encouragement has been a pillar of strength throughout the research process.

Lastly, I extend my gratitude to all those who contributed, directly or indirectly, to the successful completion of this thesis.

Shubh Shrivastava

2211002101

Bachelors of planning

Table of Contents

Bachelor of Planning	3
सारांश	1
Abstract.....	4
Acknowledgement	7
List of Figures.....	10
List of Tables:	11
Abbreviations.....	12
1. Introduction	13
1.1. Background	14
1.2. Aim.....	15
1.3. Objectives.....	16
1.4. Significance of the study	17
1.5. Scope.....	20
1.6. Limitations	21
2. Literature Review	23
2.1. Define Electric Public Transit Mobility	23
2.2. Key elements of Public Transit System	24
2.3. Note-worthy studies for the research	26
2.4. Formula For Calculations Used.....	38
2.4.1. Cycle Time Formula	38
2.4.2. Headway / Service Frequency Formula	38
2.4.3. Fleet Allocation Formula	39
2.5. Complimentary Policies:.....	39
3. Methodology.....	42
4. City Profile: Indore	45
4.1. Present Scenario: -.....	53
5. Data Collection and Data Analysis: -.....	55
5.1. Data Collection: -.....	55
5.1.1. Primary Data: -.....	55
5.1.2. Secondary Data: -.....	58
5.2. Data Analysis: -.....	62
6. Proposal.....	75
6.1. Bus Route Proposal for Increased Efficiency.....	75
6.1.1. Need for Bus Route Optimization:	75
6.1.2. Transition to Node Based Bus Network System:.....	79
6.1.3. Reduction of Route Overlap:	79
6.1.4. Improved Connectivity between Central and Peripheral Areas:.....	79

6.1.5. Efficient Fleet Utilization and Resource Optimization:.....	80
6.1.6. Reduction in Congestion and Travel Time:	80
6.1.7. Improved Service Reliability and Passenger Experience:	81
6.1.8. Overall Impact of the Proposed Bus Route System:.....	81
6.2. Bus Route Operation and Frequency Proposal.....	81
6.2.1. Need for Operational and Frequency Planning:.....	81
6.2.2. Key Parameters Used for Operational Planning:	84
6.2.3. Travel Time Calculated:	85
6.2.4. Cycle Time Determination:.....	85
6.2.5. Headway (Service Frequency):.....	86
6.2.6. Determining Number of Buses Required:.....	87
6.2.7. Derived Operation Parameters for Proposed Bus Network:	87
6.2.8. Overall Conclusion:	88
6.3. Locating Bus Depots Location Proposal	89
6.3.1. Need for Depot Planning Based on Existing System Gaps:.....	89
6.3.2. Introduction of a Cluster Based Depot Planning Approach:.....	92
6.3.3. Strategic Location of Depots based on Route Convergence:.....	92
6.3.4. Reduction of Dead Mileage and Non-Revenue Travel:.....	93
6.3.5. Operational Efficiency Through Centralized Control:.....	93
6.3.6. Support for Continuous and Flexible Bus Operations:	94
6.3.7. Alignment with Route Optimization Proposal:.....	94
6.3.8. Overall Impact of the Depot Location Proposal:	94
6.4. Bus Fare Proposal for E-Buses.....	95
6.4.1. Need of Proper Bus Fair:.....	95
6.4.2. Existing Bus Fare System:	95
6.4.3. Proposed Bus Fare System:	95
6.4.4. Data Base Justification:	96
6.4.5. Other Sources of Income for Bus operations:.....	97
6.4.6. Conclusion:	98
7. Conclusion.....	98
Reference	100

List of Figures

1. Figure. 1: Methodology Flowchart	42
2. Figure. 2: Location of Indore.....	45
3. Figure. 3: Indore Development Plan	47
4. Figure. 4: Indore Development Plan Central Area	48
5. Figure. 5: Land Cover Classification map.....	49
6. Figure. 6: Map Showing Major Road Connectivity.....	50
7. Figure. 7: Map of Urban Landmark.....	51
8. Figure. 8: Map of Important Transport Node.....	52
9. Figure. 9: Map Showing Congested corridor.....	57
10. Figure. 10: Existing Bus Route of Indore.....	60
11. Figure. 11: BRTS corridor, Indore.....	63
12. Figure. 12: Existing Bus Stop of Indore.....	64
13. Figure. 13: Morning Ridership Analysis.....	66
14. Figure. 14: Afternoon Ridership Analysis.....	67
15. Figure. 15: Night Ridership Analysis.....	68
16. Figure. 16: Traffic Congestion Analysis Map.....	70
17. Figure. 17: Traffic speed Analysis Map.....	71
18. Figure. 18: Proposed Node Based Route Map.....	78
19. Figure. 19: Proposed Depot Location Map.....	92

List of Tables:

1. Table. 1: Major Congested Corridor.....	57
2. Table. 2: Existing Bus Depots of Indore.....	61
3. Table. 3: Proposed Parameters of Indore.....	87
4. Table. 4: Proposed Bus Fair Indore.....	95

Abbreviations

AICTSL - Atal Indore City transport service Limited

BRTS – Bus Rapid Transit System

EV – Electric Vehicle

BEB - Battery Electric Bus

GIS – Geographic Information System

NEMMP – National Electric Mobility Mission Plan

FAME-I & II – Faster Adoption and Manufacturing of Electric Vehicles (Phase I & II)

TOD – Transit Oriented Development

ITS – Intelligent Transport System

GNG – Green House Gases

Km/Hr. – Kilometer per hour

Mr-10 – Major Road -10

NH – National Highway

1. Introduction

Urban mobility is rapidly emerging as one of the most crucial challenges which determine the direction of the city's future growth, particularly in terms of environmental sustainability and ease of life. In this thesis, the city of Indore was chosen as the study area, where for the last 10 years the city of Indore has experienced urban expansion (horizontally) and economic activities have increased significantly, this led to an increase in demand for efficient and reliable public transit system. However, this growth was also accompanied by increasing traffic congestion, declining air quality, and increasing stress on existing public transit systems. In this context, electric public transit (electric buses) presents a favorable road ahead toward cleaner and more efficient urban public transit system. By reducing greenhouse gas emissions, decrease in noise pollution, and improving energy efficiency and conservation, electric public transit systems have the potential to significantly change both current environmental conditions and overall public mobility performance.

Despite Indore initiative for improving Indore's public transit network (electric buses), the fast change toward electric mobility comes with its own shares of challenges. This shift requires more than simply replacing conventional fossil fuel buses, but demands careful planning considering future, infrastructure is an issue which needs to be solved, and change in current bus operations. Issues such as insufficient charging infrastructure, limited depots capacity, and the complexity of integrating electric buses into existing service systems as efficiently as possible pose significant challenges. In addition, rapid unplanned urban growth and the increasing reliance on private vehicles continue to increase the tension on the city's transport network, further complicating the transition process. These factors not only signify the immediate need for a well-coordinated planning approach but also indicate the need for strategic planning approach too.

This thesis study tries to overcome challenges mentioned above by understanding the current situation of Indore's public transit system, this also focuses on infrastructure for the electric transit, operational efficiency of the transit, and how much Indore is prepared for electric-bus integration in public transit system. It identifies key problems and proposes data-driven outcome which could make the transit system more efficient, while it includes optimized depot planning, expansion of bus route networks, route planning, and the integration of electric buses; it does not take into consideration finance (financial aspect, such as infrastructure construction finance, new electric tools cost of construction and integration, etc.). This

research also highlights the importance of planning in consideration of national and state-level electric mobility policies. Finally, this study aims to develop a practical and easy-to-integrate framework that supports the effective integration of electric public transit (electric buses) in Indore city, while it also offers valuable understanding for other mid-sized cities undergoing similar transition toward sustainable urban mobility. This study only aims towards Indore city, and all the planning is made using the same consideration.

1.1. Background

Urban mobility is one of the most important aspects of city development, in consideration of the year 2047 vision of “Viksit Bharat,” which considers sustainable urban development, since cities are the major contributors to global “greenhouse gas emissions.” Similarly, in cities, among multiple different sectors, the transport sector continues to grow along with the city and is one of the major contributors to air pollution and carbon emissions. In terms of India, the speed of urbanization due to the aim of “Viksit Bharat,” which in turn increases travel needs and demands, has also led to a rise in private vehicle ownership. This increase in urbanization adds to the level of challenges such as traffic congestion, worsening air quality, and increased constraints on existing public transit systems. These conditions highlight the urgent requirement for strategic planning of how cities move forward in the future. In this situation, for this thesis, the transition from fossil-fueled public transit toward electric public mobility showcases more than just upgrading to a suitable option, it showcases how strategic urbanization, which represents the current case for such transformation. Over the past 10 Years, Indore city has experienced significant economic growth and population expansion, along with an increase in the city area, which in turn led to increase in travel demand across its urban areas along with multiple rural areas in the outskirts of the city. As a significant commercial and industrial hub, Indore relies heavily on its transport network to sustain daily movement. While Indore initiated many policies and agencies to better the public network of the system, such as the AICTSL bus system and the iBus corridor, which have helped significantly to the city’s public transport framework, the constantly growing dependence on private vehicles and continuous outward spread of urban development put a lot of continuous pressure on existing system efficiency. This leads to increased congestion levels, higher fuel consumption, and worsening environmental conditions, underscoring the need for a more resilient and future-ready mobility approach/plan.

Electric public transport offers a promising road to the future for addressing these concerns

by significantly reducing greenhouse gas emissions, reducing noise pollution, and improving overall urban livability. However, this type of shift toward electric mobility is not very easy but is complex, and it demands careful planning which is not just restricted to the mere replacement of conventional buses. Aspects such as the availability of adequate depot facilities, constant power supply, route planning, and operations should be addressed thoroughly. In addition, the effectiveness of electric transit (electric buses) is very closely connected to urban planning elements, including land-use zoning, major corridor development, and accessibility throughout the city. Without properly understanding and consideration of these elements, the required outcome from the environmental and operational benefits may not be fully utilized for the planning.

Considering policy, national level Policies for electric Mobility were created, such as the National Electric Mobility Mission Plan (NEMMP) and the FAME-II scheme, these policies provide support for the framework, for hasten the integration and utilization of electric Vehicle. However, understanding these policy directions into Physical outcomes requires a strategy which is Context Specific and is created for the unique conditions of the specific city. Tier-2 cities like Indore operate under distinct constraints, which include limited infrastructure capacity and continuous changes in travel behaviour, due to this, localized planning approaches are also Involved.

In Continuation, a comprehensive and integrated planning framework becomes very Important. By Combining Multiple Aspects such as infrastructure Development, operational optimization, land use coordinate and properly understand and utilize the Policies, an urban Planner can ensure a smooth and effective shift from Conventional Public Mobility to electric public mobility in a city using above elements. This study first, focuses on understanding the current public transit system in the City of Indore, and then identifying the key challenges in the shift toward electric Mobility, along with giving Comprehensive proposal along with practical strategies to address them. The aim is to contribute to the development of a sustainable, efficient, and low-carbon urban transit system.

1.2. Aim

The aim of this thesis is to understand and study the current limitations of fossil fuel based urban transit systems and identify how electric public transport can offer a cleaner and more sustainable alternative as a mode of travel. It seeks to understand how electric transit can be effectively introduced through better route planning, optimized depot's location, improved

service frequency, and more efficient day-to-day operations, ultimately strengthening the overall performance of the urban mobility system.

1.3.Objectives

The following are the objectives which we will follow to achieve a certain desirable result:

- i. To analyze the existing public transport system of Indore and identify its operational and infrastructural limitations-

Objective-i Concentrate on conducting a comprehensive analysis of the current public transit system in Indore using secondary data only. This analysis will be including the operational structure along with its supporting infrastructure. This study is very important and useful to identify key components of the public transit system such as major route network, service covered by the system, fleet composition (no. of diesel buses or electric buses), frequency of services, and passenger demand patterns. Additionally, infrastructural aspects such as bus stops, depots, and intelligent transport systems (GPS chip inside the buses, etc.) will also be evaluated under this objective. The purpose is to identify critical shortcomings and limitations of the current system, including major problems like inadequate coverage in peripheral areas of the City, fleet conditions and maintenance, and inefficiency in scheduling and operations of the current system. This analysis will not only provide a base-line understanding of problems but will also help in the formulation of proposal for improvements and operation for future interventions.

- ii. To examine the key operational and environmental challenges, including congestion, emissions, and service inefficiencies-

This objective-ii aims to Look's into the major challenge's which is currently affecting the efficiency and sustainability of the public transport system. The current system suffers from operational challenges such as traffic congestion, delays, overcrowding, irregular service frequency, and lack of real-time information systems which could have been used for gaining Insite of the system. In parallel, environmental concerns including vehicular emissions, fuel consumption, and their contribution to urban air pollution will be examined. The study will assess how conventional diesel-based bus systems impact environmental quality and urban livability. This objective tries to identify these issues and this research will help provide insights on the urgency for transitioning toward cleaner and more efficient transport solutions.

- iii. To evaluate the feasibility (Bus Fare) and performance of electric transit as a sustainable alternative to conventional bus systems-

Under objective-iii, the research will assess the importance of introducing electric buses in Indore's public transport system. This includes analyzing cost components such as operational costs, maintenance Cost and particularly fare structures (bus fare) to ensure economic sustainability and affordability for users. A Comparative analysis between conventional diesel buses and electric buses will be carried out in terms of lifecycle cost, energy efficiency, emissions reduction, and service performance.

- iv. To propose planning and operational strategies for the effective integration of electric transit, including route optimization (Bus Route Planning), depot location, and policy alignment-

Objective-iv is focused on developing practical and realistic strategies to introduce electric buses into Indore's existing transport system in a smooth and effective way. It involves planning new bus routes by studying travel demand, understanding how people move across the city, and analyzing available secondary data to improve overall network efficiency. The study will also identify suitable locations for electric bus depots by considering factors such as land availability, ease of access, and the requirements for charging infrastructure. In addition, it will look into supportive policies and institutional arrangements that can help in the successful adoption of electric mobility. Overall, the aim is to create a public transport system that is cleaner, more efficient, and more convenient for the people of Indore.

1.4. Significance of the study

Electric public mobility is increasingly seen as an essential step toward creating cleaner, healthier, and more sustainable cities. However, moving from diesel-based public transport to electric systems is not just about changing vehicles, it requires careful planning, infrastructure readiness, and improvements in how the system operates. This study, titled "Decarbonization Plan for Indore's Public Transit: Planning for Infrastructure and Operations," focuses specifically on Indore's public bus transport system and takes a practical approach to understanding how this transition can be effectively achieved.

The study begins by examining how the existing system functions and then slowly builds toward identifying solutions that can support data analysis to ensure a smooth and realistic transition to electric mobility. Each aspect of the research is interconnected, ensuring that environmental, operational, and planning considerations are addressed together rather than in isolation.

1) Focuses on Indore's Public Bus Transport System:

This study is centered on the public bus system of Indore, which forms the backbone of the city's current public transport. It looks closely at how the system currently operates, including its structure, service delivery, and role in meeting daily travel needs. By concentrating on buses as the primary mode, the study ensures a detailed and grounded understanding of the city's transport dynamics, rather than taking a generalized approach.

2) Examines Transition from Fossil Fuel to Electric Transit:

A key focus of the research is to understand how Indore can shift from conventional diesel buses to electric buses in a practical and sustainable way. This transition is studied not only from a technological perspective but also in terms of operational feasibility, cost implications, and system readiness. The aim is to ensure that the shift to electric mobility is smooth, efficient, and beneficial in the long term.

3) Analyzes Route Structure and Network Efficiency:

The study examines the existing bus route structure to understand how effectively different parts of the city are connected. It evaluates whether routes are logically planned, whether there are duplications or gaps in coverage, and how efficiently the network supports passenger movement. This analysis helps in identifying areas where the system can be improved for better connectivity and performance.

4) Studies Ridership Patterns and Travel Demand:

Understanding how people travel is an important part of this research. The study analyzes ridership patterns and travel demand to identify peak travel times, high-demand routes, and underutilized services. This helps in aligning the transport system more closely with actual user needs, ensuring that services are both efficient and relevant.

5) Identifies Key Corridors and Congestion-Prone Areas:

The research identifies major travel corridors and areas that experience high levels of congestion. These locations are critical for planning improvements, as they often represent the most stressed parts of the network. By focusing on these areas, the study ensures that proposed solutions target the most pressing mobility challenges in the city.

6) Evaluates Service Performance (Frequency, Reliability):

The study evaluates how well the current bus system performs in terms of service frequency, reliability, and consistency. It looks at issues such as delays, irregular schedules, and service gaps that affect passenger experience. By identifying these problems, the research provides a basis for improving the overall quality and dependability of public transport.

7) Reducing Urban Congestion and Strengthening Public Transport Competitiveness:

With increasing private vehicle usage, congestion has become a major issue in Indore. This study highlights the importance of making public transport more attractive and competitive. By improving service quality and network efficiency, electric buses can encourage more people to shift from private vehicles to public transport, helping to reduce congestion and improve mobility across the city.

8) Improving Service Efficiency and Operational Performance:

The study emphasizes the need to improve how efficiently the transport system operates. Through better route planning, optimized scheduling, and improved resource utilization, it aims to reduce delays and enhance service reliability. A more efficient system not only benefits passengers but also improves overall system performance and sustainability.

9) Assessing Depot and Charging Infrastructure Needs:

A successful transition to electric buses depends heavily on infrastructure. The study evaluates the need for well-located depots, availability of land, and the integration of charging infrastructure. It ensures that these elements are planned in a way that supports efficient operations and long-term sustainability of the system.

10) Proposes Planning and Operational Strategies for EV Integration:

Based on the analysis, the study proposes practical strategies for integrating electric buses into the existing transport network. This includes planning new and improved routes, optimizing network performance, and aligning operations with the requirements of electric vehicles. It

also considers policy support and institutional coordination needed for successful implementation.

11) Contribution to Long-Term Urban Development Goals:

Finally, the study supports Indore's broader vision of sustainable urban development. By combining environmental improvement, infrastructure planning, and operational efficiency, it provides a clear and practical roadmap for the future. The goal is to create a public transport system that is not only efficient and reliable today but also prepared to meet the needs of a growing city in the years ahead.

1.5.Scope

The scope is deliberately centered on the city's bus network, as it serves as the backbone of mass mobility and plays a critical role in shaping everyday travel patterns. Instead of addressing all transport modes, the research concentrates on how electric buses can be integrated into the existing system in a realistic and operationally viable manner, with an emphasis on improving service delivery rather than merely introducing new technology.

To support this, the study undertakes a detailed assessment of the current bus system. It looks closely at route structures, service frequency, passenger demand, fleet characteristics, and overall operational performance. By examining how the system functions on a day-to-day basis, the research identifies key limitations associated with diesel buses, particularly in terms of emissions and service efficiency. These insights are then used to evaluate where and how electric buses could perform better. Special attention is given to factors such as route length, peak-hour demand, turnaround time, and scheduling practices to determine the corridors most suitable for electrification.

Infrastructure readiness forms another important part of the analysis. The study evaluates existing depot locations, available capacity, and their suitability for supporting electric operations. Using spatial tools like GIS, it explores more efficient depot planning and placement, aiming to reduce unnecessary travel distances and improve operational efficiency. At the operational level, the research also considers how the introduction of electric buses may influence service frequency, scheduling patterns, and fleet utilization. The intention is to ensure that electrification enhances reliability and efficiency, rather than creating additional challenges for the system.

While the study acknowledges broader policy directions at the national and state levels, its primary focus remains on practical planning and implementation within the local context of

Indore. It does not extend into areas such as large-scale power sector reforms, manufacturing processes, or detailed financial modelling, allowing it to stay focused on actionable and context-specific solutions.

Overall, this study aims to develop a clear and practical planning framework that supports the effective integration of electric buses into Indore's public transport system, contributing to cleaner mobility, improved service quality, and more sustainable urban development.

Significance of the Scope

All of the above scope areas work together to keep the study closely aligned with its core objective is to improving both the efficiency and sustainability of electric public transport in Indore. By focusing on real operational conditions, existing infrastructure, and practical planning strategies, the research goes beyond theoretical ideas and addresses the gaps that directly affect how the system performs on the ground.

Through the detailed examination of routes, service patterns, depot readiness, and system performance, the study identifies areas where improvements can make a meaningful difference. This integrated approach helps ensure that the transition to electric buses is not only environmentally beneficial but also operationally smooth and reliable for daily users.

The outcomes of this study are designed to be practical and adaptable. Rather than offering one-size-fits-all solutions, it provides context-specific insights that can guide implementation in Indore while also being useful for other mid-sized cities facing similar challenges. In this way, the research extends its relevance beyond a single city and contributes to a broader understanding of sustainable urban transport transitions.

Importantly, the study also highlights the need to view electric mobility as part of a larger urban planning framework. It emphasizes that improvements in transport systems should go hand in hand with environmental goals and better quality of life for residents. By combining structured planning, operational improvements, and alignment with policy directions, the study aims to support a transition that is both practical and forward-looking helping position Indore as a strong example of sustainable and efficient electric public transport.

1.6.Limitations

While this thesis aims to develop structured planning interventions for integrating electric public transit into Indore's mobility system, it is important to acknowledge certain limitations. These limitations will help define the boundaries of the research and provide context for interpreting the findings.

- i. The study is limited to the urban bus transport system of Indore city:

CLEAN AIR INITIATIVES FOR INDORE'S PUBLIC TRANSIT: PLANNING FOR INFRASTRUCTURE AND OPERATIONS

This research focuses only on the public bus network within Indore and does not cover other modes of transportation such as metro systems, shared mobility, private vehicles, or non-motorized transport like cycling and walking. While these modes also play an important role in shaping urban mobility, they fall outside the scope of this study. As a result, the findings and recommendations are specific to the bus system and may not fully represent the broader transport ecosystem of the city.

- ii.** Analysis is based primarily on secondary data with limited primary observations and surveys:

The study relies largely on existing data sources such as reports, official records, and previously published information. While some level of field observation and limited surveys have been included to support the analysis, they may not capture the full range of real-time operational challenges or user experiences. This means that certain ground-level variations, such as daily service inconsistencies or passenger perceptions, might not be fully reflected in the findings.

- iii.** Detailed financial feasibility and economic analysis are not included in this study:

Although the study explores the operational and planning aspects of introducing electric buses, it does not go into an in-depth financial evaluation. This includes aspects such as capital investment, lifecycle costs, funding mechanisms, or cost benefit analysis. The intention is to keep the focus on planning and implementation feasibility rather than financial modelling. Therefore, any recommendations made should be considered from an operational perspective and may require further financial assessment before actual implementation.

- iv.** Evaluation is based on current electric vehicle technology and performance standards:

The analysis is based on the present state of electric bus technology, including battery capacity, charging requirements, and operational performance. However, this is a rapidly evolving field, and advancements in technology could significantly change performance outcomes in the near future. As a result, some of the conclusions drawn in this study may need to be revisited as newer and more efficient technologies become available.

2. Literature Review

Understanding the transition toward electric public mobility requires a careful review of existing research that highlights both global experiences and local challenges in urban transport systems. This section examines key studies that explore operational inefficiencies, policy frameworks, infrastructure readiness, and the integration of electric buses into public transit networks. These insights provide a strong foundation for identifying planning strategies that can enhance the efficiency, reliability, and sustainability of electric public transport in Indore.

2.1. Define Electric Public Transit Mobility

Electric Public Transit Mobility refers to the movement of people within urban areas through electrically powered public transport systems, particularly electric buses, to meet every day travel needs such as commuting for work, education, shopping, and social activities. It is not limited to vehicles alone but represents a coordinated system involving multiple stakeholders, including transport authorities, municipal agencies, power utilities, operators, policymakers, and passengers. Together, these actors influence how efficiently and effectively the system functions. At its core, electric public transit contributes to urban development by improving accessibility, reducing dependence on fossil fuels, and lowering greenhouse gas emissions, while continuing to deliver reliable and inclusive mobility services.

With rapid urban growth and rising travel demand, increased reliance on private vehicles has led to congestion, deteriorating air quality, and higher energy consumption. In this context, electric public transit offers a cleaner, quieter, and more energy-efficient alternative to conventional diesel-based systems. Electric buses significantly reduce tailpipe emissions and noise pollution, making them particularly suitable for dense urban environments. However, the transition to electric mobility is not simply a matter of replacing vehicles; it requires careful planning and system-level integration. Factors such as charging infrastructure, depot capacity, grid readiness, and route suitability must be evaluated to ensure operational feasibility and long-term sustainability.

Electric public transit mobility is built upon several interconnected components, each playing a crucial role in determining overall system performance. Route planning and service frequency directly influence accessibility and passenger convenience, ensuring that services are both reliable and responsive to demand. Infrastructure readiness including charging stations, substations, and depot facilities is essential to support uninterrupted operations and

efficient energy use. Operational management, encompassing scheduling, fleet allocation, and energy optimization, ensures that services run smoothly on a day-to-day basis while maintaining cost and time efficiency. In addition, supportive policies and regulatory frameworks provide the necessary institutional backing, guiding investment, standardization, and implementation.

The importance of these components lies not only in their individual functions but in how effectively they are integrated. For instance, well-planned routes must align with charging infrastructure locations, while scheduling decisions must consider battery range and charging cycles. Similarly, policy support must enable infrastructure development and operational flexibility. When these elements are coordinated, they create a balanced and efficient system that enhances service reliability, optimizes resource utilization, and supports environmental sustainability.

In essence, electric public transit mobility represents a comprehensive and interconnected approach to urban transport. Its success depends on the seamless integration of planning, infrastructure, operations, and policy, working together to deliver a transit system that is efficient, sustainable, and capable of meeting the evolving mobility needs of growing cities.

2.2.Key elements of Public Transit System

Building on the understanding of electric public transit mobility as an integrated and multi-stakeholder system, its performance depends on a set of core elements that function together rather than in isolation. Each element contributes to the system's overall efficiency, reliability, and sustainability, and their coordination is essential for delivering effective urban mobility.

i. Route Planning and Network Design:

Route planning and network design form the structural foundation of the transit system, determining how different parts of the city are connected. Its role is to ensure efficient spatial coverage by linking residential areas with workplaces, educational institutions, and commercial centers. The importance of this element becomes even greater in electric transit systems, where routes must be aligned with vehicle range and charging availability. A well-designed network enhances accessibility, reduces travel time, and ensures that public transport remains a convenient and viable option for users.

ii. Service Scheduling and Frequency:

Service scheduling and frequency define the temporal efficiency of the system by

determining when and how often services are available. Its role is to maintain reliability and reduce passenger waiting time, thereby improving the overall attractiveness of public transport. In electric transit systems, scheduling must also integrate charging cycles and fleet availability, making it more complex than conventional systems. The importance of effective scheduling lies in its ability to balance demand and supply, prevent overcrowding, and ensure consistent service delivery.

iii. Infrastructure Readiness:

Infrastructure readiness provides the physical and technical backbone required for the functioning of electric public transit. Its role includes supporting operations through charging stations, depots, substations, and reliable grid connectivity. The importance of this element is critical, as inadequate infrastructure can disrupt services regardless of how well other components are planned. Properly developed and strategically located infrastructure ensures uninterrupted operations, efficient energy use, and long-term system sustainability.

iv. Fleet Management and Operations:

Fleet management and operations focus on the day-to-day functioning and efficiency of the transit system. Its role is to manage vehicle allocation, maintenance, monitoring, and energy use to ensure smooth and reliable service. In electric systems, this also involves battery performance management and charging coordination. The importance of this element lies in optimizing resource utilization, minimizing downtime, and maintaining service quality, all of which are essential for operational efficiency and cost-effectiveness.

v. Policy and Institutional Support:

Policy and institutional support provide the governance framework within which the transit system is developed and operated. Its role is to guide implementation through regulations, financial incentives, and strategic planning while ensuring coordination among various stakeholders. The importance of strong policy support lies in enabling infrastructure development, encouraging investment, and ensuring standardization. Without effective institutional backing, the transition to electric public transit can face significant challenges and delays.

vi. User Experience and Accessibility:

User experience and accessibility place the commuter at the center of the transit system. Its role is to ensure that services are comfortable, affordable, safe, and easy

to use for all segments of the population. The importance of this element lies in influencing user behavior and encouraging a shift from private vehicles to public transport. Features such as reduced noise, smoother rides, and improved accessibility enhance the appeal of electric transit, making it more inclusive and user-friendly.

2.3.Note-worthy studies for the research

- i. World Bank (2021). Decarbonizing Cities by Improving Public Transport and Managing Land Use and Traffic.

Theme – Public Transport and Land-Use Integration for Urban Decarbonization

The World Bank (2021) report provides a comprehensive examination of how urban transport, specifically private car usage, acts as a massive driver of city-level greenhouse gas (GHG) emissions. Because private cars and low-occupancy vehicles are significantly less carbon-efficient per passenger-kilometre than walking, cycling, or public transport, a paradigm shift is necessary. To achieve meaningful urban decarbonization, cities must holistically integrate public transport improvements with strategic land-use management and robust traffic demand policies.

Land-Use Integration: The "Avoid" Strategy A foundational finding of the study is that inefficient land-use regulations actively hinder urban decarbonization and public transit viability. Regulations such as strict floor area ratios (FAR), single-use zoning, and minimum parking requirements artificially cap the supply of built space, which dramatically increases housing costs. These dynamic prices the poor out of central areas and forces them to the urban fringes, creating "3-d" urban development distant, dispersed, and disconnected.

This sprawl creates long, radial travel patterns that are incredibly expensive and difficult to serve with public transport, thereby increasing private vehicle dependency. To combat this, cities must embrace Transit-Oriented Development (TOD) and flexible land-use policies that promote dense, diverse, and well-designed urban spaces. By bringing people and opportunities closer together, cities can significantly reduce overall travel distances and fundamentally "avoid" unnecessary motorized trips.

Improving Public Transport: The "Shift" and "Improve" Strategies To encourage a modal "shift" away from private vehicles, the reliability, accessibility, and overall

service quality of public transport must be drastically improved. The report highlights the highly problematic nature of "competition in the market," a common setup in developing cities where individual bus owners or drivers engage in cutthroat competition for every passenger. This system leads to unsafe driving, extreme congestion, and severe pollution from poorly maintained, aging mini-buses.

Instead, the World Bank strongly advocates for a transition to "competition for the market". In this model, governments competitively select operators who must meet strict quality and performance standards. This operational reorganization is often paired with the implementation of Bus Rapid Transit (BRT) systems that provide exclusive rights-of-way and protect operators from predatory competition. Furthermore, this reorganization serves as a critical catalyst for the "Improve" strategy: it opens avenues for fleet renewal and the deployment of lower-carbon technologies, such as electric buses, which drastically reduce emissions per passenger while enhancing service quality.

Managing Traffic and Transport Demand (TDM) Meaningful decarbonization also requires aggressive Transport Demand Management (TDM) to disincentivize private car use. The report severely criticizes the "high cost of free parking," noting that unregulated curb side parking and minimum parking requirements act as a massive, hidden subsidy for car ownership. Implementing comprehensive parking pricing and road or congestion pricing helps internalize the environmental and social costs of driving. Coupled with "soft" measures or nudges such as telework policies and corporate mobility incentives these TDM strategies successfully manage traffic while generating vital revenue that can be reinvested into complete streets and green transport infrastructure.

Empowering Gender-Inclusive and Green Mobility Crucially, the World Bank highlights the necessity of empowering female travellers, who inherently exhibit greener travel patterns. Women typically travel shorter distances, chain multiple trips together, and rely far more on walking and public transport than men. Yet, transport systems are frequently designed around the peak-hour commuting needs of men, ignoring women's off-peak travel needs and severe safety concerns. Reforming transit services to ensure reliable off-peak schedules, alongside creating "complete streets"

with safe sidewalks and better lighting, not only improves social equity but also reinforces the use of the most carbon-efficient transport modes.

By fundamentally reprioritizing urban space and financial investment for the majority of travellers who use green modes over the minority who use private cars, cities can create a virtuous cycle that ensures long-term environmental sustainability and inclusive economic access.

ii. IIHS (2022). Decarbonising Public Transport in India: An Issue Brief

Theme – Transport Decarbonization in the Indian Urban Context

Urban transport in India is experiencing immense growth, driven by shifting demographic patterns, rising incomes, and the need to service expanding economic activities. Transport is currently the fastest-growing emission sector in the country, accounting for approximately 13% of India's energy-related carbon dioxide (CO₂) emissions. If left unaddressed, models estimate that transport-linked energy demand and CO₂ emissions could surge by 4.5 times by 2050 compared to 2015 levels. Consequently, establishing a sustainable, decarbonized public transportation system is a key defining element of India's sustainable urbanization.

The State of Passenger Transport The demand for passenger transport in India has grown even faster than its economic growth, with the elasticity of passenger transport demand to gross domestic product (GDP) expected to range between 1.4 and 1.7. Between 2005 and 2015, the share of passenger road transport grew from about 60% to nearly 90%, massively outstripping rail transport. This shift is primarily driven by convenience, as buses, two-wheelers, and cars provide point-to-point connectivity and significantly shorter waiting times than alternatives.

However, the current public transportation systems in most Indian cities remain severely inadequate. Transit systems are generally characterized by overused, poor-quality bus networks and a lack of reliable intracity rail systems. The supply of buses falls far short of demand; for example, while guidelines suggest cities need at least 60 buses per 100,000 people, Delhi has operated with a deficit of roughly 4,000 to 5,000 buses for over a decade. Consequently, poor frequency, extreme overcrowding during peak hours, and an overall lack of comfort strongly discourage bus use.

This shortfall in public transit has fuelled a rapid increase in private vehicle ownership. In the 2019-20 period alone, India produced around 21 million two-wheelers and 3.4 million passenger vehicles. Within cities, two-wheelers have firmly emerged as the dominant mode of transport. The proliferation of private vehicles has led to severe traffic congestion and air pollution, which are further exacerbated by old, inefficient vehicle stocks and limited road space. Furthermore, the cost and time value of commuting force many to choose private transport, as India is still evolving its policies on transport subsidies, road taxes, and parking fees to effectively incentivize public transit.

The Avoid–Shift–Improve (ASI) Framework To successfully decarbonize the sector, India's strategy aligns closely with the Avoid–Shift–Improve (ASI) framework, which offers an effective way to strategize emissions reductions.

- **Avoid:** This strategy focuses on minimizing total vehicle travel through smart urban planning. By fostering dense, compact cities with mixed land-use patterns, planners can drastically reduce the distances between where people live, work, and pursue leisure. Implementing such urban form changes could reduce urban transport GHG emissions by up to 25% by 2050¹⁰.
- **Shift:** The core of India's decarbonization agenda relies on shifting passenger demand away from high-emitting private vehicles toward lower-emitting public and active transport modes. However, because consumers heavily factor waiting times into their travel decisions, attracting people to public transport requires providing sufficient spatial coverage alongside frequent, predictable service. Furthermore, achieving this modal shift requires policy interventions that deliberately make private car use more expensive.
- **Improve:** This strategy seeks to reduce the per-kilometre emission rates of vehicles. The Indian government is aggressively pursuing the electrification of its transport fleet alongside fuel efficiency enhancements. Initiatives such as the National Electric Mobility Mission Plan (NEMMP) and the FAME scheme provide critical buyer incentives, fund public charging infrastructure, and support technology development. Additionally, India transitioned directly to BS-VI fuel quality standards in 2020 and has mandated a 20% blending of biofuels into transport fuels to further clean up the fuel architecture.

Implementation Challenges and Systemic Alignment While the electrification of bus

fleets is essential for reducing fossil fuel dependency and improving local air quality, transitioning to electric vehicles presents significant implementation challenges. One of the most prominent barriers is the lack of widespread, reliable charging infrastructure, which fuels consumer "range anxiety". Moreover, electrification only yields long-term emission benefits if it is accompanied by the massive decarbonization of the broader power sector.

The transition to electric mobility must also be synchronized with systemic public transport reforms. Because transport infrastructure choices exhibit high path dependence, the decisions made today will dictate mobility patterns for decades. Creating efficient mass transit systems involves high upfront capital costs, requiring a delicate balance between high-cost solutions, like metro rail, and moderate-cost bus-based systems.

Finally, several institutional and socio-cultural roadblocks must be addressed to ensure effective decarbonization. Institutional fragmentation frequently prevents the development of comprehensive, integrated city-wide mobility plans. Culturally, shifting commuters to public transport means competing against an upwardly mobile, asset-acquisitive mindset that views private vehicle ownership as a status symbol. To overcome this, public transport must be radically reimagined to centre on diverse consumer needs particularly those of women, children, and the elderly focusing heavily on perceptions of safety, accessibility, and affordability. Furthermore, policy alignment must carefully navigate the complex connections between mass transit, intermediate public transport, and the livelihoods of those operating within the informal transit sectors.

iii. Ribeiro, P.J.G., Dias, G., & Mendes, J.F.G. (2024). Public Transport Decarbonization: An Exploratory Approach to Bus Electrification

Theme – Operational and Technological Considerations in Bus Electrification

Ribeiro et al. (2024) provide a comprehensive systematic review of global bus electrification practices, examining the critical transition from traditional diesel-powered urban fleets to Battery Electric Buses (BEBs). While the European Union has set ambitious targets to reduce greenhouse gas emissions by at least 55% by 2023 and

achieve climate neutrality by 2050, the current adoption rate remains strikingly low; in 2020, 93.5% of EU buses were still diesel-powered, and only 0.9% relied on electric batteries. To bridge this gap, the study thoroughly evaluates the operational, technological, and economic facets of integrating BEBs into public transport networks.

Environmental Performance and Passenger Acceptance A primary finding of the research is that BEBs offer significant environmental and operational advantages, notably zero harmful tailpipe emissions, quieter engine operation, and higher energy efficiency. Because BEBs possess fewer moving parts than traditional internal combustion engines, they also benefit from heavily reduced maintenance requirements. Interestingly, these technological improvements directly influence commuter behaviour and satisfaction. The quieter and smoother ride provided by BEBs allows passengers to read or work comfortably, making public transport a much more attractive option for both daily commuters and leisure travelers. Studies demonstrate that the deployment of BEBs increases the public's willingness to use mass transit, and users are even inclined to pay higher fares for these modernized, green services.

Life-Cycle Emissions and Grid Capacity Requirements While the direct "tank-to-wheel" emissions of BEBs are zero, Ribeiro et al. (2024) emphasize the absolute necessity of evaluating the entire "well-to-wheel" life cycle. The true environmental benefit of fleet electrification depends entirely on the energy sources powering the local electrical grid. If a city's power grid relies heavily on fossil fuels, the additional energy load required to charge a BEB fleet can inadvertently increase greenhouse gas emissions at the power plant level, effectively shifting the environmental burden rather than eliminating it. To maximize climate benefits, transit agencies must couple fleet electrification with green energy procurement. Utilizing renewable energy sources, such as solar-powered charging stations, can further reduce the operational carbon footprint and lower day-to-day operational costs by up to 8%. Additionally, the physical size of the battery plays a role in life-cycle emissions; research indicates that an optimal battery capacity of 120 kWh often yields a better overall life-cycle environmental impact than heavier 300 kWh batteries or smaller 60 kWh configurations.

Cost Implications and Fleet Replacement Strategies The financial transition to an electrified fleet presents a paradox: while BEBs are currently much more expensive to

purchase than diesel buses, they are significantly more cost-effective to operate over their lifespan. The high initial capital requirements stem from the cost of the advanced vehicles themselves, as well as the massive investments needed to install dedicated charging infrastructure. However, BEBs generate operational economic savings of up to 6.0% compared to traditional buses due to lower electricity costs versus diesel fuel and reduced maintenance overhead. Furthermore, technological advancements are continuously driving down battery prices, which is expected to make electric buses fully cost-competitive with diesel equivalents in the near future, lowering life-cycle external costs below those of conventional buses by 2030.

Operational Adjustments and Charging Infrastructure Successful deployment of BEBs introduces complex operational hurdles that require transit agencies to fundamentally rethink routing, scheduling, and charging time management. The research identifies several critical factors for optimizing BEB operations:

- **Charging Location:** The most efficient charging scheme generally involves installing charging infrastructure at the endpoints (end stops) of bus routes rather than distributing them randomly along the way. For highly dense urban areas, regular charging stations can be placed in central transit hubs where buses pass multiple times a day to maximize utility.
- **Charging Time Management:** To manage grid capacity and reduce costs, operators frequently utilize overnight charging (typically between 8 p.m. and 3 a.m.) when electricity prices are lower and overall energy availability on the grid is higher. While fast-charging opportunity technology exists and can outperform regular charging operationally, it demands significantly more robust electrical infrastructure, which may not be physically or economically feasible in all cities.
- **Route and Schedule Alignment:** Transit operators must carefully assign routes based on the specific battery capacity of the vehicles, ensuring the buses can complete their daily schedules without running out of power. Phased deployment is highly recommended, initially introducing BEBs in denser urban cores where they cover shorter routes within smaller geographical areas.

In conclusion, Ribeiro et al. (2024) demonstrate that while replacing diesel fleets with BEBs is an essential step toward decarbonizing urban transport, it cannot be done in isolation. It requires a holistic, phased approach that carefully balances high upfront costs with long-term savings, aligns route lengths with battery ranges, and intimately

links transit operations with clean grid capacity and smart charging infrastructure.

iv. Cabigiosu, A. (2025). The Adoption of Electric Vehicles in Public Transport Services: Space, Path Dependency and Embeddedness

Theme – Spatial and Institutional Barriers in Electric Public Transit Adoption

Cabigiosu (2025) expands the theoretical debate on technological adoption by demonstrating how physical space acts as an active agent that generates path dependence and embeddedness in the electrification of public transport. The transition to electric mobility is not simply a matter of replacing diesel vehicles with electric ones; it is a complex process of spatial embedding where new technologies must be shoehorned into existing, rigidly defined urban footprints.

Path Dependency and Embeddedness Pre-existing public transport systems were fundamentally designed around the operational characteristics of Internal Combustion Engine (ICE) vehicles, such as long ranges and centralized refuelling needs. This legacy creates a strong path dependency, which cognitively and physically constrains the adoption of electric vehicles (EVs). Furthermore, transit systems exhibit high embeddedness they are intricately designed to fit the specific historical, geographical, and mobility needs of existing urban areas. Because electric vehicles have vastly different infrastructure requirements than ICE vehicles, integrating them into these highly embedded systems poses a massive logistical challenge.

Spatial Barriers to Charging Infrastructure The study identifies space availability as a primary barrier to entry for fully electric transit networks. EV batteries dictate infrastructure needs: longer battery ranges require significantly more depot terrain to accommodate slow-charging infrastructure for overnight use. Conversely, utilizing buses with shorter ranges requires securing public or private land to install fast-charging substations along the actual transit routes, a procedure burdened by complex bureaucratic and ownership hurdles. Furthermore, during the transition phase, transit agencies face compounded spatial constraints because they require extra depot terrain to simultaneously house both the legacy diesel fleet and the incoming electric vehicles.

Geographical and Operational Constraints Beyond physical space, environmental and operational realities restrict electrification. Climate heavily impacts EV performance,

as battery power is drained to heat or cool the vehicle's interior in extreme weather, severely limiting the driving range. Traffic congestion further complicates matters; heavy traffic reduces battery efficiency and makes it nearly impossible for buses to reliably meet scheduled fast-charging stops. Additionally, because transit agencies typically maintain existing routes and timetables to ensure coordination with other public services, new electric technologies are forced to conform to rigid, pre-existing operational parameters.

The Venice Case Study: Tailoring Technology to Space To illustrate these barriers, Cabigiosu (2025) utilizes a quasi-experimental case study of the Venice Municipality, where a single transit provider (AVM) had to deploy entirely different electric technologies across three distinct territories due to their unique spatial constraints:

- Lido (Island): Terminal space was severely limited and could not accommodate slow-chargers for the entire fleet overnight. Consequently, the agency opted for buses with low-capacity batteries and deployed fast-charging stations along the routes. This was only feasible because Lido had available land along the paths and minimal traffic, allowing buses to punctually meet their fast-charging schedules.

- Mestre (Mainland): The Mestre terminal possessed ample space to build comprehensive slow-recharging systems. Therefore, the agency deployed fully electric buses with massive 400 km battery ranges. This long range was vital because Mestre suffers from heavy traffic congestion, which would have made en-route fast-charging highly unreliable.

- Historical Venice: In the ancient, water-based city, the agency opted to re-motorize existing *vaporetti* (water buses) into hybrids rather than going fully electric. Fully electric vessels would require tens of megawatts of power and massive charging infrastructure (sizable inverters and columns) that simply could not fit into existing, tightly constrained terminals. Furthermore, placing bulky charging infrastructure in an ancient, legally protected open-air museum presented insurmountable landscape and cultural heritage barriers. Hybrid vessels bypassed these spatial issues by recharging themselves while running.

Ultimately, the successful integration of electric transit is highly sensitive to the local operational context. It requires a holistic restructuring of infrastructure, customized to the spatial characteristics of the specific city, rather than a universal, plug-and-play vehicle replacement strategy.

- v. Fabre, A., Howes, M., & Deweerdt, T. (2023). Best Practice in Urban Transport Decarbonisation: A Case Study of Three Initiatives in Brisbane

Theme – Best Practice Framework for Urban Transport Decarbonization

Fabre et al. (2023) establish a comprehensive best-practice framework for urban transport decarbonization based on international research and systematically apply it to Brisbane, Australia. The study underscores that technological solutions, such as simply transitioning to electric vehicles, are fundamentally insufficient on their own to achieve net-zero emissions. Instead, meaningful climate mitigation requires a holistic, systemic transformation of how cities plan for and manage mobility, structured entirely around the Avoid–Shift–Improve (ASI) paradigm.

The Best-Practice Decarbonization Framework To successfully decarbonize urban transport, the research highlights several critical, interlocking interventions:

- Avoid (Transport Demand Management and Land Use): Cities must proactively reduce the overall volume and distance of required travel⁶. This is achievable through smart-growth policies, mixed-use zoning, and the development of Transit-Oriented Developments (TODs) that compactly co-locate jobs and housing around mass-transit hubs. Furthermore, behavioural economics such as congestion pricing, increased parking fees, and fuel taxes must be aggressively utilized to deliberately discourage private car use.
- Shift (Low-Emission Modes): Urban environments must be redesigned to encourage a massive modal shift away from private motorized vehicles. This involves heavy investments in making active mobility (walking and cycling) and public mass transit highly efficient, safe, and attractive. This approach also heavily emphasizes social equity, ensuring that new transport networks remain highly affordable, convenient, and accessible for low-income neighbourhoods.

- Improve (Technological Standards): For the remaining vehicles, policies must mandate stricter emission standards and actively subsidize the transition to electric vehicles (EVs) and alternative cleaner fuels, like hydrogen.

Brisbane's Paradoxical Transport Context When evaluating Brisbane against this framework, the city presents a highly paradoxical landscape. On the positive side, Brisbane operates an expansive rail network and highly successful, high-quality bus systems that run on dedicated "quick-ways" fully separated from regular traffic. The city is also actively expanding its cycling networks and investing in TODs near its urban core.

However, these strengths are severely undermined by deeply entrenched urban sprawl and a low population density averaging just 18 people per hectare. Historically, Brisbane's transport investments disproportionately favoured road infrastructure to accommodate a post-war economic boom, a legacy that continues to make private car use the most convenient option today. Consequently, Brisbane suffers from massive car dependency: roughly 80% of households own a vehicle, and a staggering 85% of all daily trips are made by private cars. Despite having high-quality transit, public transport accounts for only 13.7% of mode share, and active mobility constitutes a mere 4% of commutes. Compounding these systemic challenges is the city's vulnerability to extreme climate events, such as frequent flooding that regularly shuts down roads, ferry networks, and bikeways.

Evaluation of Three Key Transport Initiatives The researchers analyze three major Brisbane initiatives to determine their alignment with best-practice decarbonization strategies:

- The Transport Plan for Brisbane: This 25-year strategic guideline aims to make the city's network more attractive and sustainable by prioritizing active mobility, shared transport, and public-private innovation hubs. While it outlines progressive goals, it paradoxically includes initiatives to promote motorcycling to ease congestion, which actively conflicts with the fundamental best-practice goal of shifting commuters to zero-emission transport modes.
- The Cross River Rail Project: Driven by the reality that employment and

population growth in the inner city are projected to outstrip the existing rail network's capacity by the 2030s, this major infrastructure project adds a 10.2-kilometer rail line and four new underground stations. By decongesting the CBD bus network and improving service frequency, the project is projected to successfully shift 47,000 car users to trains by 2036. It also serves as a powerful catalyst for urban renewal and new TODs. Despite its strong alignment with "Shift" strategies, the \$5.4 billion project has faced criticism for construction delays and a lack of transparency regarding its cost-benefit allocation.

- The Green Bridges Program: This initiative physically transforms urban infrastructure by constructing four new river-crossing bridges exclusively dedicated to pedestrians, cyclists, and public transport. The program stands out for its strong community engagement which even led to the cancellation of one proposed bridge based on public feedback and its deliberate integration of mixed-use zoning around the bridge landings. This directly supports the framework's recommendation to physically expand safe, active mobility networks separate from cars.

Policy Coherence and the Limits of Electrification The ultimate finding of Fabre et al. (2023) is that while Brisbane demonstrates strong individual project efforts, a severe lack of broader policy coherence threatens its decarbonization goals. Transport electrification in the region remains in its infancy, with very few public charging stations and a bus fleet still heavily reliant on petrol and natural gas.

More critically, the government's financial priorities actively continue to lock in car dependency. The current budget allocated to road transport infrastructure is \$22.4 billion, which vastly outweighs the \$16.9 billion combined budget for all sustainable transport modes. The study concludes that building new green infrastructure or simply waiting for EV adoption is grossly inadequate. Meaningful decarbonization demands strict Transport Demand Management actively halting road expansions, deliberately disincentivizing private vehicle use through pricing, and fundamentally restructuring urban land use to prioritize people over cars

Key Takeaways: -

1. Strengthening public transport systems is essential for reducing urban transport emissions (World Bank, 2021).
2. The Avoid–Shift–Improve framework provides a structured approach to transport decarbonization (IIHS, 2022; Fabre et al., 2023).
3. Battery Electric Buses (BEBs) significantly reduce tailpipe emissions but require infrastructure readiness and operational adjustments (Ribeiro et al., 2024).
4. Depot planning, route suitability, and charging infrastructure are critical for successful electric bus integration (Ribeiro et al., 2024; Cabigiosu, 2025).
5. Spatial constraints and institutional path dependency influence electrification outcomes (Cabigiosu, 2025).
6. Electrification must be integrated with land-use planning and modal shift strategies for long-term sustainability (World Bank, 2021; Fabre et al., 2023).

2.4. Formula For Calculations Used

2.4.1. Cycle Time Formula

Cycle time represents the total time taken by a bus to complete a full round trip, including both travel and waiting (layover) time at terminals. It is calculated as:

$$\text{Cycle Time} = 2 \times \text{Travel Time} + \text{Layover Time}$$

This concept is important because it directly determines how efficiently buses can operate on a route. (Transportation Research Board (TCQSM, 2013), Public Transport Planning and Operation)

Literature Insight:

Avishai Ceder (2007) explains that cycle time plays a crucial role in deciding fleet size and service frequency. Layover time is not just idle time it helps absorb delays and ensures that buses stay on schedule despite traffic disruptions.

2.4.2. Headway / Service Frequency Formula

Headway refers to the time gap between two consecutive buses on the same route and is calculated as:

$$\text{Headway} = \text{Cycle Time} / \text{Number of Buses (per direction)}$$

It is one of the most important indicators of service quality from a passenger's perspective. (Transit Capacity and Quality of Service Manual, Public Transport Planning and Operation)

Literature Insight:

The TCQSM (2013) highlights that headway directly influences the Level of Service (LOS). Shorter headways reduce waiting time, improve reliability, and make public transport more attractive, while longer headways discourage users.

2.4.3. Fleet Allocation Formula

Fleet allocation determines how buses are distributed across different routes. A commonly used approach is:

$$\text{Buses per Route} = (\text{Route Distance} / \text{Total Network Distance}) \times \text{Total Fleet}$$

This method ensures that longer routes receive more buses compared to shorter ones. (Urban Transit Systems and Technology, World Bank)

Literature Insight:

This proportional approach helps maintain balanced service across the network. However, recent studies suggest that combining distance-based allocation with passenger demand data leads to more efficient and responsive transit systems.

2.5. Complimentary Policies:

i. PM E-Bus Sewa Scheme, 2023

Policy Explanation:

The PM E-Bus Sewa Scheme was introduced by the Government of India to strengthen urban public transport by promoting the use of electric buses. The scheme aims to deploy a large number of electric buses across Indian cities in order to reduce air pollution and improve the quality of urban mobility. It also supports the development of charging infrastructure, operational support for city transport agencies, and institutional capacity building. By encouraging cities to adopt electric buses instead of diesel-powered fleets, the scheme helps move urban transport systems toward cleaner and more sustainable operations.

Relation to the Thesis:

This scheme is closely connected to the focus of this thesis as it promotes the large-scale introduction of electric buses in urban transport systems. It supports the

transition from diesel/Petrol buses to low-carbon electric buses, which is a key aspect of decarbonization of public transport. The scheme also provides a practical policy framework that cities can use while planning and implementing electric bus systems.

ii. National Electric Mobility Mission Plan (NEMMP),2013

Policy Explanation-

The National Electric Mobility Mission Plan was launched in 2013 as a national strategy to promote electric and hybrid vehicles in India. The policy aims to reduce dependence on fossil fuels and lower greenhouse gas emissions from the transport sector. It encourages the development of electric vehicle manufacturing, charging infrastructure, technological research, and market incentives to support electric mobility. The plan also focuses on creating a supportive ecosystem that can enable the wider adoption of electric vehicles across different sectors, including public transportation.

Relation to the Thesis-

NEMMP provides the overall policy direction for electric mobility in India. For this thesis, the policy is important because it lays the foundation for electrifying public transport systems. By promoting electric vehicles and supporting infrastructure development, the policy helps cities transition from diesel-based buses to electric buses, contributing to the reduction of emissions in urban transport systems.

iii. Faster Adoption and Manufacturing of Electric Vehicles (FAME I & II), 2015 and 2022

Policy Explanation-

The FAME scheme was introduced as part of the National Electric Mobility Mission Plan to accelerate the adoption of electric vehicles in India. The scheme provides financial incentives and subsidies for electric vehicles, including electric buses used in public transportation. It also supports the development of charging infrastructure and promotes domestic manufacturing of electric vehicle components. The second phase of the scheme, FAME II, places greater emphasis on electrifying public transport fleets and shared mobility systems, particularly buses operating in urban areas.

Relation to the Thesis-

The FAME scheme plays a significant role in supporting the adoption of electric buses in Indian cities. By offering financial incentives and infrastructure support, it reduces the economic barriers that transport agencies face when transitioning from diesel buses to electric buses. This makes the scheme highly relevant to the thesis, as it directly supports the decarbonization of urban bus transit systems.

iv. National Urban Transport Policy,2006

Policy Explanation-

The National Urban Transport Policy was introduced to guide Indian cities toward more sustainable and efficient urban transportation systems. The policy emphasizes the need to prioritize public transport over private vehicles in order to improve mobility and reduce congestion. It promotes integrated planning between land use and transport, and encourages the development of environmentally friendly transport modes such as bus systems, Bus Rapid Transit (BRT), and non-motorized transport infrastructure. A key principle of the policy is to focus on moving people rather than vehicles, which helps improve overall urban mobility.

3. Methodology



Fig:1 Methodology Flowchart

The above, Fig 1 is showing the methodology in flowchart format.

The methodology for this study follows a structured and sequential approach to assess the feasibility and integration of electric public transit in Indore. It is designed to move from understanding the existing system to identifying challenges, evaluating alternatives, and proposing practical planning solutions.: -

Step 1: Analysis of the Existing Public Transit System

The study begins with establishing a comprehensive understanding of Indore's existing public bus system to create a baseline for comparison. This involves analyzing route networks, service coverage, operational efficiency, and infrastructure conditions of the current fossil fuel-based system. Both primary and secondary data are utilized at this stage. Primary data includes field observations along major corridors, assessment of route-wise performance such as trip frequency, travel time, passenger load, and fuel consumption, along with interactions with drivers and transit officials. Secondary data is collected from AICTSL reports, land-use maps, and traffic studies. This step helps identify existing inefficiencies such as route overlaps, service gaps, and operational constraints.

Step 2: Identification of Operational and Environmental Challenges

Building on the baseline analysis, the next step focuses on identifying key operational and environmental issues within the current system. The study examines factors such as congestion-related delays, irregular service frequency, high fuel dependency, maintenance-related downtime, and emission impacts in dense urban corridors. Data is collected through passenger surveys, field observations, and supporting reports on air quality and traffic conditions. This step highlights the limitations of the existing system and establishes the need for a cleaner and more efficient alternative.

Step 3: Comparative Evaluation of Electric Transit

After identifying system limitations, the study evaluates electric buses as a potential alternative. This involves a comparative analysis between electric and conventional buses based on parameters such as distance travelled, operational performance, energy consumption, service adaptability, and emission reduction potential. Technical specifications, policy documents, and case studies from other cities are reviewed to understand real-world applicability. The assessment also considers operational factors such as battery capacity, charging time, and route compatibility to ensure a realistic evaluation.

Step 4: Planning for Electric Transit Integration

Based on the insights derived from the analysis, this step focuses on developing planning

strategies for integrating electric buses into the existing network. It includes route optimization by identifying high-demand corridors, reducing redundancies, and improving service efficiency. Depot planning is carried out by evaluating land availability, charging infrastructure needs, and grid readiness. GIS-based spatial analysis is used to support decision-making through route mapping and identification of suitable depot locations. This stage ensures that electrification enhances system performance without disrupting existing operations.

Step 5: Integration with Technology and Policy Framework

The final step focuses on aligning the proposed system with technological advancements and policy frameworks. Recommendations include the adoption of smart fleet management systems, real-time monitoring, and energy optimization tools. Relevant national and state EV policies are reviewed to ensure alignment and support for implementation. Stakeholder perspectives are also considered to ensure practical feasibility. This step ensures that the proposed system is not only operationally efficient but also institutionally and technologically sustainable.

Why is this methodology Suitable?

The adopted methodology is suitable for this research as it follows a clear and logical progression aligned with the study objectives. It begins with a detailed analysis of the existing transit system using both primary and secondary data, ensuring a realistic understanding of current conditions. This is followed by the identification of operational and environmental challenges, which establishes a strong foundation for evaluating electric transit as an alternative.

Further, the methodology incorporates comparative analysis and planning strategies such as route optimization and depot location, making the study both analytical and solution-oriented. The inclusion of policy and technological considerations enhances its practical relevance. Overall, the methodology effectively integrates analysis, evaluation, and planning, enabling the research to generate feasible and context-specific outcomes.

4. City Profile: Indore

Indore, located in the western part of Madhya Pradesh, serves as both the district and divisional headquarters and is widely recognized as the commercial capital of the state. The city is strategically positioned on the southern edge of the Malwa Plateau at an average elevation of about 553 meters above sea level, making it one of the highest major cities in central India. It lies approximately 190 kilometres west of Bhopal and falls between latitudes 22°31'N to 23°05'N and longitudes 75°25'E to 76°15'E. Historically, the presence of the Kanh and Saraswati rivers supported its emergence as an important trading centre, while the surrounding fertile black cotton soil region continues to support agricultural activities such as soybean and cotton cultivation.

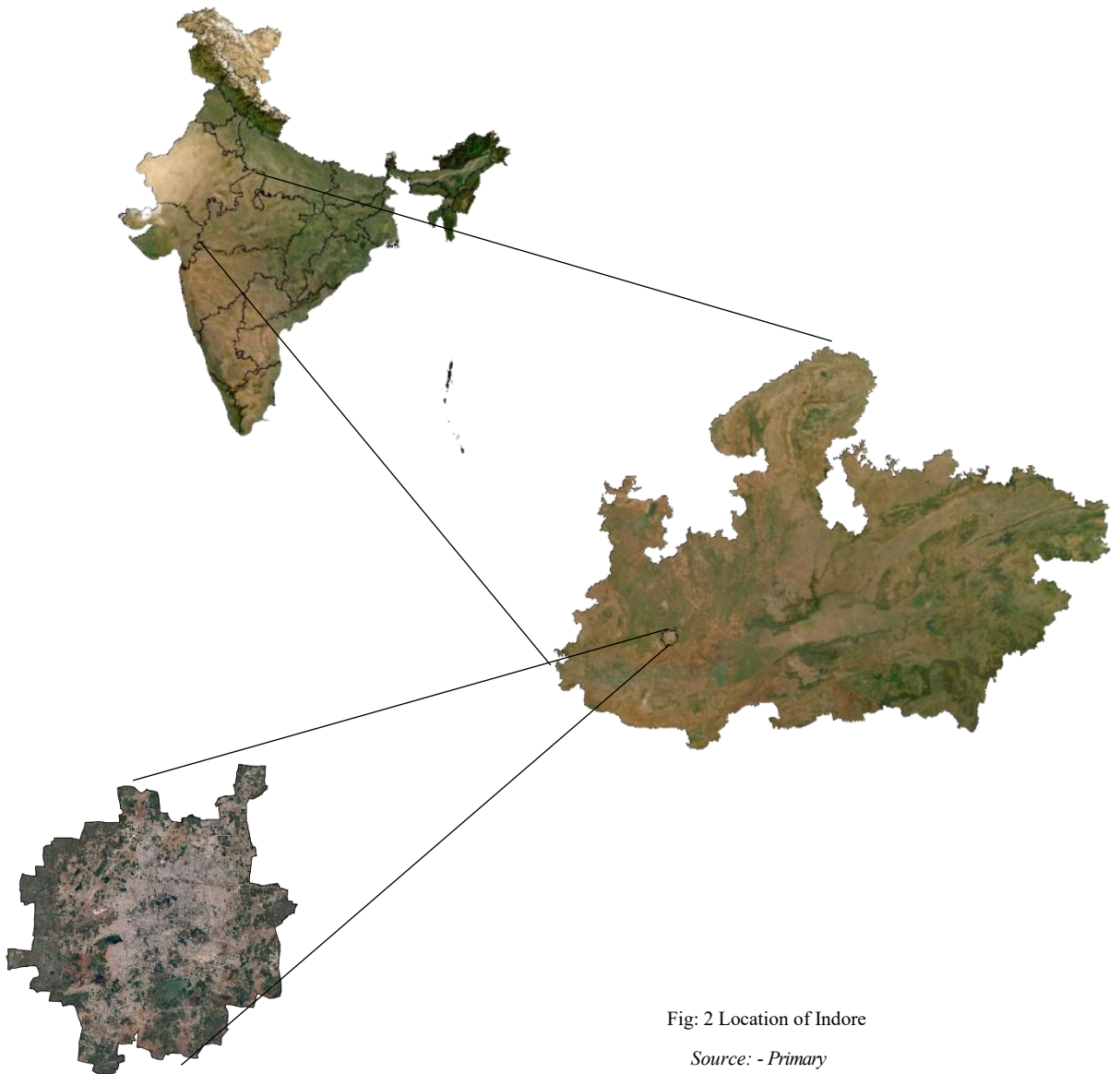


Fig: 2 Location of Indore

Source: - Primary

The city experiences a transitional climate between humid subtropical and tropical savanna types, characterized by three distinct seasons. Summers are typically hot, with temperatures often exceeding 40°C, while the monsoon season brings moderate to heavy rainfall that supports regional water availability. Winters are comparatively mild and comfortable, contributing to favourable living conditions. These climatic characteristics influence not only daily life but also urban infrastructure and transport demand patterns.

According to the 2011 Census, Indore has a population of nearly 2 million within the municipal limits and over 2.1 million in the urban agglomeration, reflecting its status as a densely populated and rapidly growing urban centre. With a high literacy rate of 85.5%, the city demonstrates a strong educational base, supported by reputed institutions and a growing knowledge economy. Although the sex ratio remains slightly below the national average, the city continues to make progress in social development indicators.

Indore is culturally diverse, with a majority Hindu population alongside significant Muslim and Jain communities, and smaller groups of Christians, Sikhs, and Buddhists. Hindi is the primary language of communication, while regional dialects such as Malvi and Nimadi are also widely spoken. The presence of multiple linguistic and cultural communities adds to the city's inclusive and dynamic social fabric.

Economically, Indore stands as a major industrial and commercial hub in central India. It has a well-developed industrial base spanning textiles, pharmaceuticals, and automobile manufacturing. The nearby Pithampur Industrial Area, often referred to as the “Detroit of India,” plays a significant role in driving industrial growth. In recent years, the city has also emerged as a growing centre for information technology and startups, supported by premier institutions such as Indian Institute of Technology Indore and Indian Institute of Management Indore, which foster innovation and skilled human resources.

In terms of urban governance, the Indore Municipal Corporation manages civic services and infrastructure development across 85 administrative wards. The city has gained national recognition for its effective urban management, particularly in solid waste management, consistently ranking as the cleanest city in India. This achievement reflects strong institutional capacity and active public participation.

Overall, Indore represents a rapidly growing urban centre with a strong economic base, diverse population, and efficient governance structure. These characteristics, combined with increasing travel demand and urban expansion, make it an important case for studying sustainable and efficient public transport systems, including the integration of electric transit solution.

Fig 3, outlines the city's planned land use, zoning regulations, transportation networks, and key infrastructure projects. It highlights residential, commercial, industrial, and green zones while depicting proposed roads, and urban expansion areas. The map serves as a blueprint for sustainable growth, guiding urban development and policy implementation across Indore.

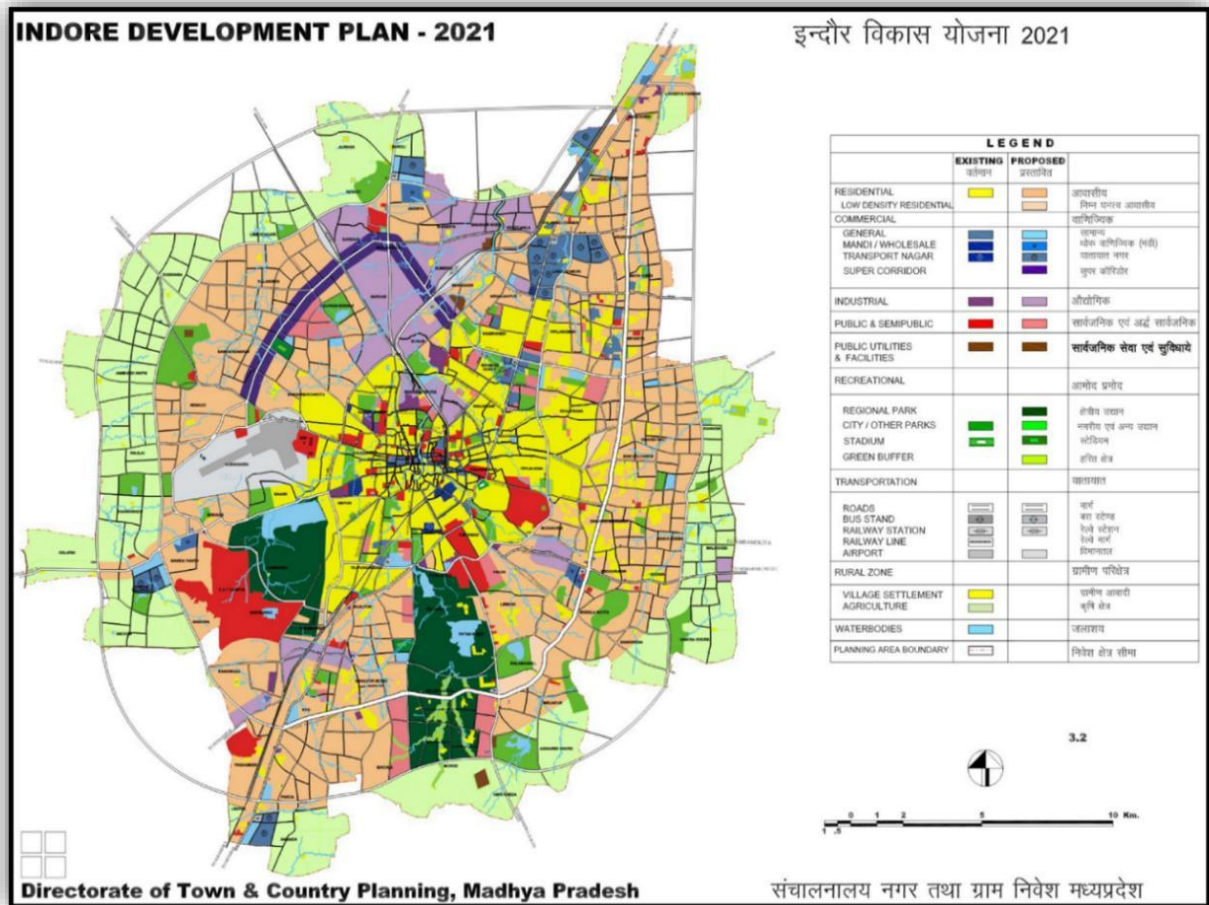


Fig:3 Indore Development Plan 2021 Map

Source: - mptownplan.gov.in

Fig. 3 illustrates the spatial structure and future urban growth pattern of Indore through the Development Plan 2021, emphasizing the relationship between land use distribution and urban mobility. The map reveals a predominantly radial urban form where major activity zones and transport corridors converge toward the central city area, creating high movement concentration

along key arterial routes. Commercial and mixed-use activities are largely concentrated within the inner urban core, while residential expansion is visible toward peripheral areas, indicating increasing travel demand between outer and central zones. Industrial pockets are strategically located along major highway corridors, supporting regional connectivity and freight movement. The proposed transport network shown in the plan highlights the importance of corridor-based mobility and improved accessibility across the city. From the perspective of this study, the map provides an important spatial foundation for understanding travel patterns, identifying high-demand public transport corridors, evaluating congestion-prone areas, and proposing efficient electric bus integration, depot planning, and route optimization strategies within Indore's evolving urban structure.

Fig 4, Brings to life how the core of Indore is thoughtfully planned and organized. Instead of a chaotic mix of uses, the city is carefully divided into residential areas where people live, commercial zones that support business and trade, industrial pockets for production, and mixed-use spaces that blend daily activities. What makes this plan especially meaningful is how it connects these zones through well-designed roads, transit corridors, and accessible public spaces. Green areas and community facilities are not treated as afterthoughts but as essential parts of everyday urban life.

More than just a technical map, this layout reflects a vision for a city that works smoothly for its people. It considers how Indore will grow in the future and ensures that infrastructure keeps pace with that growth. By doing so, it aims to reduce congestion, improve accessibility, and create a more balanced, liveable environment where different parts of the city support each other rather than compete.

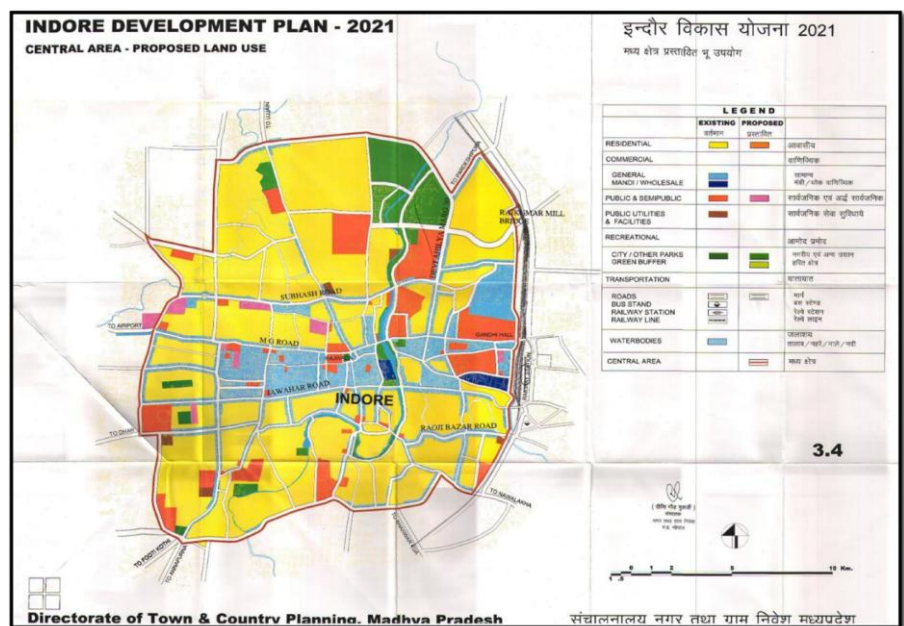


Fig: 4 Indore Development Plan 2021 Central Area Map

Source: - mptownplan.gov.in

Fig 5, presents a detailed spatial representation of land use within the Indore planning boundary, highlighting the region's environmental and urban structure. The map classifies the area into water bodies (4.57 sq. km), Green/Agricultural land (237.79 sq. km), built-up areas (221.41 sq. km), and barren land (43.28 sq. km), providing a clear understanding of existing land distribution.

Green/Agricultural land forms the largest share, reflecting the region's agrarian character and the presence of extensive open spaces, particularly along the periphery. Built-up areas are concentrated in the central and surrounding zones, indicating dense urban development with gradual expansion toward outer areas. Water bodies are limited but dispersed, contributing to ecological balance and local water systems. Barren land appears in smaller patches, suggesting areas with potential for future development.

Overall, the map highlights a transitional landscape where expanding urbanization coexists with significant agricultural land. This spatial pattern is crucial for guiding sustainable urban planning, infrastructure development, and environmental conservation within the study area.

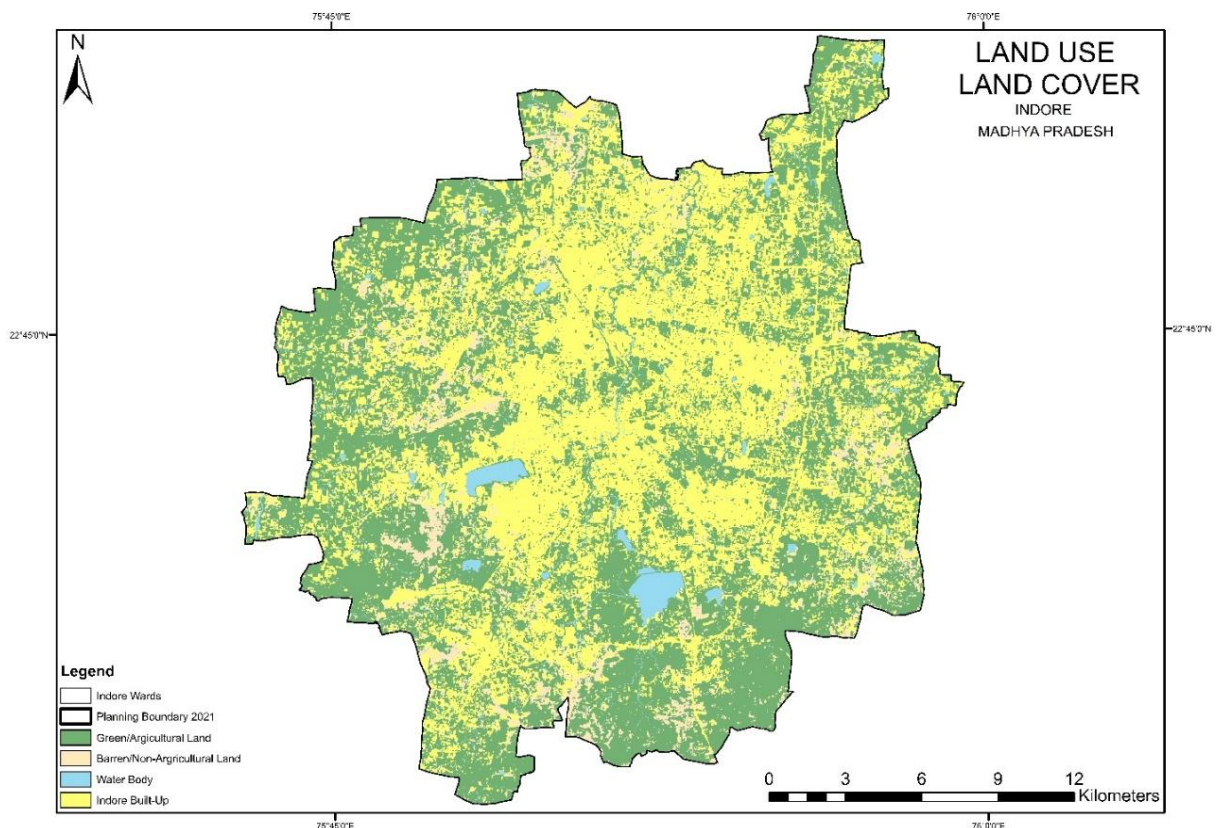


Fig:5: Land Cover Classification Map

Source: - Primary

Fig 6, illustrates the road hierarchy and connectivity pattern within the Indore planning boundary, highlighting the structure of the city's transportation network. The map presents a comprehensive road system with a total length of approximately 1,443 kilometres, including major corridors, city roads, state highways, and national highways. Key regional linkages such as NH 47 and NH 52, spanning around 60 kilometres, play a crucial role in connecting Indore with surrounding regions.

The road network shows a radial pattern, with major corridors extending from the city centre toward peripheral areas, ensuring connectivity between core urban zones and outer regions. National and state highways form the primary high-capacity routes, facilitating intercity movement and freight transport, while major corridors support intra-city mobility. The dense concentration of city roads in the central area reflects high urban activity and traffic demand.

Overall, the map highlights a well-developed but centrally concentrated network, indicating potential congestion in core areas. This spatial understanding is essential for improving traffic management, enhancing accessibility, and planning efficient public transport systems within the city.

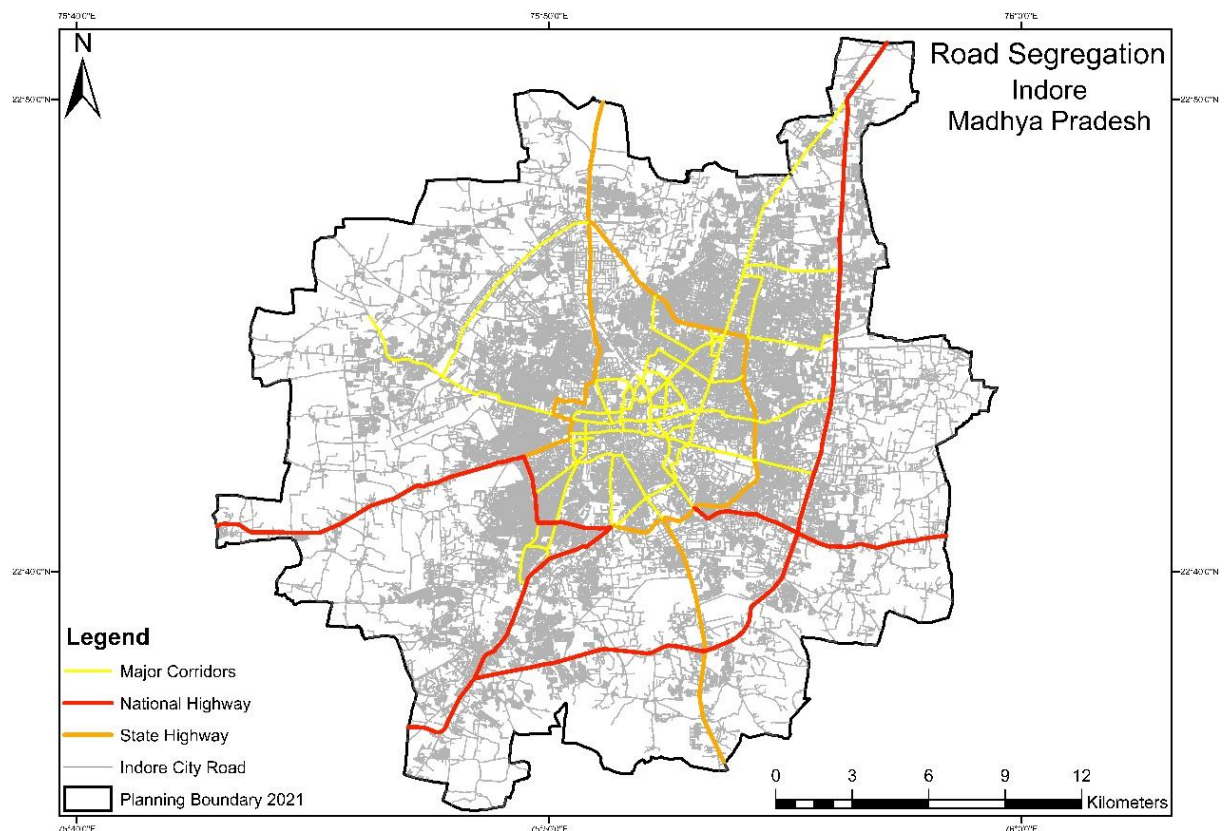


Fig: 6 Map showing Major Road Network

Source: - BBBike.org

Fig 7 shows the distribution of key urban landmarks across Indore, such as commercial areas, educational institutions, hotels, and major tourist spots. Instead of just helping with navigation, the map gives a clear picture of how different parts of the city function. It highlights where activities are concentrated, showing areas that are economically active or socially important. Commercial hubs, usually located along major roads and intersections, attract a large number of people due to jobs and services. Because of this, these areas generate more movement and travel demand. This connection between land use and movement helps explain why public transport infrastructure, like bus stops, is more concentrated in certain parts of the city.

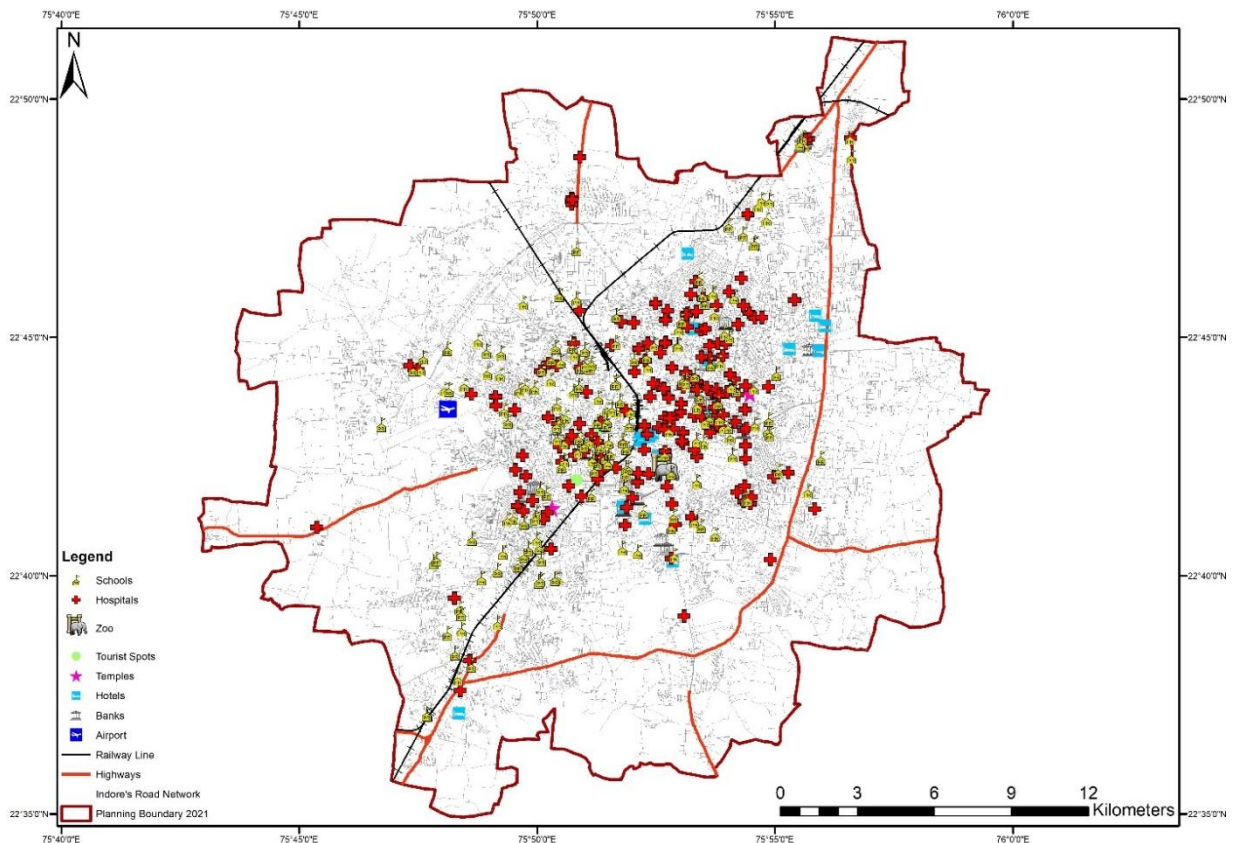


Fig: 7 Map of Urban Landmarks

Source: - Primary

Major tourist locations: -

- Lal Bagh Palace
- Khajrana Ganesh Temple
- Ralamandal Wildlife Sanctuary
- Sarafa Bazaar
- Annapurna Temple
- Rajwada Palace

Fig 8, illustrates the city's key transportation hubs, including bus stops, railway stations, the airport. It provides a spatial understanding of passenger and freight movement, highlighting critical nodes for urban mobility. This map is essential for transport planning, optimizing connectivity, and improving infrastructure for public Transport.

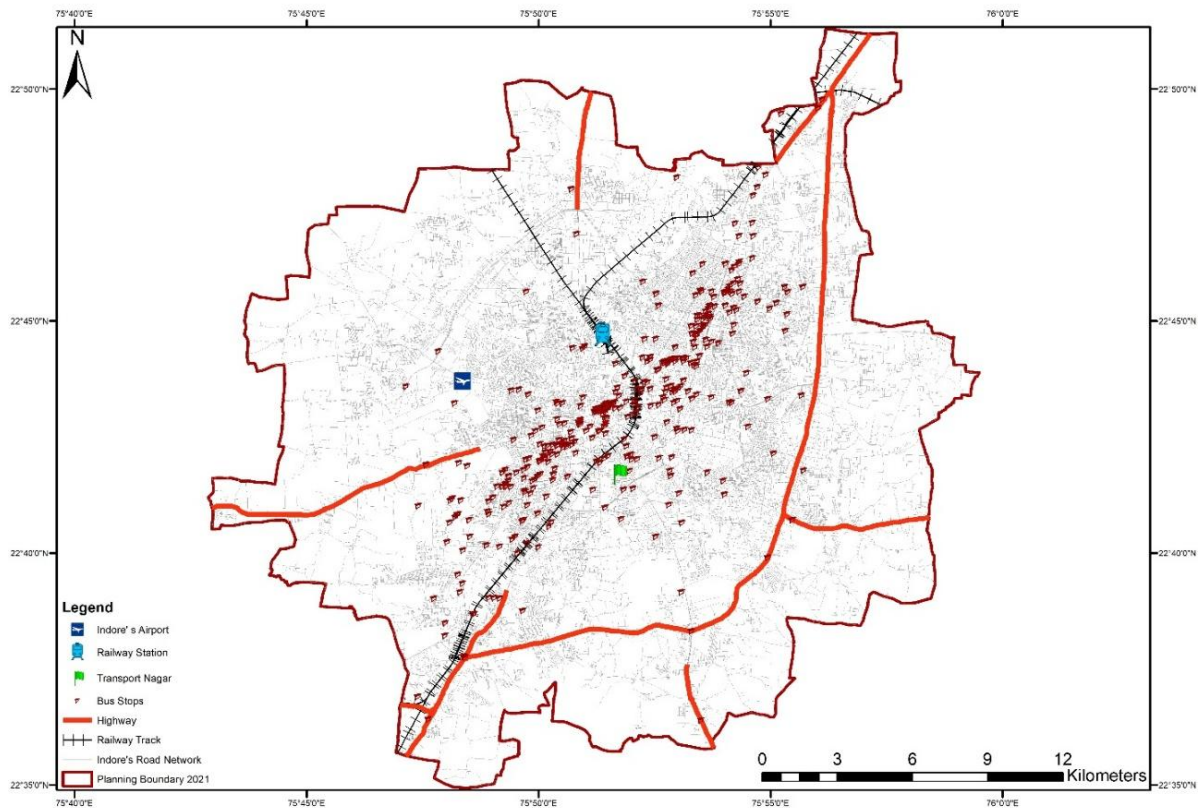


Fig: 8 Map showing Important Transport Node and Bus Stops
Source: - Primary

Railways, the airport, and Transport Nagar act as the main entry points through which people enter Indore's public transport system. The railway line, running through the city, brings in the largest number of passengers and naturally attracts a dense cluster of bus stops around it, making it the primary movement spine. The airport, located on the outskirts, handles fewer but more specific travelers and depends on road connectivity for distributing passengers into the city. Transport Nagar, on the other hand, works as a key interchange hub, helping to redistribute passengers and goods across different parts of Indore. Together, these nodes shape the overall pattern seen in the map, where bus stops are concentrated near high-demand areas and spread out towards the periphery, reflecting how people enter and move through the city.

4.1. Present Scenario: -

Indore has a relatively structured public transport system supported by city bus services and the Bus Rapid Transit System (BRTS), which was once a key mobility corridor. However, despite this infrastructure, a significant share of daily travel is still dominated by private vehicles such as two-wheelers and intermediate public transport modes like auto-rickshaws. This indicates a clear gap between the availability of formal public transport and user preference, often driven by issues of accessibility, convenience, and connectivity.

The spatial distribution of bus stops further reflects this imbalance. A higher concentration of stops is observed along major arterial corridors such as AB Road, Ring Road, and the former BRTS route, indicating corridor-based planning. In contrast, peripheral and newly developing areas exhibit sparse bus stop coverage, limiting access to formal public transport. This uneven distribution creates a dependency on informal and para-transit systems for first- and last-mile connectivity.

Land use plays a crucial role in shaping this pattern. Central areas with a mix of commercial, institutional, and high-density activities show a dense clustering of bus stops, corresponding to higher travel demand. On the other hand, predominantly residential and fringe areas tend to have fewer stops and lower service frequency, reinforcing spatial inequality in transport accessibility.

With rapid urban expansion, Indore has witnessed an increase in average trip lengths and travel demand. The city's role as a regional economic hub also attracts daily commuters from surrounding areas, further intensifying pressure on the transport network. This is particularly evident during peak hours, when congestion levels rise and travel times become unpredictable.

Although the BRTS corridor was designed to provide faster and more efficient transit along selected routes, its effectiveness has been limited by weak feeder systems and inadequate last-mile connectivity. Many users find it difficult to access bus stops within a comfortable walking distance (typically 400–500 meters), reducing the overall usability of the system. This highlights a lack of integration between trunk routes and local accessibility networks.

At the same time, the increasing reliance on private vehicles has contributed to growing traffic congestion, higher fuel consumption, and rising air pollution levels. These trends not only affect mobility efficiency but also have broader environmental and public health implications.

Improving the coverage, spacing, and integration of bus stops is therefore critical. A more evenly distributed and well-connected public transport network which is supported by reliable feeder services, non-motorized transport infrastructure, and route optimization which can significantly enhance accessibility. Such improvements can encourage a modal shift toward public transport, contributing to a more sustainable, efficient, and inclusive urban mobility system in Indore.

5. Data Collection and Data Analysis: -

To gain a clear understanding of the challenges and gaps in Indore's public transport system particularly from a clean air perspective a structured and systematic approach to data collection and analysis was followed. The aim was not only to study how the system currently functions but also to understand how it impacts everyday travel and the urban environment.

Secondary data and a little of Primary Observation were used to build a comprehensive picture. Primary data included observations and assessments of travel behaviour, accessibility to bus stops, and on-ground traffic conditions. Secondary data was gathered from existing reports, planning documents, and transport-related studies, along with the help of AICTSL Agency, providing insights into route networks, vehicle usage patterns, and emission trends.

The collected information was carefully analysed to identify key issues affecting the system. These included uneven distribution of bus stops, limited accessibility in certain areas, a growing dependence on private vehicles, and zones experiencing higher levels of congestion and pollution. Rather than looking at these challenges in isolation, the analysis focused on how they are interconnected and how they influence both mobility and air quality in the city.

The findings from this analysis form a strong foundation for developing targeted planning and infrastructure strategies. By addressing gaps in accessibility, improving network efficiency, and encouraging a shift toward cleaner modes of transport (electric Buses), these strategies aim to support a more sustainable, efficient, and environmentally responsible mobility system for Indore.

5.1.Data Collection: -

5.1.1.Primary Data: -

To understand the operational challenges of Indore's public transport system and their impact on traffic conditions and air quality, specific primary data components were identified. These were collected through field-based observations, surveys, and user interactions, focusing on traffic behavior, congestion patterns, and mobility constraints across the city.

I. Traffic and Mobility Data: -

a) Traffic Flow and Congestion Study: -

This study focuses on examining traffic movement patterns across key

locations in Indore to identify congestion hotspots, peak-hour variations, and high-pressure corridors that influence public transport performance. The objective is to understand how traffic conditions affect bus operations in terms of travel time, delays, and service reliability.

Data collection was carried out through field observations at major intersections, BRTS corridors, and high-traffic zones during different times of the day. Traffic volume, flow characteristics, and vehicle composition were noted to capture variations between peak and non-peak hours. Particular attention was given to locations experiencing frequent congestion, where delays, idling time, and bottlenecks were observed and recorded.

In addition to physical observations, informal interactions with bus drivers and commuters were conducted to understand real-life challenges such as recurring delays, route-level issues, and peak-hour travel difficulties. These insights helped connect observed traffic conditions with user experience.

The analysis of this data helps in identifying critical congestion points and understanding their direct impact on public transport efficiency. Addressing these issues can improve travel time reliability, reduce unnecessary fuel consumption due to idling, and contribute to lowering vehicular emissions supporting cleaner and more efficient urban mobility.

b) Congestion Corridor Analysis: -

This component builds upon the broader traffic study by focusing specifically on major corridors that experience consistent congestion and significantly affect public transport movement. The aim is to analyze how corridor-level issues such as delays, bottlenecks, and interruptions influence the overall efficiency of bus services.

Field observations were conducted along key arterial roads and major transit corridors, including high-demand routes and former BRTS alignments. Data was collected during both peak and off-peak periods to understand temporal variations in congestion. Parameters such as traffic density, vehicle speed, intersection delays, and stoppage time were recorded.

Special attention was given to factors contributing to congestion, including on-street parking, encroachments, informal stopping of vehicles, and

passenger boarding and alighting patterns. These micro-level observations helped in identifying not just where congestion occurs, but why it occurs.

The findings provide a corridor-level understanding of congestion dynamics and their impact on public transport performance. This supports the identification of targeted interventions such as improved traffic management, better regulation of roadside activities, and the need for dedicated or priority lanes for buses. Such measures can enhance system efficiency, reduce delays, and contribute to a reduction in emissions, aligning with the goal of promoting cleaner and more sustainable mobility in Indore.

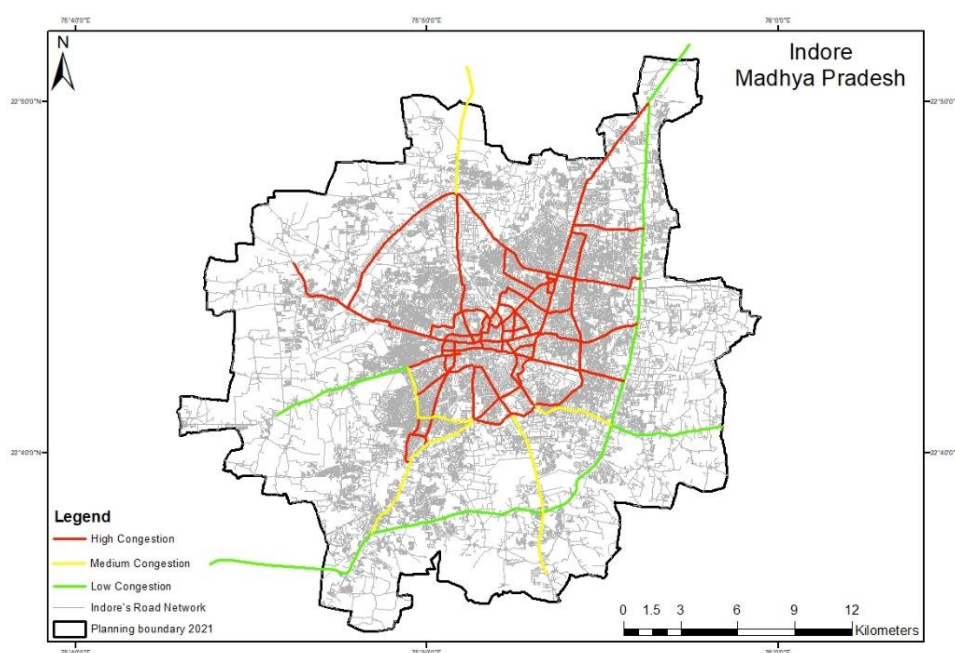


Fig: 9 Map showing Congested Corridors
Source: - Primary

S. No.	Corridor / Road Stretch	Key Locations Covered
1	AB Road (Agra–Bombay Road)	Vijay Nagar to Rajiv Gandhi Square
2	Ring Road	Bengali Square to MR 10 to Dewas Naka
3	BRTS Corridor (former)	Niranjanpur to Rajiv Gandhi Square
4	MG Road	Rajwada to Palasia Square
5	MR 10 Road	Super Corridor Junction to Airport Road

6	Dewas Naka Corridor	MR 10 to Industrial Area
7	Airport Road	Bada Ganpati to Devi Ahilya Bai Holkar Airport
8	Bhawar Kuan Square Corridor	Bhawar Kuan to Khandwa Road
9	Annapurna Road	Annapurna Temple to Rajendra Nagar
10	Sapna Sangeeta Road	Tower Square to Bhawar Kuan

Table 1, Major Congested Corridor

Source: - Primary

5.1.2. Secondary Data: -

This is the listing of secondary data what is required for the study with their sources: -

I. Public Transport System Data: -

a) Ridership and Operational Data: -

(Source: - Atal Indore city transport service Ltd. Report)

Ridership and operational data were collected to understand how the public transport system is currently functioning in terms of usage, efficiency, and service delivery. This includes information on daily passenger ridership, fleet size and composition, route coverage, and overall service operations across the city.

This data helps in identifying which routes experience high passenger demand and which ones are underutilized. It also provides insights into how effectively the existing system is meeting the travel needs of the population. By analysing these patterns, it becomes possible to recognize gaps in service frequency, accessibility, and connectivity.

In addition, operational data supports the evaluation of system performance by highlighting issues such as uneven service distribution, inefficiencies in fleet utilization, and variations in demand across different parts of the city. This understanding is essential for improving route planning, optimizing resource allocation, and enhancing the overall efficiency of the public transport system.

b) Public Transit Routes (Bus Routes): -

(Source: - Atal Indore City Transport Service Ltd. PPT.)

Data related to existing bus routes was collected to examine the spatial structure and connectivity of Indore's public transport network. This includes information on route alignments, major corridors, feeder routes, and their coverage across different parts of the city.

The available data shows that the bus network is primarily concentrated along major corridors such as AB Road, Ring Road, and the former BRTS routes. These corridors provide strong connectivity within central areas, linking important residential, commercial, and institutional zones. However, peripheral and newly developing areas have comparatively limited route coverage.

By analysing this route network, it becomes possible to identify gaps in accessibility, areas with overlapping services, and regions that are underserved by public transport. This helps in understanding how well the current system is distributed spatially and whether it effectively connects all parts of the city.

Such analysis is important for improving network planning, strengthening connectivity between different areas, and ensuring better integration with other modes of transport. It also provides a foundation for proposing improvements that can enhance system efficiency and make public transport a more reliable option for daily travel. Fig. 10 shows the existing bus route network of Indore, with major corridors and feeder routes connecting different parts of the city. The routes are more concentrated in the central areas, while peripheral regions have relatively less coverage. This highlights a core-focused network with some gaps in connectivity, especially in developing areas and peripheral Areas.

a) Performance and Scheduling: -

(Source: - AICTSL Data Excel)

Data related to performance and scheduling was collected to assess the efficiency and reliability of the public transport system. This includes information on service frequency, fleet utilization, adherence to schedules, and variations in ridership throughout the day.

This data helps in understanding how well the system is able to meet passenger demand during peak and non-peak hours. It also highlights issues such as delays, irregular service intervals, and overcrowding on certain routes.

By analysing scheduling patterns and operational performance, it becomes possible to identify gaps in service delivery and areas where improvements are needed. This includes optimizing route frequency, reducing waiting time, and improving consistency in service. Such insights are essential for enhancing user experience and making public transport a more reliable option for daily commuters.

d) Depot Location and Infrastructure: -

(Source: - AICTSL Report)

Data related to depot locations and infrastructure was collected to understand the operational support system of Indore's public transport network. Bus depots function as essential service hubs where vehicles are parked, maintained, and dispatched for daily operations. Studying the location of these depots helps in assessing how effectively they are positioned in relation to major routes, service areas, and high-demand corridors.

This data provides insights into whether the existing depot network is adequately supporting smooth and efficient operations across the city. It also helps in identifying if certain areas are underserved in terms of depot access, which may lead to increased travel time for buses before and after service, ultimately affecting overall efficiency.

In addition to location, information on depot infrastructure was analysed, including maintenance facilities, parking capacity, and availability of space for future expansion. These factors are important in determining how well the system can handle current demand as well as future growth.

With the introduction of electric buses, depot infrastructure becomes even more critical. The data highlights the need for additional facilities such as charging stations, power supply arrangements, and dedicated space for electric fleet management. Understanding these requirements helps in identifying gaps in existing infrastructure and the need for upgrading or developing new depots.

Overall, this data supports better planning of depot locations and infrastructure, which is essential for improving operational efficiency, reducing unnecessary delays, and ensuring smooth functioning of the public transport system in Indore.

S.No.	Location Address- Name of City Bus Depot	Hectares	Land owner/ status	Bus parking facility
1	2	5	6	7
1	Khajarana Bus Depot	0.789	Under scheme 53	80
2	Star Chouraha City Bus Depot,	1.183	Government land	100
3	AICTSL Campus/ Depot 30 Residency Area, A. B. Road Indore	1.012	Government land	0
4	Agriculture City Bus Depot	1.639	MP Tourism	250
5	Home Guard Bus Depot-	0.570	Government land	30
6	Rajiv Gandhi City Bus Depot,	0.665	Government land	50
7	Niranjanpur, I-Bus Depot	0.635	Under scheme 78	50
8	Chandan Nagar City Bus Depot	0.445	Government land	40
9	Rasoma/Vijay Nagar Bus Depot	1.500	Under scheme 54	100
Total				700

Table 2, Existing Bus Depots of Indore.

Source: - AICTSL Report

5.2.Data Analysis: -

By correlating and analysing the different sets of primary and secondary data collected during the study, it becomes possible to develop a comprehensive understanding of the current condition of urban public transit system particularly bus-based systems in Indore. This combined approach allows for a more balanced and reliable assessment, where on-ground realities captured through surveys and field observations are supported and validated by existing reports, policies, and statistical data.

Through this process, patterns begin to emerge regarding operational efficiency, infrastructure availability, service quality, and user perception. It helps in identifying not only the visible challenges such as congestion, inadequate infrastructure, or service gaps but also determines the underlying issues that affect system performance, including planning limitations, resource constraints, and policy-level gaps.

At the same time, this analysis provides insights into opportunities for improvement, especially in the context of transitioning toward more sustainable solutions like electric mobility. By bringing together different data sources, the study is able to present a clearer, more connected picture of how the public transport system currently functions, where it falls short, and what areas require immediate as well as long-term attention.

In essence, this data-driven analysis forms the foundation for understanding the real situation of public transit in Indore and supports the development of practical, informed, and future-oriented planning strategies.

I. Infrastructure Deficiencies and future Needs:

The analysis of the existing public transport infrastructure in Indore has been carried out using spatial interpretation of BRTS Corridors and Existing Bus Stops, as illustrated in Fig. 11 and Fig. 12. These maps provide a combined understanding of how the bus-based transit system is organized and how supporting infrastructure is spatially distributed across the city.



Fig. 11, BRTS Corridor, Indore

Source: CMP Report

Fig. 11 (BRTS Corridor Map) illustrates the structure of high-capacity transit corridors across the city, primarily aligned along major arterial routes. The map reveals that the Bus Rapid Transit System (BRTS) is largely concentrated along key linear corridors, forming a strong but limited backbone of the public transport network. These corridors facilitate efficient movement along specific directions; however, their linear nature restricts accessibility to areas beyond their immediate influence. The absence of adequate feeder systems and lateral connectivity reduces the overall effectiveness of the BRTS network, particularly for intra-city and cross-peripheral travel. As a result, passengers travelling between outer zones are often required to depend on multiple transfers or alternative modes, leading to increased travel time and reduced system efficiency. (Although now the BRTS Corridors is being Removed from the City of Indore).

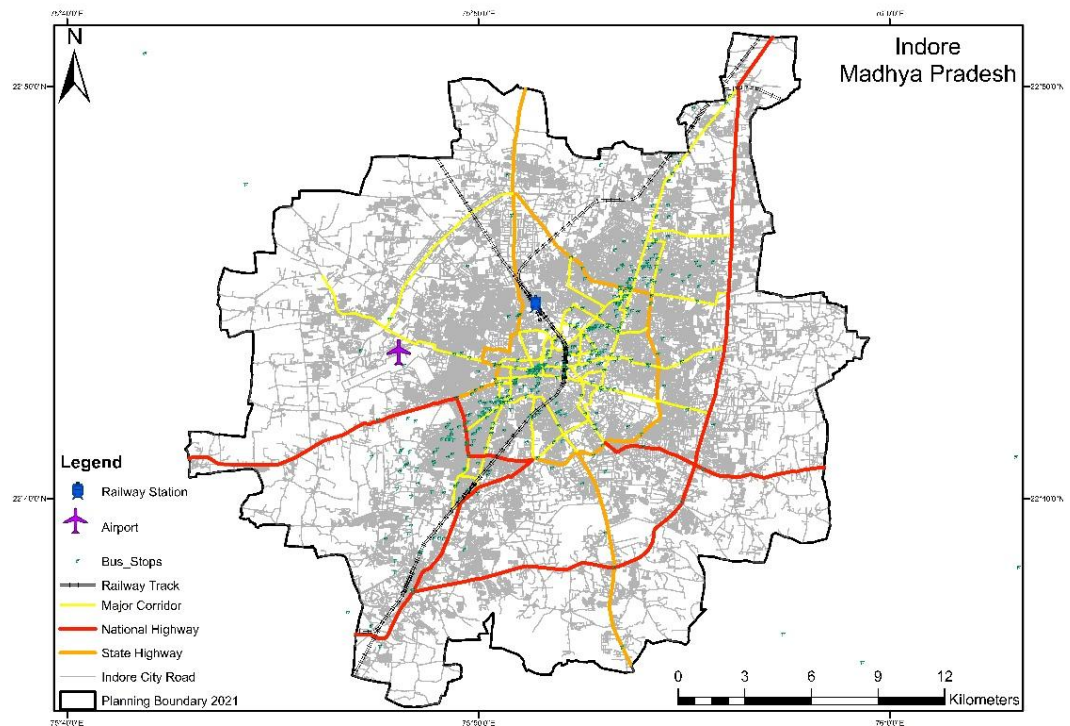


Fig.12, Existing Bus Stops of Indore.

Source: - Primary

Fig. 12 (Existing Bus Stops and Transport Infrastructure Map) provides further insight into the spatial distribution of bus stops on road networks, and key transport nodes such as railway stations and the airport. The map clearly indicates a high concentration of bus stops within the central and densely developed areas, while peripheral and newly developing regions exhibit significantly lower coverage. This uneven distribution highlights a critical gap in accessibility, where large sections of the urban population remain underserved by formal public transport. Additionally, the clustering of stops in central zones suggests potential redundancy and

congestion, whereas the sparse distribution in outer areas points to inadequate service reach and poor last-mile connectivity.

A combined interpretation of both maps reveals that the existing transport network in Indore follows a predominantly radial and corridor-based pattern, with most routes converging toward the city center. While this structure supports centralized movement, it places excessive pressure on core areas and limits the system's ability to efficiently handle decentralized travel demand. The lack of a well-developed grid or ring network further restricts connectivity between different parts of the city, making the system less flexible and resilient.

From an infrastructure perspective, these spatial patterns also indicate a lack of preparedness for future transitions, particularly toward electric mobility. The current distribution of bus stops and corridors does not reflect coordinated planning for supporting infrastructure such as charging stations or upgraded depots. This misalignment suggests that without strategic intervention, existing deficiencies may further constrain the adoption of electric buses.

The Analysis highlights that while Indore possesses a structured transit backbone in the form of BRTS corridors now no more in the city and an established bus network, the system suffers from uneven spatial coverage, over-centralization, inadequate peripheral connectivity, and weak multimodal integration. These deficiencies not only impact present-day operational efficiency but also pose significant challenges for the development of a sustainable and future-ready public transport system.

II. Ridership Data Analysis: -

The analysis of ridership patterns was conducted during different time periods morning (6:00 AM to 12:00 PM), afternoon (12:00 PM to 6:00 PM), and evening/night (6:00 PM to 11:00 PM), this provides valuable insights into the dynamic travel behaviour of passenger in Indore. The spatial distribution of passenger flows, as illustrated in Fig. 13 (Morning Ridership Pattern), Fig. 14 (Afternoon Ridership Pattern), and Fig. 15 (Night Ridership Pattern), highlights how demand varies across time and space, reflecting daily activity cycles within the city.

Fig. 13 (Morning Ridership Pattern: 6:00 AM to 12:00 PM) clearly showcase a strong concentration of passenger movement along major radial corridors converging toward the central city. High-intensity ridership is observed along key routes connecting residential areas in the periphery to core employment, commercial, and institutional zones. This pattern reflects typical work and education-related trips, where a large number of commuters travel toward centralized destinations during peak hours. The clustering of high passenger volumes along specific corridors suggests that these routes function as primary mobility spines; however, it also indicates potential congestion and pressure on limited infrastructure. Peripheral areas, while contributing to outbound flows, show relatively lower internal connectivity, reinforcing the dependence on central routes

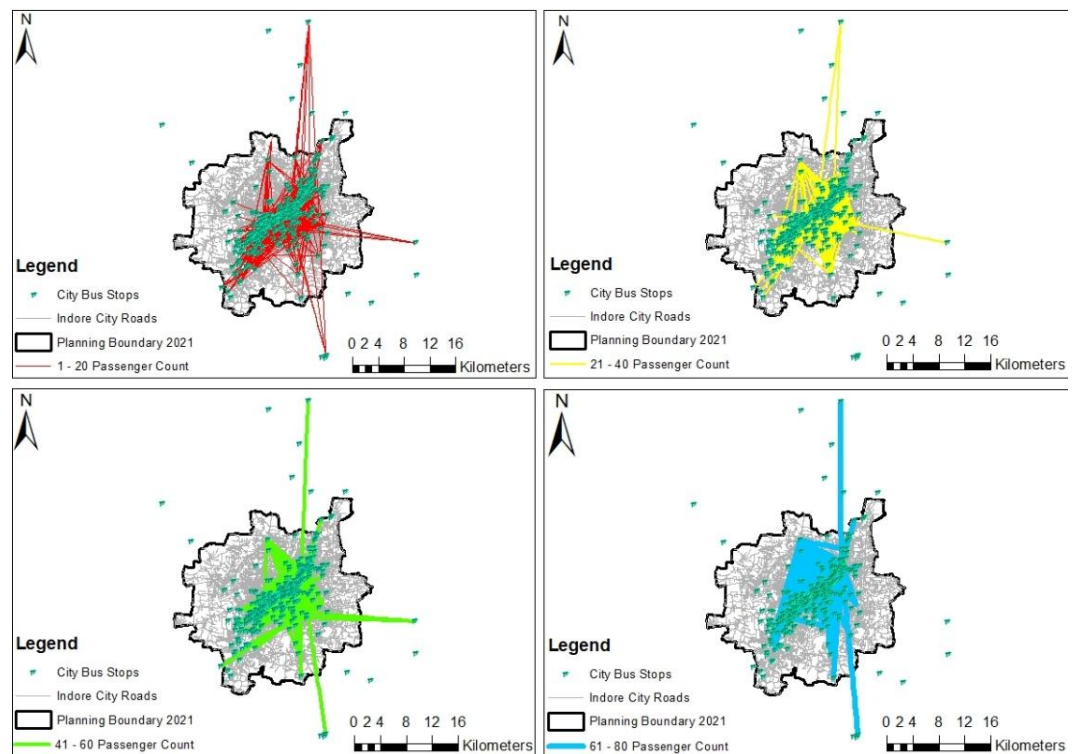


Fig 13, Morning Ridership Analysis map

Source: - Primary

These maps showcase one month of data which was combine then analyzed to identify the Gaps and Problems and using this insight in Proposal not only provide a field view of how to solve a problem but also help to ensure that this problem does not occur in the future

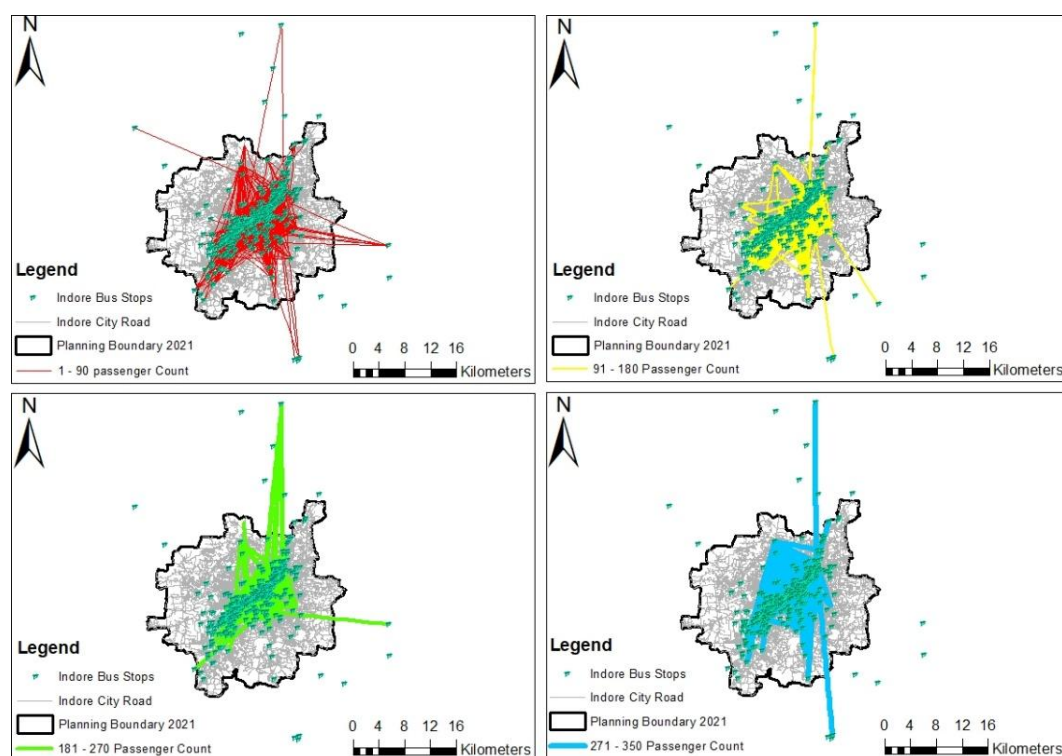


Fig 14, Afternoon Ridership Analysis map

Source: - Primary

Fig. 14 (Afternoon Ridership Pattern: 12:00 PM to 6:00 PM) illustrates a relatively moderate yet more spatially distributed level of ridership across the transport network in Indore. In contrast to the highly directional and concentrated flow observed during morning peak hours, afternoon travel patterns are more dispersed and reflect a wider variety of trip purposes. These include school and college dispersal, shopping activities, service-related movements, and staggered return trips from workplaces. As a result, movement is not limited to central corridors but extends across secondary routes and intra-city connections, indicating increased utilization of the broader network. However, major corridors continue to carry a significant share of passenger loads, highlighting their ongoing importance within the system. Despite this wider distribution, certain routes remain consistently overburdened, suggesting an imbalance in demand allocation. This indicates that the transport network, while active across multiple areas, still relies heavily on a few dominant corridors.

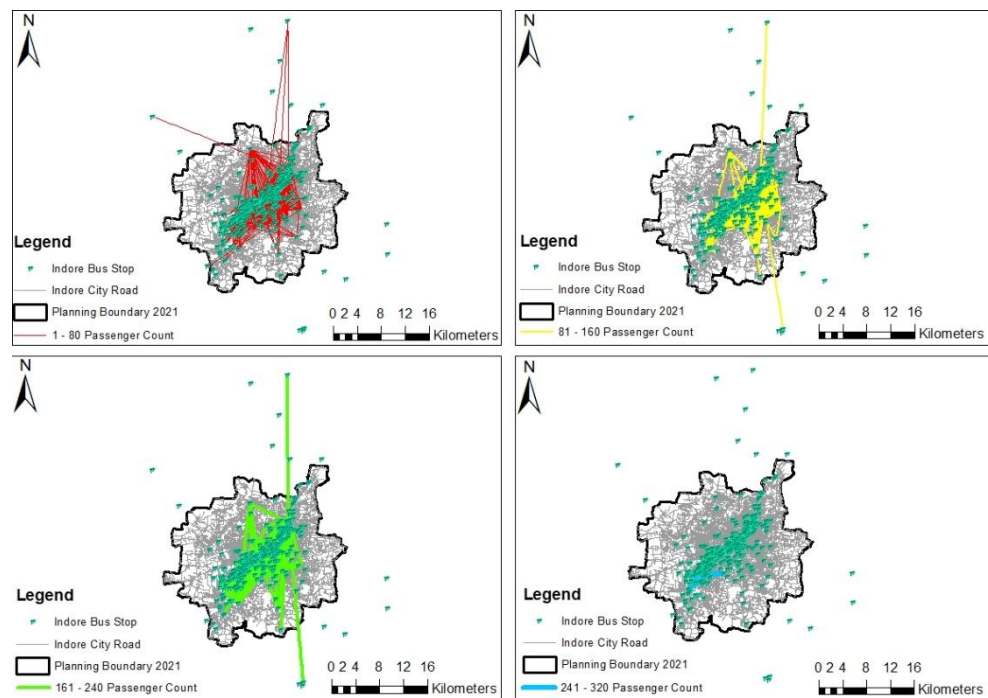


Fig 15, Night Ridership Analysis map

Source: - Primary

Fig. 15 (Night Ridership Pattern: 6:00 PM to 11:00 PM) illustrates a clear reconcentration of passenger flows across the public transport network in Indore, primarily reflecting return trips from central work and activity zones to residential areas. Similar to the morning pattern, movement is strongly directional but occurs in the opposite direction, away from the city center toward the periphery area indicating continued reliance on a few major corridors as primary mobility routes. However, the overall intensity of ridership is lower than the morning peak, suggesting a gradual decline in travel demand as the day progresses due to staggered work hours and reduced non-essential trips. While key corridors continue to carry substantial passenger volumes, reinforcing their importance within the network, many peripheral areas exhibit relatively low ridership. This may be attributed to limited-service frequency, weaker connectivity, and concerns related to safety and convenience during evening hours. These patterns highlight the need for more balanced service provision, improved accessibility, and enhanced reliability to support efficient and inclusive public transport during nighttime periods.

A comparative analysis of all three time periods reveals that Indore's public transport system is heavily corridor-dependent and centrally oriented, with peak demand concentrated along a few major routes. While these corridors efficiently handle high passenger volumes, they also experience significant operational

pressure, leading to potential overcrowding and reduced service quality. At the same time, the relatively low ridership in peripheral and non-corridor areas highlights gaps in service coverage and connectivity, particularly for intra-zonal and cross-peripheral travel.

Overall, the temporal ridership patterns indicate the need for time-sensitive and demand-responsive planning strategies. Enhancing service frequency during peak hours, strengthening feeder and intermediate routes during off-peak periods, and improving connectivity in underserved areas can help create a more balanced and efficient transport system. Aligning route planning and service provision with these observed demand patterns will be essential for improving user experience, increasing ridership, and supporting sustainable urban mobility in Indore.

III. Traffic Volume and Congestion Analysis:

The analysis of traffic conditions, supported by both primary field observations and secondary data sources, provides a clear understanding of how congestion affects the performance of the public transport system in Indore. The spatial distribution of congestion levels is illustrated in Fig. 16 (Congestion Corridor Map) along with Fig 17 (Traffic Speed Analysis Map) which highlights high, medium, and low congestion zones across the city's road network.

Fig. 16 highlights the spatial distribution of congestion across the city, where the highest levels are concentrated within the central urban core and along key arterial corridors. Major intersections such as Sarwate Bus Stand, Vijay Nagar Square, Rajwada, and Geeta Bhawan emerge as critical pressure points, where multiple traffic streams converge. These areas experience frequent bottlenecks due to high traffic volumes, mixed land use, and continuous activity throughout the day. The map also shows that major corridors like AB Road, Ring Road, and MR-10 carry significant traffic loads, acting as primary movement channels but also experiencing recurring congestion, especially during peak hours. In contrast, peripheral areas display relatively lower congestion levels, reflecting reduced traffic density but also indicating limited connectivity and activity intensity.

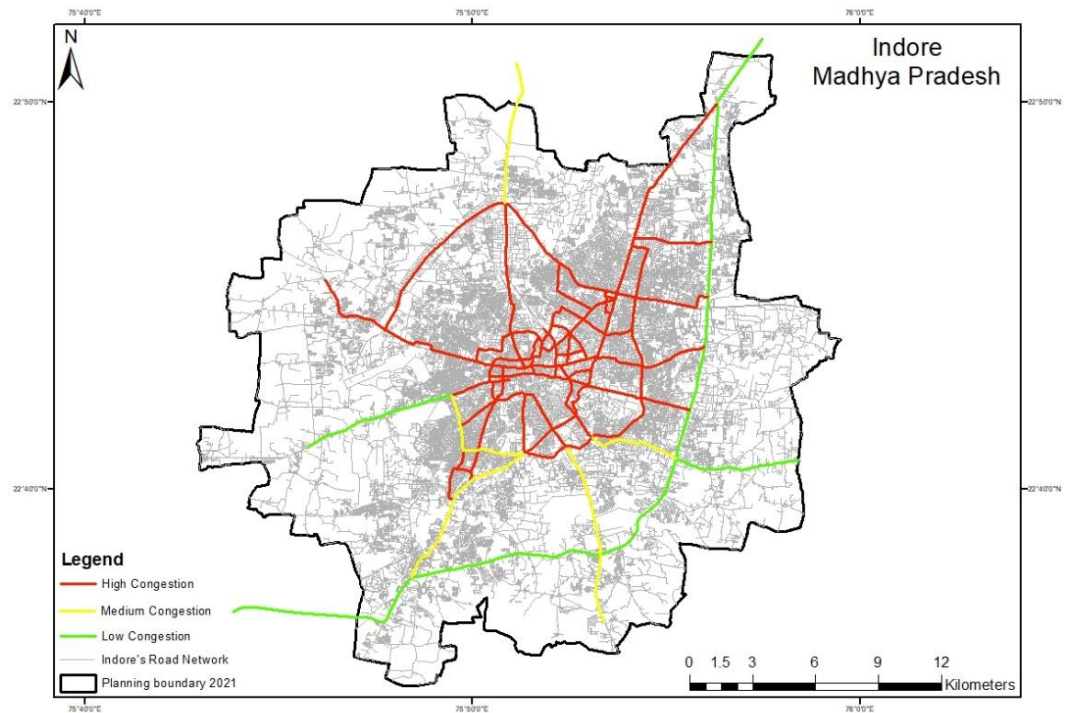


Fig 16, Traffic Congestion Analysis map

Source: - Primary

Fig. 17 provides a deeper understanding of how traffic conditions directly influence the operational performance of the transport network by mapping journey speeds across different parts of the city. The figure clearly reveals a strong inverse relationship between congestion levels and travel speeds, meaning that areas experiencing higher congestion consistently record lower speeds. In the central zones and along major activity corridors where commercial activities, intersections, and mixed land use are highly concentrated travel speeds frequently drop below 15 km/h. These areas are characterized by continuous traffic interruptions, frequent stopping, high pedestrian movement, and signal delays, all of which significantly slow down bus movement and reduce service reliability.

Moving outward from the city centre, transitional zones exhibit moderate speeds ranging between 15–25 km/h. These areas generally experience less intense congestion compared to the core but are still influenced by traffic spillover, junction delays, and moderate vehicular density. As a result, while buses operate more smoothly than in central areas, they still face variability in travel time, especially during peak hours.

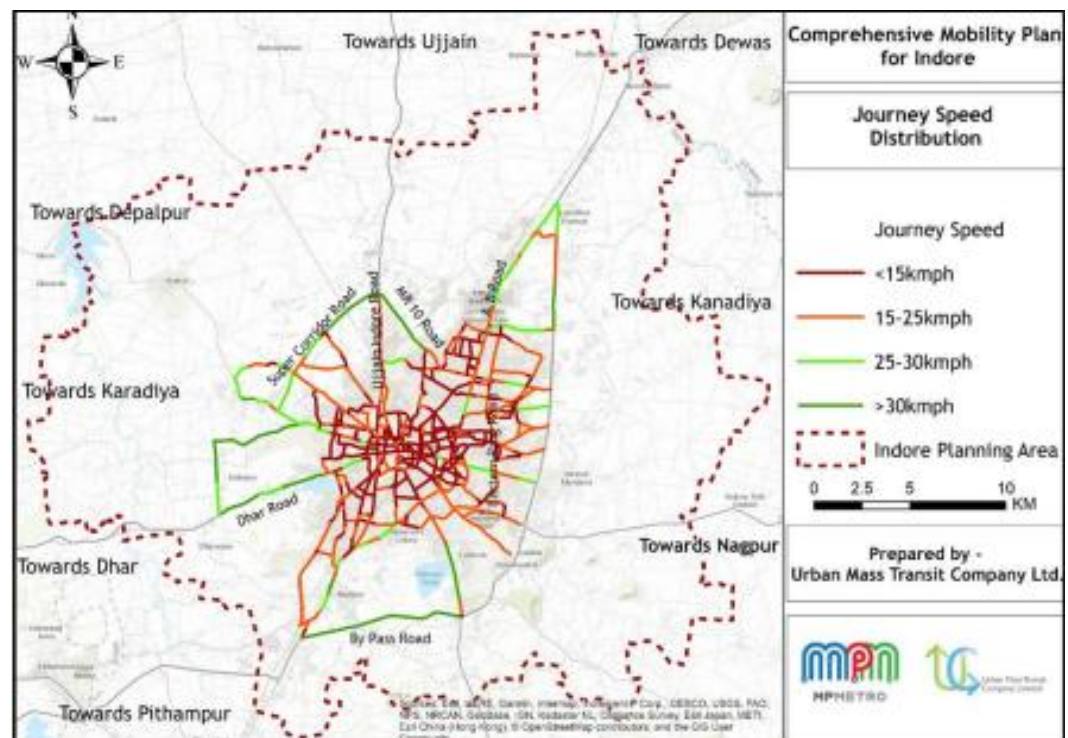


Fig 17, Traffic Speed Analysis map

Source: - CMP Report

From a public transport perspective, these patterns have direct operational implications. Buses operating in high-congestion and low-speed zones face frequent delays, leading to unreliable schedules and increased travel times. Since buses share road space within a mixed traffic environment, their efficiency is significantly affected by surrounding traffic conditions. The lack of dedicated bus lanes, combined with on-street parking and inefficient intersection management, further reduces their operational speed and consistency.

Another key insight is the centralized nature of congestion, which reflects the concentration of economic and social activities in the inner city. This not only increases travel demand toward these areas but also intensifies competition for limited road space. The growing number of private vehicles adds further pressure, reducing the relative efficiency and attractiveness of public transport.

Overall, the analysis demonstrates that congestion and low travel speeds are critical challenges affecting the effectiveness of Indore's public transport system. Improving traffic flow through better corridor management, prioritizing public transport through dedicated lanes, and enhancing intersection efficiency can significantly improve travel speeds and service reliability. Such interventions will

be essential in creating a more efficient, user-friendly, and sustainable urban mobility system.

IV. Buses Schedule Analysis: -

The bus schedule analysis was carried out using timetable data from multiple routes operating across Indore, including C-series, M-series, and other city routes. The objective was to assess service frequency, time intervals between buses, and the extent to which existing schedules align with the travel demand patterns observed in earlier ridership analysis.

The analysis reveals a clear variation in service frequency across different time periods. During peak hours particularly in the morning and evening Time, bus services are relatively frequent, with shorter headways that reduce passenger waiting time and improve accessibility. This reflects an attempt by operators to match higher commuter demand during work and education-related travel periods. However, during non-peak hours, the number of operating buses declines significantly, leading to longer waiting times and reduced service availability. This inconsistency makes public transport less convenient for users who travel outside peak periods, such as for shopping, services, or off-shift work.

Another important finding is the uneven distribution of service frequency across routes. Major corridors and high-demand routes are comparatively better served, with more regular and predictable schedules. In contrast, routes serving peripheral and developing areas experience lower frequency and irregular service intervals, which limits accessibility and reduces the attractiveness of public transport in these regions. This imbalance reinforces the existing centralization of the network and contributes to unequal service provision across the city.

The study also indicates that scheduled timings often do not match actual operations due to prevailing traffic conditions. Congestion along key corridors leads to delays, causing buses to deviate from planned schedules. As a result, passengers experience unpredictability in arrival times, reducing trust in the system. The absence of real-time tracking systems and adaptive scheduling mechanisms further limits the ability to respond to such variations in demand and traffic conditions.

In addition, there is limited coordination between routes, which affects transfer efficiency and increases total travel time for passengers requiring multi-route journeys. This highlights a gap in integrated scheduling and network-level planning.

Overall, the analysis suggests that while the existing scheduling system partially addresses peak-hour demand, it lacks consistency, flexibility, and responsiveness. Improving service reliability will require increasing frequency during off-peak hours, ensuring better coverage in underserved areas, and introducing real-time monitoring and dynamic scheduling systems. A more balanced and demand-responsive scheduling approach will enhance user convenience, improve operational efficiency, and support the broader goal of sustainable urban mobility in Indore.

V. Bus Fair Analysis:

The bus fare analysis was conducted using available route-wise fare data across multiple services operating in Indore, including C-series, M-series, and other city routes. The objective was to understand how fares vary with distance, route type, and service coverage, and to evaluate the affordability and effectiveness of the current fare system.

The analysis indicates that the fare structure is distance-based, where ticket prices increase progressively with travel length. This type of system ensures a logical pricing mechanism, making shorter trips relatively affordable while charging higher fares for longer distances. For most inner-city routes, fares remain low and accessible, which supports daily commuters such as students, workers, and low-income groups. This reflects a positive aspect of the system, as affordability is a key factor in encouraging public transport usage.

However, as distance increases especially on routes connecting peripheral or outer areas the fare levels rise noticeably. While this is expected in a distance-based model, it can become a financial burden for regular long-distance commuters, particularly those travelling daily from suburban or developing regions to central work zones. This may discourage consistent use of public transport and increase dependence on private or intermediate modes.

Another important observation is the variation in fare structures across different route categories. High-demand and well-served corridors often provide better value in terms of frequency and travel time relative to fare paid, whereas routes in less-served areas may offer lower service quality despite similar or slightly higher fares. This creates a perception of unequal service value, where passengers in peripheral areas pay comparable fares but receive less frequent and less reliable service.

The analysis also suggests that the current system lacks integration and flexibility in fare policies. There is limited evidence of fare integration across routes, meaning passengers making transfers may need to pay multiple fares for a single journey. This increases the overall cost of travel and reduces the attractiveness of multi-leg public transport trips.

Overall, while the existing fare structure in Indore is generally affordable and logically designed, it requires better integration, equity, and user-oriented improvements. Introducing measures such as integrated ticketing, concessional passes for regular commuters, and distance-based fare optimization can enhance affordability and encourage greater use of public transport. Aligning fare policies with service quality and accessibility will be essential in creating a more inclusive and efficient urban mobility system.

6. Proposal

Based on the insights gathered from data collection and analysis, this section presents targeted planning proposals aimed at addressing the key challenges identified in Indore's freight transport system. These proposals are designed to improve infrastructure, streamline freight operations, and support sustainable urban mobility through practical, data-driven interventions.

6.1. Bus Route Proposal for Increased Efficiency

6.1.1. Need for Bus Route Optimization:

The proposal for improving the bus route system in Indore emerges directly from the detailed analysis of the existing transit network, which revealed several structural, operational, and spatial inefficiencies. The current public transport system is largely dependent on direct corridor-based routes that primarily converge toward the central parts of the city. While this structure may provide direct connectivity for certain trips, it has gradually created excessive route overlap, operational inefficiency, traffic congestion, and uneven service distribution across the urban area. As observed through earlier network analysis, ridership patterns, congestion mapping, and route structure assessment, the majority of bus routes are concentrated along a few major central corridors such as AB Road, MG Road, Rajwada, Vijay Nagar, and Sarwate Bus Stand. This excessive concentration of routes places significant pressure on already congested road infrastructure while limiting the efficiency and flexibility of the overall transit system.

The existing route network map (Fig. 10) clearly demonstrates the issue of overlapping routes within the city core. Multiple bus routes follow identical or nearly identical alignments through central corridors before diverging toward outer areas. This creates repetitive movement patterns where several buses operate simultaneously along the same stretches of road, resulting in inefficient utilization of fleet resources. Instead of distributing public transport services evenly across the city, the current structure concentrates buses within a limited number of corridors, creating congestion hotspots and operational delays. At the same time, many peripherals and newly developing areas remain under-served, with lower service frequency and weaker connectivity to the rest of the city.

This imbalance between central and peripheral connectivity creates multiple operational and passenger-related challenges. Central areas experience overcrowding,

slower travel speeds, and irregular bus movement due to excessive bus concentration and traffic congestion. On the other hand, peripheral zones often suffer from limited-service availability, longer waiting times, and poor accessibility. Such uneven distribution reduces the attractiveness of public transport, particularly for people living in outer residential areas who may increasingly depend on private vehicles or intermediate transport modes for daily travel. The earlier ridership and congestion analysis also indicated that several major corridors operate under heavy directional passenger flow during peak hours, further intensifying operational inefficiencies within the network.

Another important issue associated with the existing route system is the large number of operational routes currently functioning within Indore's transit network. The city presently operates approximately 65 routes, many of which partially duplicate each other within central corridors. While a larger number of routes may initially appear beneficial, excessive fragmentation often reduces operational efficiency and complicates service management. Managing numerous overlapping routes requires greater fleet allocation, more complex scheduling, and higher operational coordination, which may not necessarily improve service quality. In many cases, buses operating on overlapping routes compete for the same passenger demand, leading to uneven passenger distribution and inefficient fleet utilization.

To address these structural inefficiencies, the proposal introduces a transition from the existing conventional route structure toward a node-based bus route system, as illustrated in Fig. 17 (Proposed Bus Routes). The node-based system is designed to create a more organized, efficient, and interconnected transit network by reducing unnecessary route overlap and improving overall service distribution across the city.

The concept of a node-based system is based on creating strategically connected transit nodes where multiple routes intersect and allow passengers to transfer between services efficiently. Instead of every route directly entering the city centre through overlapping corridors, routes are reorganized around key operational nodes distributed across the city. These nodes function as interchange points connecting different corridors and travel directions. This approach significantly reduces the concentration of buses within central areas while improving network flexibility and operational efficiency.

One of the primary advantages of the node-based system is the reduction in overlapping routes. By restructuring routes around interconnected nodes, buses no longer need to follow repetitive alignments through the same central corridors. This helps reduce congestion caused by excessive bus movement and improves traffic flow within high-density urban areas. Fewer overlapping routes also simplify operational management and reduce unnecessary competition between buses operating along identical corridors.

The proposed system also reduces the overall number of operational routes within the network. Rather than maintaining multiple partially duplicated routes, the network becomes more streamlined and interconnected. This creates a more efficient public transport structure where buses can be redistributed strategically according to demand levels and operational requirements. Reducing the number of overlapping routes allows better fleet allocation and helps improve service frequency along important corridors. Instead of concentrating excessive buses within central areas, vehicles can be reallocated toward underserved peripheral routes and feeder services, thereby improving overall network coverage and accessibility.

A common concern associated with node-based systems is the issue of last-mile connectivity and passenger transfers. However, the proposed route structure addresses this challenge through the careful placement of operational nodes and corridor integration. Each proposed route is connected to at least one major node, which allows seamless transfer between routes while maintaining connectivity between the core city and peripheral areas. These nodes are strategically located near high-demand activity centres, transport corridors, and major urban intersections to minimize transfer inconvenience and improve accessibility.

The node-based approach also strengthens connectivity between different parts of the city rather than forcing all travel movements through the central business district. Peripheral areas receive improved integration with the overall transit network, allowing passengers to travel across the city more efficiently without depending entirely on central corridors. This not only reduces travel time but also improves operational balance across the network.

From an operational perspective, the node-based system improves scheduling flexibility, fleet management, and service reliability. Since routes become shorter, more organized, and less dependent on congested central corridors, buses can maintain more consistent travel times and better schedule adherence. Reduced congestion exposure also improves operational predictability and enhances passenger confidence in the transit system.

Furthermore, the proposed route optimization framework creates a stronger foundation for the future integration of electric buses within Indore's public transport system. Electric buses require efficient route planning, balanced operational distances, and optimized energy usage. A node-based network supports these requirements by reducing unnecessary travel distances, improving route efficiency, and enabling more manageable operational structures for electric mobility integration.

Overall, the need for bus route optimization arises from the limitations of the existing centralized and overlapping route structure currently operating within Indore. By transitioning toward a node-based system, the proposal aims to create a more efficient, balanced, and sustainable public transport network that improves connectivity, reduces congestion, enhances service reliability, and supports the long-term transition toward cleaner and more efficient urban mobility.

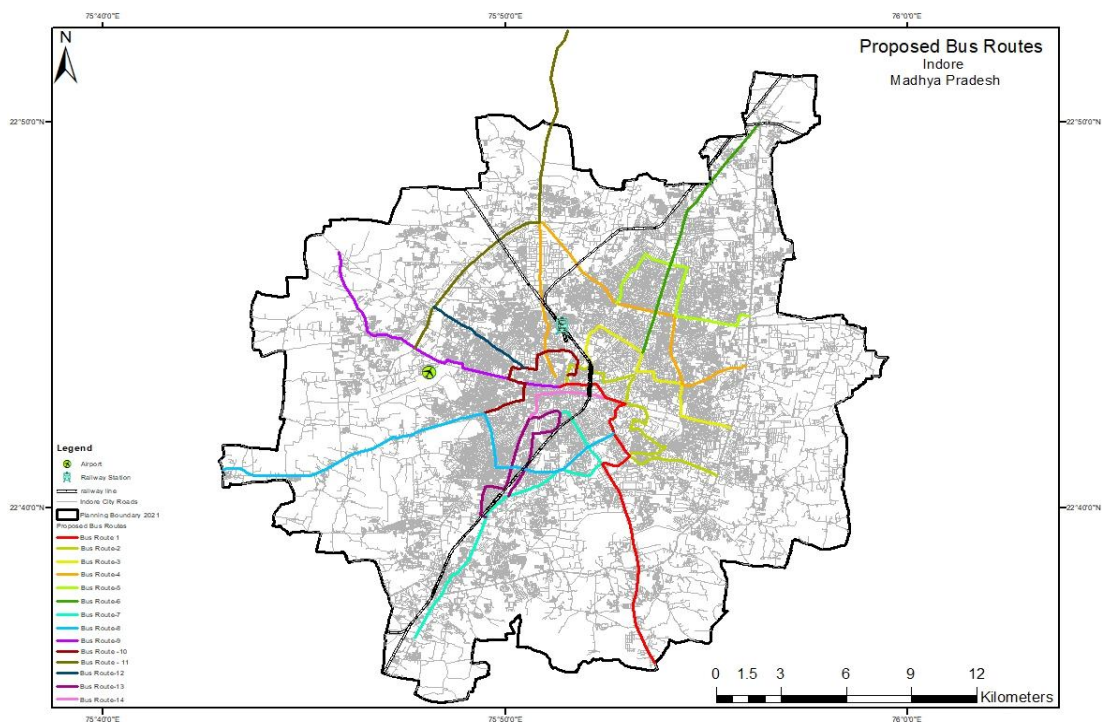


Fig 18, Proposed Node Based route map

Source: - Primary

6.1.2. Transition to Node Based Bus Network System:

A key feature of the proposed system is the transformation of the existing route structure into a node-based network, similar to metro systems. Instead of relying on long, continuous routes connecting distant points directly, the new system introduces interconnected nodes where routes intersect, allowing passengers to transfer between buses efficiently. This concept is visually represented in the proposed bus route map (Fig.18), where routes are reorganized to connect at strategic points across the city.

In this system, bus stops are not just boarding points but function as transfer hubs, enabling smoother passenger distribution across the network. This reduces the dependency on central corridors and prevents unnecessary duplication of routes. By encouraging transfers, the system becomes more flexible and adaptable to changing travel demands, ensuring that buses are used more efficiently across the network.

6.1.3. Reduction of Route Overlap:

One of the most significant improvements introduced in the proposal is the reduction of route overlap. In the existing system, multiple routes operate along the same corridors, especially in central areas, leading to congestion and inefficient use of fleet resources. The proposed network addresses this issue by consolidating routes and eliminating redundancy.

According to the analysis, the existing system consists of approximately 65 routes operated by 611 buses, many of which overlap and compete for the same passenger demand. The proposal restructures this into 14 optimized routes, each designed to serve a specific corridor or function within the network.

This reduction not only simplifies the network for passengers but also improves operational clarity for transit authorities. A smaller number of well-planned routes makes it easier to manage scheduling, monitor performance, and implement future improvements.

6.1.4. Improved Connectivity between Central and Peripheral Areas:

Another critical improvement in the proposed system is the enhancement of connectivity between central and peripheral regions of the city. Earlier analysis showed that while central areas experience high service frequency, peripheral areas

suffer from limited accessibility and poor coverage. This creates a demand-supply mismatch, where buses are overcrowded in some areas and underutilized in others.

The proposed routes, as shown in the Fig 18, extend more effectively into outer areas and connect them with major activity nodes through a structured network. Instead of forcing all routes through the city centre, the system distributes movement across multiple corridors, reducing pressure on central zones. This approach ensures that developing and expanding areas of Indore are better integrated into the public transport system, supporting future urban growth.

6.1.5. Efficient Fleet Utilization and Resource Optimization:

The proposal significantly improves how buses are utilized within the network. In the current system, due to overlapping routes and inefficient planning, buses are often either overcrowded or underused. The new system allocates buses more strategically across routes.

With the introduction of 220 electric buses under the PM E-bus seva scheme, each of the 14 routes can be assigned 15 or more buses based on the demands, ensuring a balanced distribution of fleet resources. Additional buses are maintained as reserves to handle operational uncertainties such as maintenance, breakdowns, or charging requirements.

6.1.6. Reduction in Congestion and Travel Time:

One of the major expected outcomes of the proposed route restructuring is the reduction in congestion, particularly in central corridors. Since the new system eliminates unnecessary route overlaps and distributes traffic more evenly, the pressure on high-density corridors is significantly reduced.

Earlier congestion analysis showed that central areas suffer from low speeds and high delays due to traffic concentration. By redesigning routes to avoid excessive central convergence, the proposal helps in:

- Improving average bus speeds
- Reducing travel time
- Enhancing overall system efficiency

This improvement directly impacts passenger experience by making journeys faster and more predictable.

6.1.7. Improved Service Reliability and Passenger Experience:

The simplified and structured route system contributes to improved service reliability. In the current system, irregular scheduling and overlapping routes lead to issues such as bus bunching and inconsistent service intervals. By introducing a clearly defined route network with balanced bus allocation, the proposed system ensures more stable operations.

Passengers benefit from:

- Easier route understanding
- Reduced waiting time
- Better interchange options
- More reliable travel schedules

The node-based system also allows passengers to plan their journeys more efficiently, similar to metro systems, where transfers are an expected and well-managed part of travel.

6.1.8. Overall Impact of the Proposed Bus Route System:

In summary, the proposed bus route system transforms the existing inefficient and overlapping network into a structured, efficient, and future-ready transit system. The integration of node-based routing, route consolidation, and balanced fleet allocation results in a system that is easier to manage, more reliable for users, and better aligned with the city's growth patterns.

The proposed route map (Fig.18), when compared with the existing network (Fig.10), clearly demonstrates this transformation lead from a congested, overlapping system to a clean, organized, and efficient network.

This proposal not only improves current operations but also lays the foundation for a scalable and sustainable public transport system in Indore.

6.2. Bus Route Operation and Frequency Proposal

6.2.1. Need for Operational and Frequency Planning:

While route optimization improves the spatial efficiency and connectivity of the public transport network, it alone is not sufficient to ensure an effective and reliable transit system. The overall success of any bus-based public transport system depends not only on where buses operate, but also on how efficiently they are managed, how frequently

services are provided, and how effectively operations respond to changing traffic conditions and passenger demand throughout the day. Even a well-designed route network may fail to deliver satisfactory service if operational planning remains weak, irregular, or poorly coordinated. Therefore, operational and frequency planning becomes a critical component in improving the quality, reliability, and efficiency of public transport services in Indore.

The earlier analysis of Indore's existing bus system highlighted several operational limitations that directly affect passenger experience and overall system performance. One of the most significant issues observed was the presence of irregular headways between buses across many routes. Instead of maintaining a consistent service interval, buses often operate unpredictably, creating long waiting times for passengers. In several corridors, particularly during off-peak periods and in peripheral areas, passengers were found waiting between 15 to 30 minutes for bus services. Such delays reduce the convenience and attractiveness of public transport and encourage users to shift toward private vehicles or intermediate transport modes.

In addition to long waiting times, the existing system also suffers from inconsistent service reliability. Due to the absence of scientific scheduling and proper fleet management, buses frequently arrive in clusters or experience uneven spacing between services. This phenomenon, commonly referred to as "bus bunching," results in inefficient passenger distribution and overcrowding in certain vehicles while other buses remain underutilized. The lack of coordination between travel demand and service frequency further weakens the operational efficiency of the system.

Traffic congestion across major corridors of Indore such as AB Road, Vijay Nagar, Rajwada, and MR-10 further complicates daily operations. High traffic volumes, mixed land-use activities, frequent intersections, and roadside parking reduce average travel speed and increase delays in bus movement. Since existing schedules are not adequately adjusted according to real-time traffic conditions, delays occurring on one route often affect subsequent trips, reducing overall schedule adherence throughout the network. This creates uncertainty for passengers and negatively impacts the reliability of public transport services.

Another major challenge is the unequal distribution of services across the city. Central

corridors generally receive better service frequency because of higher passenger demand, while peripheral and newly developing areas remain underserved. This imbalance creates accessibility gaps and limits the ability of public transport to function as a citywide mobility system. In many outer areas, lower service frequency combined with poor last-mile connectivity discourages people from depending on public transport for regular travel needs.

The transition toward electric public transit further increases the importance of proper operational planning. Unlike conventional diesel buses, electric buses require additional operational considerations such as charging duration, battery range limitations, energy consumption management, and charging infrastructure availability. Without carefully planned schedules and optimized fleet operations, electric bus systems may face operational inefficiencies, reduced reliability, and charging-related disruptions. Therefore, operational planning is essential not only for improving passenger service but also for ensuring the successful integration of electric buses into the existing network.

To address these challenges, this proposal introduces a data-driven operational and frequency planning framework that focuses on improving predictability, reducing waiting time, and enhancing overall transit efficiency. The framework uses standard public transport planning methods to determine travel time, cycle time, service frequency, and fleet allocation based on route characteristics, passenger demand, and operational conditions.

Travel time estimation forms the basis of the operational framework. Instead of relying on generalized assumptions, the proposed system considers route length, congestion levels, average operating speed, stop frequency, and passenger boarding time to calculate more realistic travel durations. This allows schedules to better reflect actual field conditions and improves the reliability of bus operations.

Based on travel time calculations, cycle time is determined for each route. Cycle time refers to the total time required for a bus to complete a full round trip, including travel time and terminal layover time. Proper cycle time estimation helps maintain service consistency and provides flexibility for handling traffic delays and operational disruptions. This forms the foundation for determining headway and service

frequency.

The proposal further aims to reduce headway along high-demand corridors to improve passenger convenience and accessibility. Shorter headways reduce waiting time and make public transport more dependable for daily users. During peak periods, higher service frequency is proposed on major corridors connecting commercial, institutional, and residential zones, while balanced service levels are maintained during off-peak hours to optimize operational efficiency.

Fleet allocation within the proposed system is also planned scientifically rather than distributing buses uniformly across all routes. Routes with higher passenger demand and strategic importance receive greater fleet allocation to improve service quality and reduce overcrowding. At the same time, feeder and peripheral routes are integrated into the operational structure to improve connectivity and support equitable access to public transport across the city.

The proposed framework also supports the use of Intelligent Transport Systems (ITS) and real-time operational monitoring tools. Technologies such as GPS-based vehicle tracking, centralized control systems, and digital scheduling platforms can improve schedule adherence, fleet coordination, and operational efficiency. Real-time monitoring enables transit agencies to respond quickly to congestion, delays, and fluctuating passenger demand, thereby improving the overall reliability of the network. Overall, operational and frequency planning serves as a critical link between route design and actual service delivery. While route optimization improves the physical structure of the network, effective operational planning ensures that the system functions efficiently on a daily basis. By introducing scientific scheduling methods, optimized frequency planning, and demand-responsive fleet allocation, the proposed framework aims to create a more reliable, efficient, and passenger-friendly public transport system for Indore. Furthermore, it establishes a strong operational foundation for the successful integration of electric buses, supporting the city's long-term transition toward cleaner and more sustainable urban mobility.

6.2.2. Key Parameters Used for Operational Planning:

The proposal is based on real time data of operational parameters which were identified

from earlier analysis:

- Average Speed (Peak Conditions): 15 km/h
- Average Speed (Normal Conditions): 20 km/h
- Route Length Range: 4 km to 22 km
- Traffic Conditions Considered: Congested (Peak) and Normal

These parameters reflect actual urban conditions in Indore, where congestion significantly affects bus performance, especially in central corridors.

6.2.3. Travel Time Calculated:

The first step in operational planning is to calculate the time required for a bus to complete a route, which directly influences scheduling and frequency.

Formula Used:

$$\text{Travel Time} = \text{Distance} / \text{Time}$$

Calculation Example:

Under Peak Traffic Time:

- Distance = 22 Km
- Speed (Peak time) = 15 Km/Hr.

$$\text{Travel Time} = 22/15 = 1.46 \text{ Hr. or } 87 \text{ Minutes}$$

Under Normal Traffic Condition:

- Distance = 22 Km
- Speed = 20 Km/Hr.

$$\text{Travel Time} = 22/20 = 1.1 \text{ Hr. or } 66 \text{ Minutes}$$

This Shows that Congestion increases the travel time for the buses by 20 Minutes, which directly impact the Service, Frequency and operations of the Buses

6.2.4. Cycle Time Determination:

To understand how long a bus takes to complete a full round trip, the concept of cycle time is used.

Formula Used:

$$\text{Cycle Time} = 2 * \text{Time Travel} + \text{Layout Time}$$

Where,

- Time Travel = One-way Journey
- Layout Time = Rest/Recovery Time at Terminal (assume 15 Minutes)

Calculation Example:

Under Peak Traffic Time:

- Time Travel (one way) = 87 Minutes
- Round Trip = $2 * 87 = 174$ Minutes
- Layover = 15 Minutes

$$\text{Cycle Time} = 174 + 15 = 189 \text{ Minutes}$$

Under Normal Traffic Condition:

- Time Travel (one way) = 66 Minutes
- Round Trip = $2 * 66 = 132$ Minutes
- Layover time = 15 Minutes

$$\text{Cycle Time} = 132 + 15 = 147 \text{ Minutes}$$

Cycle Time is Crucial because it Determines how Many Buses are Needed to Maintain a Certain Frequency of Buses

6.2.5. Headway (Service Frequency):

The first step in operational planning is to calculate the time required for a bus to complete a route, which directly influences scheduling and frequency.

Formula Used

$$\text{Headway} = \text{Cycle Time} / \text{Number of Buses on that Route}$$

Example for a calculation:

Under Peak Traffic Time:

- Cycle Time = 189 Minutes
- Number of Buses = 26 Electric Buses

$$\text{Headway} = 189 / 26 = 7.3 \text{ Minutes (Per Direction: 14 Minutes)}$$

Under Normal Traffic Condition:

- Cycle Time = 147 Minutes

- Number of Buses on that Route = 26 Electric Buses

$$\text{Headway} = 147 / 26 = 5.6 \text{ Minutes (Per Direction: 11 Minutes)}$$

6.2.6. Determining Number of Buses Required:

The number of buses required for each route is calculated based on route length and total system demand.

Formula Used

$$\text{No. of Buses} = \text{Route Distance} / \text{Total Network Distance} * \text{Total No. of Fleet}$$

This Ensures,

- Longer Routes gets more Buses.
- Shorter Routes get fewer Buses.
- Service Remain Balanced across the Network.

Example:

- Total Fleet = 220 Electric Buses
- Route Distance = 22 Km
- Total Network Distance = 189 Km

$$\text{No. of Buses} = 22 / 189 * 220 = 26 \text{ Buses}$$

6.2.7. Derived Operation Parameters for Proposed Bus Network:

The table presents the calculated operational performance of the proposed bus routes (R1 to R14), including route distance, fleet allocation, travel time, and service frequency under both peak (15 km/h) and normal (20 km/h) traffic conditions. It shows a clear relationship between route length and operational parameters, where longer routes such as R4 (22 km) and R8 (20 km) require more buses (up to 26) and have higher travel times (up to 87 minutes in peak conditions), while shorter routes like R12 and R14 require fewer buses and less time.

The data also highlights the impact of congestion on performance. During peak conditions, headways range between 14 to 20 minutes, indicating longer waiting times, whereas under normal conditions, headways improve to 11 to 13 minutes, showing a reduction of about 20-25%. This reflects improved efficiency with better traffic flow.

Route	Distance	Total Buses	Speed (Peak Traffic) in Km/Hr	time Taken by Bus (in Min)	Headway (15Km/Hr.)	Speed (Normal) in Km/Hr	time Taken by Bus (in Min)	Headway (20Km/Hr.)
R1	11	13	15	46	16	20	34	12
R2	18	21	15	71	15	20	53	11
R3	17	20	15	67	14	20	50	11
R4	22	26	15	87	14	20	65	11
R5	11	13	15	43	15	20	32	11
R6	12	14	15	49	15	20	37	12
R7	16	19	15	64	15	20	48	11
R8	20	23	15	81	15	20	61	12
R9	13	15	15	52	15	20	39	12
R10	9	10	15	35	16	20	26	12
R11	18	21	15	71	15	20	54	11
R12	5	6	15	19	16	20	15	13
R13	13	15	15	50	15	20	38	12
R14	4	4	15	17	20	20	13	18

Table 3, Proposed parameter of Indore.

Source: - Primary

Overall, the table demonstrates a balanced and data-driven allocation of buses based on route characteristics, ensuring efficient service distribution, reduced waiting time, and improved reliability across the proposed network.

6.2.8. Overall Conclusion:

The Bus Route Operation and Frequency Proposal transform the system from an irregular and inefficient service into a scientifically planned, data-driven transit system. By integrating travel time analysis, cycle time calculation, and demand-based fleet allocation, the proposal ensures that the network operates smoothly under varying traffic conditions.

6.3. Locating Bus Depots Location Proposal

6.3.1. Need for Depot Planning Based on Existing System Gaps:

The proposal for locating bus depots is directly derived from the analysis of operational inefficiencies, infrastructural limitations, and spatial gaps identified within the existing public transport system of Indore. While the current transit network provides citywide connectivity through multiple routes and operational corridors, the supporting depot infrastructure remains insufficiently planned to meet present operational requirements as well as future electric mobility needs. Depot planning is a critical component of any efficient public transport system because depots function as the primary operational base for bus parking, fleet maintenance, dispatching, fuelling or charging activities, and overall fleet management. Without properly planned depots, even an optimized route network and improved operational schedules may fail to function efficiently.

The earlier analysis revealed that the existing depot system in Indore is largely based on conventional operational requirements and lacks integration with long-term transit planning strategies. Most existing depots were developed primarily to support diesel bus operations and therefore do not adequately address the infrastructural requirements associated with electric buses. Electric public transit systems require dedicated charging infrastructure, energy management facilities, battery maintenance spaces, and specialized operational arrangements that are not available within many of the existing depot locations. As a result, the current infrastructure framework creates significant barriers for the large-scale integration of electric buses into the city's public transport system.

One of the major operational issues identified in the existing system is the presence of high dead mileage, which refers to the non-revenue distance travelled by buses between depots and operational routes. Since several existing depots are not strategically aligned with major route corridors or passenger demand zones, buses are required to travel long distances before entering service. This increases fuel or energy consumption, raises operational costs, and reduces overall fleet efficiency. In the context of electric buses, excessive dead mileage becomes even more problematic because battery range limitations require more efficient energy utilization and route planning. Long non-revenue trips can reduce the effective operating range of electric buses and create additional charging pressure on the system.

Another important issue observed in the current system is inefficient fleet management caused by inadequate depot distribution. The concentration of depot facilities in limited areas creates operational imbalance across the network. Buses operating in peripheral or outer areas often experience delays in dispatching, maintenance coordination, and schedule recovery due to the absence of nearby operational facilities. This reduces flexibility in fleet allocation and limits the ability of transit agencies to respond effectively to service disruptions, congestion, or fluctuating passenger demand.

The analysis also highlighted that the existing depot infrastructure lacks proper integration with the proposed route optimization framework. Since the earlier transit network developed incrementally over time without comprehensive operational coordination, depot locations do not effectively correspond with current travel patterns, high-demand corridors, or future urban expansion zones. As Indore continues to expand outward, many emerging residential and mixed-use areas remain relatively disconnected from efficient depot-based operational support. This spatial mismatch creates inefficiencies in service delivery and limits the overall performance of the public transport network.

From an infrastructure perspective, the absence of a structured depot hierarchy further affects operational efficiency. Existing facilities primarily function as basic parking and maintenance spaces rather than integrated operational centers capable of supporting advanced transit management systems. Modern electric transit systems require depots to function as multifunctional infrastructure nodes incorporating charging stations, maintenance workshops, operational control systems, energy monitoring facilities, and parking management. Without these facilities, the transition toward electric public mobility may remain operationally fragmented and financially inefficient.

The need for depot planning becomes even more important when considering the future growth and sustainability objectives of Indore. The city is experiencing rapid urban expansion, increasing travel demand, and greater dependence on public mobility systems. As passenger volumes increase, transit operations must become more efficient, reliable, and responsive to changing urban conditions. Strategically located depots can significantly improve route coverage, reduce turnaround time, minimize operational delays, and support more balanced fleet distribution across the city.

Depot planning also plays an essential role in reducing congestion and improving environmental performance. Poorly located depots contribute to unnecessary bus movement across congested corridors, increasing traffic pressure and operational inefficiency. By strategically locating depots closer to major operational clusters and high-demand routes, the system can reduce non-revenue trips, lower energy consumption, and improve overall operational sustainability. This becomes particularly beneficial for electric bus systems where energy efficiency and charging optimization are critical operational concerns.

In addition, properly planned depots support operational resilience and long-term scalability. As the public transport system expands in the future, new routes, additional fleet capacity, and higher service frequency will require stronger infrastructure support. A decentralized and strategically distributed depot system allows for better operational flexibility and easier future expansion without placing excessive pressure on individual facilities.

The proposed depot planning framework therefore focuses on aligning depot locations with route convergence patterns, travel demand distribution, major corridors, and future urban growth areas. The objective is not simply to create parking spaces for buses, but to develop an integrated operational infrastructure system capable of supporting efficient fleet management and sustainable electric transit operations. GIS-based spatial analysis and corridor-level operational assessment are used to identify suitable depot locations that minimize dead mileage, improve accessibility to routes, and enhance overall system efficiency.

Overall, depot planning is an essential operational requirement for strengthening Indore's public transport system and enabling the successful transition toward electric mobility. By addressing existing infrastructural gaps, improving operational coordination, and supporting efficient electric bus integration, the proposed depot planning strategy contributes toward creating a more reliable, sustainable, and future-ready public Transit System For the City.

6.3.2. Introduction of a Cluster Based Depot Planning Approach:

The proposed depot system is based on a cluster-based approach, where routes are grouped into clusters and each cluster is served by a dedicated depot. Instead of assigning a separate depot to each route, multiple routes are efficiently managed from a single depot, improving coordination and reducing unnecessary movement of buses.

As illustrated in the depot proposal map (Fig. 19), the system consists of four major depots, each strategically positioned to serve multiple interconnected routes. This approach ensures that depot locations are not random but are carefully selected based on route convergence, accessibility, and operational efficiency.

This structured clustering enables the system to function in an organized manner, where buses operate within defined zones while maintaining flexibility for inter-route movement.

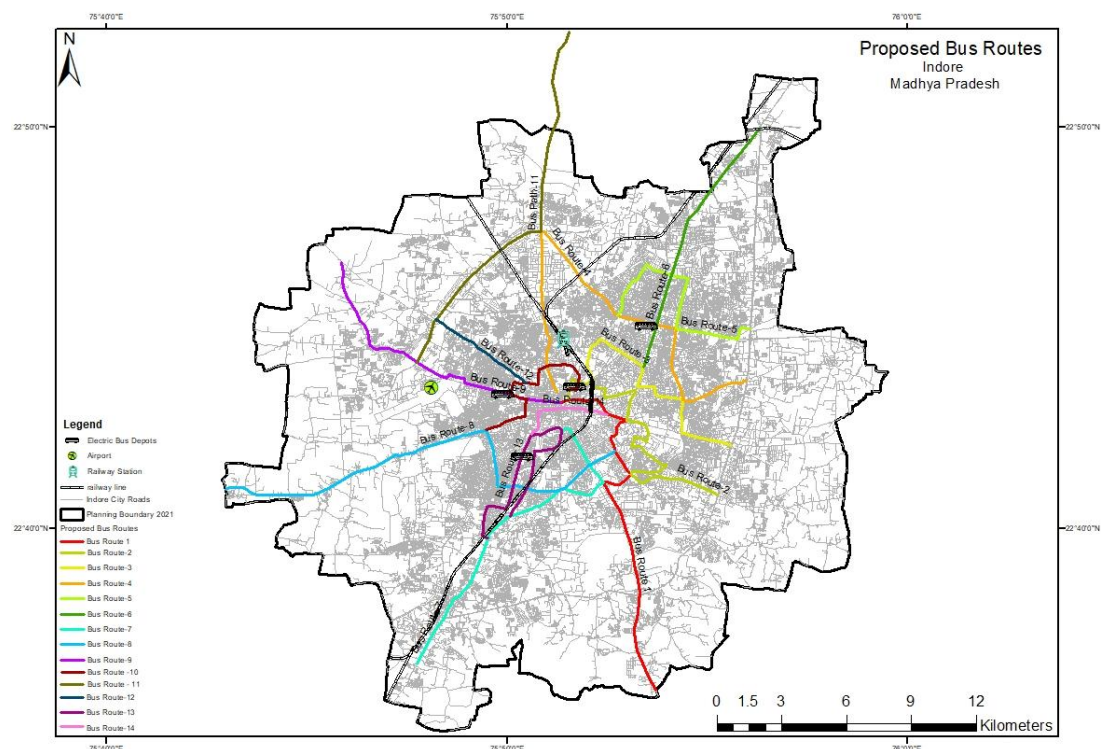


Fig 19, Proposed Depots Location map

Source: - Primary

6.3.3. Strategic Location of Depots based on Route Convergence:

The placement of depots is primarily based on high route convergence points, ensuring that each depot is centrally positioned relative to the routes it serves. This minimizes the distance buses need to travel without passengers, thereby reducing fuel/energy consumption and improving efficiency.

According to the proposal (Fig. 18), the route allocation is as follows:

- Depot 1: Routes 9, 10, 11, 12
- Depot 2: Routes 7, 8, 13, 14
- Depot 3: Routes 1, 2, 4
- Depot 4: Routes 3, 5, 6

This grouping ensures that:

- Routes with geographic proximity are managed together
- Depots are located near major operational zones
- Fleet movement remains compact and efficient

The map shown in above clearly illustrates how these depots are positioned in relation to the proposed route network, ensuring balanced spatial coverage across the city

6.3.4. Reduction of Dead Mileage and Non-Revenue Travel:

One of the most critical advantages of the proposed depot system is the reduction of dead mileage, which refers to the distance travelled by buses without carrying passengers. In the existing system, poorly located depots often require buses to travel long distances before starting service, leading to wasted energy, increased operational costs, and inefficiency.

The cluster-based depot model ensures that:

- Buses start their service closer to operational routes
- Return trips to depots are shorter and more efficient
- Idle movement is minimized

This directly contributes to:

- Lower operational costs
- Improved energy efficiency (especially important for electric buses)
- Increased revenue-generating travel

6.3.5. Operational Efficiency Through Centralized Control:

The cluster-based depot system also enhances operational control and fleet management. By centralizing operations within defined depots, transit authorities can:

- Monitor fleet performance more effectively
- Manage schedules and dispatching efficiently
- Respond quickly to operational disruptions

Each depot acts as a control centre for its assigned routes, ensuring that services run smoothly and consistently. This structured system reduces complexity compared to the

existing scattered and uncoordinated depot arrangement.

6.3.6. Support for Continuous and Flexible Bus Operations:

The proposed system ensures continuous operation of buses throughout the day. Since each depot serves multiple routes, buses can be redistributed dynamically based on demand and operational requirements.

For example:

- If demand increases on a particular route, buses can be reassigned from the same depot
- Maintenance or charging of one bus does not disrupt the entire route
- Backup buses are readily available within the same cluster

This flexibility is essential for maintaining reliable service, especially in a dynamic urban environment.

6.3.7. Alignment with Route Optimization Proposal:

The depot proposal is closely integrated with the bus route optimization strategy. The cluster-based depot system supports the node-based route network by ensuring that:

- Depots are located near key interchange nodes
- Routes are efficiently connected to operational bases
- Fleet allocation remains balanced across the network

This alignment creates a fully integrated transit system, where route planning and infrastructure planning work together rather than independently.

6.3.8. Overall Impact of the Depot Location Proposal:

In conclusion, the proposed depot location strategy transforms the existing unstructured depot system into a planned, efficient, and future-ready infrastructure network. By adopting a cluster-based approach, the proposal achieves:

- Reduced operational inefficiencies
- Improved fleet utilization
- Lower energy consumption
- Better integration with electric transit systems

The depot planning map and operational diagram in Sheet 11 clearly demonstrate how this system functions as a backbone for the entire transit network, supporting both route operations and electric mobility integration.

6.4. Bus Fare Proposal for E-Buses

6.4.1. Need of Proper Bus Fair:

A well-designed fare system plays a crucial role in ensuring the success of any public transport network. In Indore, the existing bus fare structure provides a basic distance-based pricing mechanism; however, it lacks integration with operational efficiency, route optimization, and the upcoming transition to electric mobility. Therefore, a revised fare proposal is required that is not only affordable but also aligned with energy consumption, passenger demand, and system performance.

This section presents a comparative analysis of the existing and proposed fare systems, followed by a data-driven fare proposal suitable for the electric bus network.

6.4.2. Existing Bus Fare System:

The current fare structure in Indore follows a broad distance-based slab system, where fares increase gradually with distance. Typically:

- ₹5–₹10 for very short trips (0–2 km)
- ₹10–₹15 for short trips (2–5 km)
- ₹15–₹20 for medium trips (5–10 km)
- ₹20–₹30 for longer trips (10–20 km)
- ₹30–₹40 for trips beyond 20 km

While this system ensures basic affordability, it has several limitations:

- Irregular slab distribution, making it confusing for users
- Not linked to operational cost, especially for electric buses
- No integration with transfer-based travel, which is essential for a node-based system
- Inefficient for optimized route networks, as it assumes direct travel

Thus, although functional, the existing system is not suitable for a modern, integrated, and electric transit system.

6.4.3. Proposed Bus Fare System:

The proposed fare structure is designed based on:

- Electric bus operational data (battery, cost per unit, range)
- Route length variation (4 km to 22 km)
- Passenger demand patterns
- Need for simplicity and usability

Distance Range (Km)	Proposed Price (rupees)
0 to 5	10
5 to 10	15
10 to 15	20
15 to 25	30

Table 4, Proposed Bus Fair Indore.

Source: - Primary

6.4.4. Data Base Justification:

The proposed fare system is derived using electric bus operational data:

- Battery capacity: 450 kWh
- Range: 190 km
- Electricity cost: ₹25/unit
- Total cost per charge: ₹11,250

Cost per km Calculation

$$\text{Cost per Km} = 11,250 / 190 = 60 \text{ rupee/Km}$$

Cost per Passenger

- Bus capacity: 60 Passengers
- Effective occupancy: 60 to 70 percent: 45 passengers

$$\text{Cost of Passenger per Km} = 60 / 45 = 1.3 \text{ rupee/Km}$$

Fare Justification

- 0 to 5 km = 10 Rupees
- 5 to 10 km = 15 Rupees
- 10 to 15 Km = 20 Rupees
- 15 to 25 Km = 30 rupees

This Can ensures:

- Cost recovery
- Operational buffer
- Infrastructure sustainability

6.4.5. Other Sources of Income for Bus operations:

For any public transport system, passenger fare alone is often not sufficient to cover the complete operational and maintenance costs, especially in the case of electric bus systems where initial infrastructure investment is high. Therefore, identifying additional and sustainable revenue sources becomes important for improving the long-term financial stability of bus operations. In the context of Indore's public transit system, multiple alternative income sources can support operational efficiency while reducing dependence on fare collection alone.

One of the major additional revenue sources is advertisement revenue. Public buses, bus shelters, terminals, and depots can be used for commercial advertising through digital displays, vehicle wrapping, and hoardings. Since buses move across major corridors and high-activity zones of the city, they provide strong visibility for advertisements, generating continuous revenue for the transit agency.

Another important source is transit-oriented commercial development around major bus terminals and depots. Commercial activities such as retail shops, kiosks, food stalls, parking facilities, and small business spaces can be integrated within transport hubs. This helps in generating rental income while simultaneously improving passenger convenience and activity around transit nodes.

Smart ticketing and digital systems can also create additional financial opportunities. Mobile applications, smart cards, and integrated digital payment systems can support partnerships with private companies and financial institutions. Data collected from these systems can further help improve operational planning and service optimization. Government subsidies and policy-based incentives also play a major role in supporting electric bus operations. Schemes such as FAME-II, PM E-Bus Sewa Scheme, and National Electric Mobility Mission Plan (NEMMP) provide financial assistance for electric bus procurement, charging infrastructure, and operational support. These policy interventions help reduce the financial burden on local transit agencies during the transition toward electric mobility.

Carbon credits and environmental incentives may become another future revenue source. Since electric buses reduce greenhouse gas emissions and dependence on fossil fuels, transit agencies may benefit from sustainability-linked funding mechanisms and

environmental programs introduced at national or international levels.

Public-private partnerships (PPP) can further improve financial sustainability by involving private operators in depot development, charging infrastructure management, and fleet operations. This reduces operational pressure on government agencies while encouraging technological innovation and efficient service delivery.

In addition, rental and leasing of transit infrastructure such as depot spaces, charging stations, and parking facilities can contribute to non-fare revenue generation. Integration of multi-modal transport facilities and last-mile connectivity services can also create supplementary operational income.

Overall, diversifying revenue sources is essential for maintaining a financially stable and operationally efficient public transport system. For Indore, combining fare revenue with advertisements, commercial development, government incentives, and smart infrastructure utilization can significantly strengthen the long-term sustainability of electric bus operations.

6.4.6. Conclusion:

The comparison clearly shows that while the existing fare system is functional, it lacks the structure and efficiency required for a modern public transport network. The proposed fare system, with its simple slab design, cost-based justification, and alignment with electric bus operations, offers a more efficient, user-friendly, and sustainable solution.

By combining affordability with operational logic, the proposed fare structure strengthens the overall transit system and supports the transition toward clean, efficient, and integrated urban mobility in Indore.

7. Conclusion

The study on “Clean Air Initiatives for Indore’s Public Transit: Planning for Infrastructure and Operations” highlights the urgent need to transform the existing public transport system into a more efficient, reliable, and environmentally sustainable network. As identified in the initial chapters, Indore is experiencing rapid urban growth, increasing travel demand, and rising dependency on private vehicles, which together contribute to congestion, operational inefficiencies, and deteriorating air quality.

Through a detailed analysis of the current bus system, this research identified key challenges such as route overlap, uneven service distribution, lack of infrastructure readiness, and operational inefficiencies. These issues clearly indicate that simply expanding the existing system is not sufficient; instead, a planned and integrated approach is required to improve both performance and sustainability.

To address these challenges, the study proposed a comprehensive electric public transit framework consisting of route optimization, operational restructuring, depot planning, and a data-driven fare system. The transition to a node-based route network reduces congestion and improves connectivity across both central and peripheral areas. Similarly, the proposed operational improvements, including better scheduling and frequency, ensure more reliable and user-friendly services.

The depot location strategy further strengthens the system by minimizing dead mileage, improving fleet management, and supporting efficient charging infrastructure for electric buses. Together, these planning interventions create a well-structured system where infrastructure, operations, and network design are fully aligned.

A key contribution of this study is the development of a scientifically derived fare structure, based on energy consumption, passenger capacity, and operational efficiency. Unlike conventional fare systems, the proposed model ensures a balance between affordability and financial sustainability, making it suitable for long-term implementation in an electric transit system.

Overall, the findings of this research demonstrate that the successful integration of electric buses is not just a technological shift but a planning-led transformation. It requires coordination between route design, infrastructure development, operational efficiency, and policy support. When these elements are properly integrated, electric public transit can significantly reduce emissions, improve service quality, and enhance urban mobility.

In conclusion, this study provides a practical and scalable framework for transforming Indore's public transport system into a cleaner, more efficient, and future-ready network. The proposed strategies not only address present challenges but also create a strong foundation for sustainable urban mobility. Furthermore, the approach developed in this research can serve as a reference for other mid-sized cities in India that are planning a transition toward electric public transport systems.

Reference

Source	Type	In-text Citation	Reference List Format
Ardila-Gomez et al.	Journal	(Ardila-Gomez et al., 2021)	Ardila-Gomez A et al. (2021), <i>Decarbonizing Cities by Improving Public Transport and Managing Land Use and Traffic</i> , World Bank Group.
Atiya et al.	Journal	(Atiya et al., 2026)	Atiya A et al. (2026), <i>Decarbonizing Urban Transportation: A Case Study of Montreal</i> , <i>Applied Sciences</i> .
Banister	Journal	(Banister, 2008)	Banister D (2008), <i>The sustainable mobility paradigm</i> , <i>Transport Policy</i> .
Cabigiosu	Journal	(Cabigiosu, 2025)	Cabigiosu A (2025), <i>The adoption of electric vehicles in public transport services: Space, path dependency and embeddedness</i> , <i>Technological Forecasting and Social Change</i> .
Cervero	Journal	(Cervero, 2013)	Cervero R (2013), <i>Transport Infrastructure and the Environment: Sustainable Mobility and Urbanism</i> , <i>Journal of Urban Planning and Development</i> .
Comprehensive Mobility Plan for Indore	Government Report	(Comprehensive Mobility Plan for Indore, 2025)	Comprehensive Mobility Plan for Indore (2025), <i>Final Report</i> , Urban Mass Transit Company, Government of Madhya Pradesh.
Fabre et al.	Journal	(Fabre et al., 2023)	Fabre A et al. (2023), <i>Best practice in urban transport decarbonisation: A case study of three initiatives in Brisbane</i> , <i>Australian Planner</i> .
GIZ India	Organization Report	(GIZ India, 2020)	GIZ India (2020), <i>Electric Mobility in India: Opportunities and Challenges for Public Transport</i> , Deutsche Gesellschaft für

CLEAN AIR INITIATIVES FOR INDORE'S PUBLIC TRANSIT: PLANNING FOR INFRASTRUCTURE AND OPERATIONS

			Internationale Zusammenarbeit.
HUDCO	Organization Report	(HUDCO, 2014)	HUDCO (2014), <i>Best Practices in Urban Transport (Mass Public Transport): Indore BRTS</i> , HUDCO Best Practices Awards.
IEA	Organization Report	(IEA, 2022)	IEA (2022), <i>Global EV Outlook 2022: Securing Supplies for an Electric Future</i> , International Energy Agency.
Indian Institute for Human Settlements	Organization Report	(Indian Institute for Human Settlements, 2022)	Indian Institute for Human Settlements (2022), <i>Decarbonising Public Transport in India: An Issue Brief</i> .
Indore Development Plan	Government Report	(Indore Development Plan, 2021)	Indore Development Plan (2021), <i>Town and Country Planning Department</i> , Government of Madhya Pradesh.
International Energy Agency	Organization Report	(International Energy Agency, 2023)	International Energy Agency (2023), <i>Global EV Outlook 2023</i> , Available at: https://www.iea.org/reports/global-ev-outlook-2023
IPCC	Organization Report	(IPCC, 2022)	IPCC (2022), <i>Climate Change 2022: Mitigation of Climate Change</i> , Intergovernmental Panel on Climate Change.
Litman	Report	(Litman, 2021)	Litman T (2021), <i>Evaluating Public Transportation Health Benefits</i> , Victoria Transport Policy Institute.
Ministry of Housing and Urban Affairs	Government Report	(Ministry of Housing and Urban Affairs, 2017)	Ministry of Housing and Urban Affairs (2017), <i>National Urban Transport Policy</i> , Government of India.
Mohan and Tiwari	Book	(Mohan and	Mohan D and Tiwari G (2016),

		Tiwari, 2016)	<i>Sustainable Transport Systems: Policy, Planning, and Implementation</i> , CRC Press.
Newman and Kenworthy	Book	(Newman and Kenworthy, 2015)	Newman P and Kenworthy J (2015), <i>The End of Automobile Dependence: How Cities are Moving Beyond Car-Based Planning</i> , Island Press.
NITI Aayog	Organization Report	(NITI Aayog, 2021)	NITI Aayog (2021), <i>India's Electric Mobility Transformation Report</i> , Available at: https://www.niti.gov.in
OECD	Organization Report	(OECD, 2021)	OECD (2021), <i>ITF Transport Outlook 2021</i> , Organisation for Economic Co-operation and Development.
Pojani and Stead	Book	(Pojani and Stead, 2017)	Pojani D and Stead D (2017), <i>The Urban Transport Crisis in Emerging Economies</i> , Springer.
Ribeiro et al.	Journal	(Ribeiro et al., 2024)	Ribeiro PJG et al. (2024), <i>Public Transport Decarbonization: An Exploratory Approach to Bus Electrification</i> , <i>World Electric Vehicle Journal</i> .
Rodrigue	Book	(Rodrigue, 2020)	Rodrigue JP (2020), <i>The Geography of Transport Systems</i> , 5th ed., Routledge.
Sclar et al.	Book	(Sclar et al., 2016)	Sclar E et al. (2016), <i>Improving Bus Transit Systems in Cities</i> , Routledge.
Transit Cooperative Research Program	Organization Report	(Transit Cooperative Research Program, 2013)	Transit Cooperative Research Program (2013), <i>Transit Capacity and Quality of Service Manual</i> , 3rd ed., Transportation Research Board.
UN-Habitat	Organization Report	(UN-Habitat, 2020)	UN-Habitat (2020), <i>Enhancing Urban Mobility through Public Transport Systems</i> , United Nations

			Human Settlements Programme.
United Nations Environment Programme	Organization Report	(United Nations Environment Programme, 2022)	United Nations Environment Programme (2022), <i>Electric Mobility and Sustainable Transport Systems</i> , Available at: https://www.unep.org
World Bank	Organization Report	(World Bank, 2020)	World Bank (2020), <i>Transforming Transportation: Clean Buses for Cleaner Cities</i> , World Bank Publications.
World Resources Institute	Organization Report	(World Resources Institute, 2022)	World Resources Institute (2022), <i>Electric Mobility in India: Policy and Implementation Framework</i> .
Wright and Fulton	Journal	(Wright and Fulton, 2005)	Wright L and Fulton L (2005), <i>Climate Change Mitigation and Transport in Developing Nations, Transport Reviews</i> .
Zhang and Batterman	Journal	(Zhang and Batterman, 2013)	Zhang X and Batterman S (2013), <i>Air Pollution and Health Risks Due to Vehicle Traffic, Science of the Total Environment</i> .

CANDIDATE'S DECLARATION

I Shubh Shrivastava, Scholar No. 2211002101 hereby declare that the Thesis Project “Clean Air Initiative for Indore's Public Transit: Planning for Infrastructure and Operations”, submitted by me in partial fulfilment of the requirement for the award of degree of Bachelor of Planning at the Department of Architecture and Planning, Maulana Azad National Institute of Technology, Bhopal, India, is a record of Bonafide the work carried out by me. The matter/result embodied in this project has not been submitted to any other University or Institute for the award of any degree or diploma.

If, in future, it is found that the above statement is false, then I have no objection in withdrawal of Bachelor of Planning Degree awarded to me by the Institute.

Signature of the Student

Date: 07/05/2026

CERTIFICATE

This is to certify that the declaration of Mr. Shubh Shrivastava is true to the best of my knowledge and that the student has worked under my guidance for one semester in preparing this thesis.

RECOMMENDATION

Signature of the Guide
(Dr. Rahul Tiwari)

ACCEPTED



Signature of
Head, Department of
Architecture and Planning
(Dr. Nakul Dhagat)

Date: _____
Place: _____

Signature of
Thesis Coordinator for Year of
2025-26
(Dr. Preeti Onkar)
(Dr. Premjeet Das Gupta)

Date: 7/05/26
Place: Bhopal.