# Passenger Comfort Assessment Comparing Electric and CNG Buses in Delhi

**Master of Planning**
**(Transport Planning and Logistics Management)**


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*Thesis Report*

*In the partial fulfillment of the requirements for the award of the degree of*

## Master of Planning
## (Transport Planning and Logistics Management)


By

**Suhail Masood**

2022MTPLM013


Under the guidance of

**Dr. Mayank Dubey**


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**May 2024**

# Declaration

I **Suhail Masood**, Scholar No. **2022MTPLM013** hereby declare that the thesis titled **"Passenger Comfort Assessment: Comparing EV and CNG Buses in Delhi"** submitted by me in partial fulfilment for the award of **Master of Planning**, at School of Planning and Architecture, Bhopal, India, is a record of bonafide work carried out by me. The matter/result embodied in this thesis has not been submitted to any other University or Institute for the award of any degree or diploma.

Signature of the Student

Date: _______________

# Certificate

This is to certify that the declaration of **Suhail Masood** is true to the best of my knowledge and that the student has worked under my guidance in preparing this thesis.

RECOMMENDED

_________________

Signature of the Guide
Dr. Mayank Dubey

ACCEPTED

___________________

Saurabh Popli
Head, Department of Transport Planning

May 2024

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# Abstract

Public transportation plays a vital role in urban mobility, and enhancing passenger comfort is crucial for attracting ridership and promoting sustainable transportation choices. With the increasing adoption of electric vehicles (EVs) and compressed natural gas (CNG) buses, it is essential to examine how these alternative fuel sources impact passenger comforts. This research investigates the factors that influence passenger comfort in electric vehicles (EVs) and compressed natural gas (CNG) buses, offering a comparative analysis of passenger experiences in these sustainable public transportation modes. The study focused on key comfort parameters like noise levels, passenger count, temperature, humidity, and vehicle speed etc. within the Delhi National Capital Territory (NCT). A mixed-methods approach was employed, combining device-based measurements of objective comfort factors with questionnaire-based surveys to capture passengers' subjective experiences and preferences. The collected data was analysed to create a passenger comfort index using the Analytic Hierarchy Process (AHP). This index incorporates insights from the research and accounts for additional comfort parameters often missing from traditional Service Level Benchmarking (SLB) in public transportation. The findings indicate that EVs and CNG buses offer distinct advantages and potential areas for improvement in terms of passenger comfort. The resulting passenger comfort index and accompanying analysis provide a valuable resource for transportation planners, policymakers, and vehicle manufacturers. By understanding the nuances of passenger comfort in these environmentally friendly modes, stakeholders can implement targeted strategies to enhance the overall passenger experience. This research contributes to promoting sustainable transportation choices by ensuring passenger comfort remains a central consideration in urban mobility solutions. In conclusion, the study offers valuable insights into the factors that influence passenger comfort in environmentally-conscious public transportation. The resulting passenger comfort index and policy recommendations can inform decision-makers, transportation providers, and vehicle manufacturers, leading to improved passenger experiences and increased adoption of transportation modes.

**Keywords:** Passenger comfort, public transportation, Noise levels, Analytic Hierarchy Process (AHP), Service Level Benchmarking (SLB)

## सारांश

सार्वजनिक परिवहन शहरी गतिशीलता में महत्वपूर्ण भूमिका निभाता है ,और सवारियों को आकर्षित करने और टिकाऊ परिवहन विकल्पों को बढ़ावा देने के लिए यात्री सुविधा को बढ़ाना महत्वपूर्ण है। इलेक्ट्रिक वाहनों) ईवी (और संपीड़ित प्राकृतिक गैस) सीएनजी (बसों की बढ़ती स्वीकार्यता के साथ , यह जांचना आवश्यक है कि ये वैकल्पिक ईंधन स्रोत यात्री सुविधाओं को कैसे प्रभावित करते हैं। यह शोध उन कारकों की जांच करता है जो इलेक्ट्रिक वाहनों) ईवी (और संपीड़ित प्राकृतिक गैस )सीएनजी (बसों में यात्री आराम को प्रभावित करते हैं ,इन टिकाऊ सार्वजनिक परिवहन साधनों में यात्री अनुभवों का तुलनात्मक विश्लेषण पेश करते हैं। अध्ययन में दिल्ली राष्ट्रीय राजधानी क्षेत्र )एनसीटी (के भीतर शोर के स्तर ,यात्री संख्या ,तापमान ,आर्द्रता और वाहन की गति आदि जैसे प्रमुख आराम मानकों पर ध्यान केंद्रित किया गया। यात्रियों के व्यक्तिपरक अनुभवों और प्राथमिकताओं को पकड़ने के लिए प्रश्नावली-आधारित सर्वेक्षणों के साथ वस्तुनिष्ठ आराम कारकों के उपकरण-आधारित मापों को मिलाकर एक मिश्रित-तरीके दृष्टिकोण को नियोजित किया गया था। विश्लेषणात्मक पदानुक्रम प्रक्रिया) एएचपी (का उपयोग करके यात्री सुविधा सूचकांक बनाने के लिए एकत्र किए गए डेटा का विश्लेषण किया गया था। यह सूचकांक अनुसंधान से अंतर्दृष्टि को शामिल करता है और सार्वजनिक परिवहन में पारंपरिक सेवा स्तर बेंचमार्किंग) एसएलबी (से अक्सर गायब होने वाले अतिरिक्त आराम मापदंडों को ध्यान में रखता है। निष्कर्षों से संकेत मिलता है कि ईवी और सीएनजी बसें यात्री आराम के मामले में सुधार के लिए विशिष्ट लाभ और संभावित क्षेत्र प्रदान करती हैं। परिणामी यात्री सुविधा सूचकांक और संबंधित विश्लेषण परिवहन योजनाकारों ,नीति निर्माताओं और वाहन निर्माताओं के लिए एक मूल्यवान संसाधन प्रदान करते हैं। इन पर्यावरण अनुकूल तरीकों में यात्री आराम की बारीकियों को समझकर ,हितधारक समग्र यात्री अनुभव को बढ़ाने के लिए लक्षित रणनीतियों को लागू कर सकते हैं। यह शोध शहरी गतिशीलता समाधानों में यात्री सुविधा को केंद्रीय विचार बनाए रखते हुए टिकाऊ परिवहन विकल्पों को बढ़ावा देने में योगदान देता है। निष्कर्ष में , अध्ययन उन कारकों पर मूल्यवान अंतर्दृष्टि प्रदान करता है जो पर्यावरण के प्रति जागरूक सार्वजनिक परिवहन में यात्री आराम को प्रभावित करते हैं। परिणामी यात्री सुविधा सूचकांक और नीति सिफारिशें निर्णय निर्माताओं ,परिवहन प्रदाताओं और वाहन निर्माताओं को सूचित कर सकती हैं ,जिससे यात्री अनुभवों में सुधार होगा और परिवहन साधनों को अपनाने में वृद्धि होगी।

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# List of Abbreviations

MoUD - Ministry of Urban Development

KPPs - Key performance parameters

ULBs - Urban Local Bodies

WHO - World Health Organisation

EV - Electric Vehicle

CNG - Compressed Natural Gas

PT - Public Transport

DTC - Delhi Transport Corporation

DIMTS - Delhi Integrated Multi-Modal Transit System

RTO - Regional Transport Office

SLB - Service Level benchmarking

LoS - Level of Service

GoI - Government of India

AHP - Analytical Hierarchical Process

dB - Decibels

CR - Consistency Ratio

CI - Consistency Index

RI - Random Index

MCDM - Multi Criteria Decision-Making

# CHAPTER 1: INTRODUCTION

## 1 Background

### 1.1 Urbanization, Transportation Challenges and Public Transit in India

India's transportation system plays a vital role in its economic development, with the sector contributing significantly to the nation's GDP (Gupta, 2017). However, rapid urbanization poses significant challenges to urban transportation infrastructure. Government initiatives are underway to enhance India's urban mobility, including congestion policies and investments in infrastructure (Halarnkar, 2017). Despite these efforts, inadequate public transportation, inconsistent pricing policies, and a lack of integrated transport planning continue to hinder efficient urban mobility.

The past decades have witnessed a surge in India's urban population, outpacing overall population growth (Rumani & Phukan, 2014). This trend, coupled with rising personal mobility aspirations, has led to a proliferation of private vehicles, contributing to congestion and its associated impacts like air pollution, noise pollution and economic losses (Singh, 2012). While public transport infrastructure expansion is crucial, improving the quality and appeal of existing public transport services is equally essential to address this issue.

### 1.2 The Evaluation and Improvement of Urban Transport Systems

Every industry relies on performance evaluation parameters to assess its effectiveness and identify areas for improvement. This applies equally to the urban transport sector, where robust frameworks are crucial for ensuring quality services that meet the needs of a growing urban population. The concept of benchmarking offers a powerful tool for this purpose. The World Bank defines benchmarking as the comparison of performance against a predetermined standard (World Bank, 2007). It allows organizations to learn from top performers, adapt best practices, and continuously enhance their performance management processes.

The origins of benchmarking lie in land surveying, but its principles have been successfully adopted across various fields. In the context of transportation development, benchmarking involves gathering comparative information and serves as a management tool for assessing, monitoring, and refining urban transport strategies. It assists governments in their regulatory role, ensuring better availability of information and services to citizens. Urban transport service providers benefit by identifying performance gaps, setting targets, and improving the overall quality of services. Additionally, benchmarking allows for comparison with international standards, aiding financial institutions in designing development plans for the country's transportation infrastructure.

Benchmarking promotes accountability within service delivery mechanisms (Unnisa and Hassan, 2013). By enabling Urban Local Bodies (ULBs) and other agencies to pinpoint performance shortcomings and share best practices, benchmarking drives improvements in urban public transport. This translates into better services for the public, while also supplying a common framework for monitoring and reporting service quality levels.

## 1.3 Service Level Benchmarking in Urban Transport

Key performance parameters (KPPs) are fundamental to the benchmarking process. In urban transport, the identification of these parameters and the subsequent evaluation of a city's transportation system is termed "service level benchmarking." This comprehensive assessment illuminates the system's current efficiency and effectiveness. By setting targets for accepted KPPs, service level benchmarking guides performance improvement initiatives for the years ahead.

While relatively new to India, benchmarking is gaining traction in the public transport sector, facilitating the identification and rectification of inefficiencies (Bharadwaj et al., 2017). This aligns with the growing urgency of addressing the challenges faced by India's urban transport system. To enhance mobility and user experience, government agencies are employing various methods, including benchmarking and performance monitoring frameworks, to deliver higher quality services.

## 1.4 Initiatives by the Ministry of Urban Development

Recognizing the need for long-term sustainability in benchmarking activities, India's Ministry of Urban Development (MoUD) has played a pivotal role in operationalizing and institutionalizing these practices. Urban cities are encouraged to undertake service level benchmarking procedures to inform performance plans and internal decision-making processes. This data-driven approach also aids in reporting progress to higher-level government and external stakeholders.

Since urban transport agencies previously lacked performance measurement and action systems, establishing standardized performance benchmarks is crucial. These benchmarks, tailored to the specific needs of each city, enable the systematic enhancement of urban transport quality (WHO, 2018). Crucially, continuous monitoring against these benchmarks fosters a culture of improvement and adaptation.

The MoUD's initiative to define Service Level Benchmarks (SLBs) for Indian public transport systems marks a significant step forward (MoUD, 2009). Benchmarking is a multi-stage, long-term process, encompassing identification of best practices, performance measurement, adaptation, and continuous improvement. By embracing the principles of benchmarking, India's public transport landscape has the potential to undergo significant transformation, ultimately benefiting the millions of citizens who rely on these services daily. Benchmarking is said to be a long-term procedure that involves the number of successive processes as shown in Figure 1.

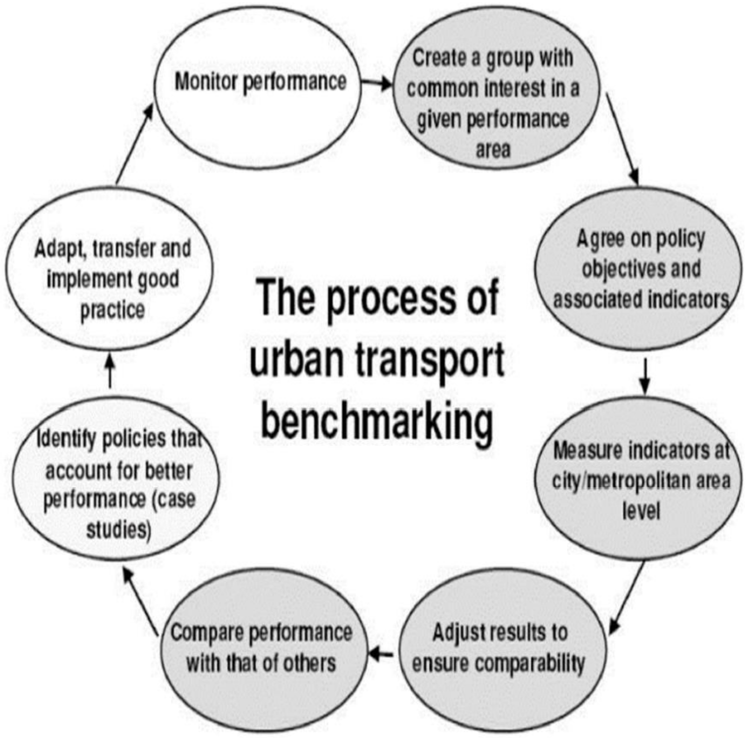


*Figure 1: Benchmarking Process Flow*
*Source: MoUD*

## 1.5 The Case for Enhancing Passenger Comfort in Public Transportation

To counteract the growing reliance on private vehicles, India's public transportation systems need to offer a comfortable and attractive alternative. Passenger comfort plays a crucial role in encouraging the use of public transportation. Improving the in-cabin experience in buses can help shift commuters away from private modes and reduce congestion-related externalities. This aligns with a broader global emphasis on ensuring passenger comfort as a core element of sustainable urban transport planning.

## 1.6 **Passenger Comfort: A Key Determinant of Ridership**

Within the realm of public transportation, passenger comfort emerges as a central factor influencing ridership patterns and shaping the overall public transit experience. A comfortable journey encourages individuals to choose public transportation over private vehicles, leading to cascading environmental and social benefits. Passengers who find their commutes pleasant are more likely to become regular users, contributing to a sustained and robust public transportation system. Conversely, a system plagued by discomfort discourages ridership, undermining its effectiveness and environmental benefits.

## 1.7 **Environmental Sustainability: The Rise of Electric and CNG Buses**

Traditional diesel-powered buses, while instrumental in urban mobility for decades, pose significant environmental challenges. Their reliance on fossil fuels contributes to air pollution, greenhouse gas emissions, and the associated health consequences. In response to these concerns, the global landscape of public transportation is witnessing a significant shift towards environmentally friendly alternatives. Electric Vehicles (EVs) and Compressed Natural Gas (CNG) buses are gaining traction as cleaner and more sustainable transportation solutions.

Electric Vehicles (EVs): EVs boast zero-tailpipe emissions, eliminating direct air pollution in urban centers. Their operation relies on electric motors powered by batteries, which are recharged from the grid. While the environmental impact of electricity generation needs consideration, the shift from fossil fuels to renewable energy sources can further reduce the overall environmental footprint of EVs.

Compressed Natural Gas (CNG) Buses: CNG buses offer a cleaner alternative to diesel buses. CNG burns more efficiently, resulting in lower emissions of harmful pollutants like particulate matter and nitrogen oxides. While not entirely emission-free, CNG buses represent a significant step towards cleaner public transportation.

As governments and transportation authority's prioritize environmental sustainability, the integration of EVs and CNG buses into public transport fleets is poised to surge.

## 1.8 Aim and Objectives

### Aim

To enhance passenger comfort in EVs and CNG buses within the context of urban public transportation.

### Objectives

To fulfil this overarching aim, the study will pursue the following specific objectives:

i. **Identify the parameters influencing passenger comfort in public transport.**

This objective entails a comprehensive examination of the key factors that contribute to overall passenger comfort in public transportation vehicles.

ii. **Assess passenger comfort in public transport, comparing experiences between EV and CNG bus users.**

The research will conduct a comparative analysis of passenger comfort levels between these two bus types, identifying both areas of strength and potential shortcomings in each.

iii. **Evaluate parameters of passenger comfort in public transport, examining differences between EV and CNG users.**

This objective involves a detailed analysis of specific comfort parameters, such as noise levels, temperature, and air quality, to highlight any significant variations in passenger experiences between EV and CNG buses.

iv. **Develop recommendations for integrating passenger comfort in urban transportation planning and policy-making.**

Based on the research findings, the study will generate actionable recommendations to prioritize passenger comfort and provide a passenger comfort index for SLB.

## 1.9 Scope

This research focuses on enhancing passenger comfort within air-conditioned electric vehicles (EVs) and compressed natural gas (CNG) buses operating in the urban setting of Delhi, India. The study examines the following specific parameters of passenger comfort:

- **Objective Measurements:** Noise level, humidity, temperature, and speed. These parameters will be recorded at one-minute intervals during bus operation using appropriate instrumentation.
- **Subjective Assessments:** Passenger perceptions of comfort will be captured through survey questionnaires, gathering their experiences and preferences regarding various comfort-related aspects.

The research is limited to air-conditioned EV and CNG bus types. This focus allows for a more controlled comparison and analysis of passenger comfort in these sustainable transport technologies within the context of Delhi's specific environmental and operational factors.

## 1.10 Limitations:

- **Geographical Limitation:** The study is confined to Delhi, India, which may limit the generalizability of the findings to other cities with different urban layouts, traffic patterns, and environmental conditions.
- **Bus Types:** The research exclusively examines air-conditioned electric and CNG buses, excluding other types of buses and forms of urban transportation, which could also impact passenger comfort.
- **In cabin Environmental Variables:** While the study considers humidity, temperature, and bus speed, noise levels only and other variables such as road surface conditions, traffic congestion, and bus age or maintenance, were not within the scope of this analysis.
- **Temporal Scope:** The data collection was conducted over a specific period.

## 1.11 Need of the Thesis

Service Level Benchmarking (SLB) provides a framework for evaluating the quality and performance of public transportation systems. Traditional SLB indicators often focus on metrics such as frequency, reliability, and accessibility. While these factors are critical, passenger comfort plays an equally significant role in influencing ridership and fostering a positive public transport experience. A comfortable journey encourages individuals to choose public transportation over private vehicles, leading to benefits such as reduced congestion and improved air quality.

Current passenger comfort indicators in SLB might not fully capture the nuances experienced in modern EV and CNG buses. These alternative fuel vehicles offer distinct technological characteristics that may present unique advantages or challenges compared to traditional diesel buses. Understanding these differences in the context of passenger comfort is essential for optimizing SLB frameworks and maximizing the effectiveness of these sustainable transportation modes.

This thesis aims to address the following needs:

- **Identifying Key Comfort Parameters:** The research will explore the primary factors that influence passenger comfort within EVs and CNG buses. This knowledge will contribute to refining existing SLB indicators or introducing new ones specific to these vehicles.
- **Benchmarking Comfort in EVs and CNG Buses**: The study will develop a passenger comfort index, allowing for comparison and benchmarking between EVs and CNG buses. This index will help transportation providers identify areas of improvement and make targeted interventions.
- **Policy-Oriented Recommendations:** Insights from the research will inform policy recommendations for enhancing passenger comfort in public transportation. These recommendations will aid policymakers and transportation planners in creating a more user-centric and attractive public transport system.

By revising SLB indicators through the lens of passenger comfort in EVs and CNG buses, this research seeks to promote sustainable transportation choices and enhance the overall appeal of public transportation in urban environments.

## 1.12 **Methodology**

This section outlines the research methods employed to investigate passenger comfort in EVs and CNG buses operating within the Delhi National Capital Territory

(NCT). A mixed-methods approach was adopted, combining device-based data collection for objective comfort parameters with questionnaire surveys to capture passengers' subjective experiences and preferences.

**Objective 1:** Identify parameters influencing passenger comfort in public transport

- Conduct a literature review to understand existing knowledge on passenger comfort in public transport.
- Conduct a site visit to observe passenger behaviour and identify potential comfort factors.

**Objective 2:** Assess passenger comfort in public transport comparing experiences between electric vehicle (EV) and CNG bus users

- Conduct a passenger survey to collect data on user experience and perception of comfort factors like noise levels, temperature and safety.
- Use instruments to measure objective data on noise levels and temperature inside the buses.

**Objective 3:** Evaluate parameters of passenger comfort in public transport, examining differences between EV and CNG users

- Analyse the collected data to identify correlations between noise levels, speed, and user ratings of comfort.
- Use statistical tests like Mann-Whitney U test to compare noise levels and user ratings between EV and CNG buses.

**Objective 4:** Develop recommendations for integrating passenger comfort in urban transportation planning and policy-making

- Develop a framework for integrating passenger comfort considerations into urban transportation planning. This might involve benchmarking best practices from other cities through Analytic Hierarchy Process (AHP).
- Formulate policy recommendations to improve passenger comfort in public transport based on the findings of the study.

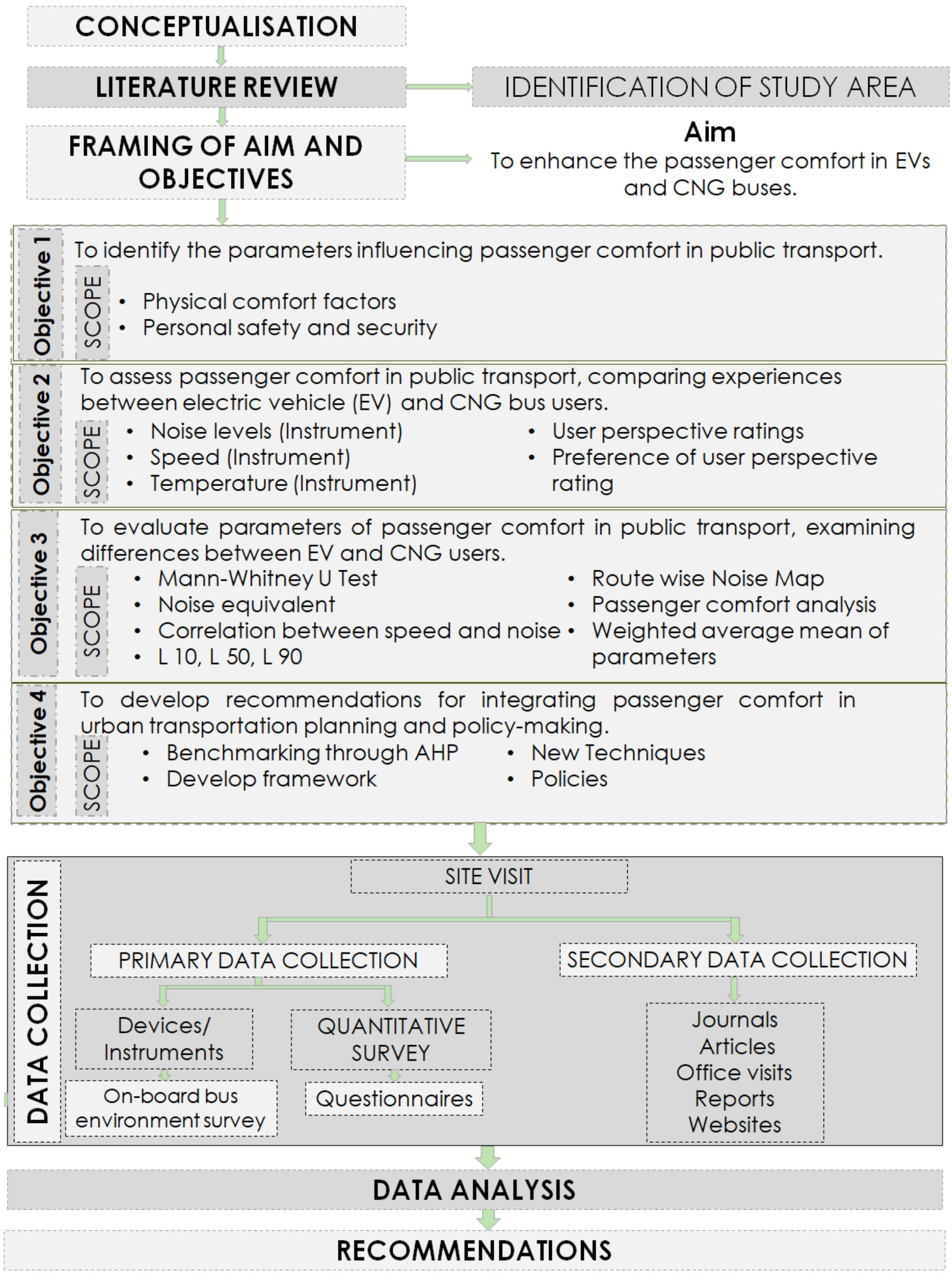


*Figure 2: Methodology flow chart*
*Source: Author*

## 1.13 **Expected Outcome:**

The research aims to uncover the essential factors contributing to passenger comfort in India's public transport system, potentially absent from current assessments, through a thorough review of existing literature. By establishing correlations between these factors and Service Level Benchmarks (SLBs), the study will propose recommendations for enhancing the current public transport benchmarking process in India. These recommendations will provide tailored and achievable goals for cities based on their unique characteristics.

## 1.14 Thesis Structure

The study report has been divided into five main chapters to meet the research objectives and achieve the aim of the study.

### Chapter 1: Introduction

This is the first chapter of the research study where the researcher has introduced the topic while providing a background of the research work as well. The concept of service level benchmarking and detailed passenger comfort assessment has been introduced with reference to the public transport system of India. The benchmarking of the urban transport system has been discussed in this section followed by the research aim and objectives.

### Chapter 2: Literature Review

In this section of the study, the researcher has developed the research objectives in a detailed manner to meet the aim of the research work. The researcher has collected the evidence from the unique secondary resources like books, articles, journals and other websites that are significant to the research topic. Besides that, he explores several works related to the Benchmarking Parameters, for effective evaluation of the Public Transport services. In association with this, the chapter gives a detailed view of the justification for the evaluation passenger comfort of public transport service. The study also focuses on the identification of parameters required for evaluating passenger comfort in the public transport.

### Chapter 3: Study Area and Data Collection

The third chapter of the study furnishes an outline of the study area, research strategy, sampling plan, data collection process, data types, and data analysis and interpretation techniques employed in this research. The researcher introduced the research methods utilized for data collection and ensuring the completion of the study effectively.

**Chapter 4: Data Analysis and Study Findings**

In this chapter, the researcher has used various data analysis techniques and analysed the collected primary data. The results have been presented in a theoretical manner or in the form of graphs and charts to make the readers understand it. The collected result has been interpreted in this section of the study to make an index for passenger comfort for service level benchmarking.

**Chapter 5: Way forwards and Recommendations**

Here, the researcher has discussed the analysed result from the collected primary data. The chapter also provides justification about the outcomes of the present study, "Passenger comfort Assessment: comparing Electric and CNG buses in Delhi" and provides informational outlook of the researcher which are based on the objectives of the research. In this is chapter of the study where the researcher has described the whole study in brief. The results of the study have been summarized at the end of this chapter to verify the research aim. Besides that, the researcher has described the summary of results obtained through the data analysis section and also provides conclusions to the research followed by recommendations and suggestions based on the study findings.

At the end of the thesis report, a list of references used in the research work has been included in the report, followed by relevant annexure.

# CHAPTER 2: LITERATURE REVIEW

## 2 Public Transport Benchmarking in India

India is undergoing urbanization in a faster way that requires the assessment of gaps in the service delivery by the transport sector. This could be achieved by collection of relevant information and management, monitoring the performance of the service sectors, benchmarking based on the evaluation. The benchmarking plays a major role in delivering responsible service by the agencies. The performance gaps can be identified and it could be filled by improvising the existing model with the help of best practices that in turn guarantees for best service offered to the people. The system of identifying the performance parameters and evaluating a service on basis of these parameters is known as Service Level Benchmarking (SLB). The performance management of the transport sector of India utilizes various techniques; one of them which are used by various ULBs is the benchmarking process. For effective comparison of the urban public transport services offered by State Transport Undertakings (STUs) and Special Purpose Vehicles (SPVs) in India, a standardized framework for performance monitoring, MoUD, GoI has brought out a handbook of Service Level Benchmarking. This SLB handbook is based on evaluating the public transport service in any city on a Level of Service (LoS) based scale.

The SLB for public transport as released by MoUD is attached as an Annexure and has been explained further in this section. Since the public transport services are meant for commuters of a particular city, it becomes invariably important to include the aspirations of the city commuters, as to what they want from their city transport service; this aspect is presently missing in the present SLB handbook. This becomes more important in light that transport being an indirect demand, and demand is dependent on the socio-economic characteristic of the user. The released SLB handbook aspires to benchmark the public transport services in the cities irrespective of city characteristics and requirements. Hence an attempt has been made in the research to fix the identified drawbacks in the benchmarking process and make these SLB’s more effective in measuring the performance of urban public transport systems and make it suitable for cities in India. MoUD SLB Handbook (2009) for the service level benchmarking in India on the public transport system was analysed and it was observed that the government focused on the achievement of best service with the help of key parameter analysis.

The SLB handbook focused solely on the organized public transport system in India which includes only organized bus transit and rail-based Mass Rapid Transit System (MRTS) operational in major metro cities only. The table below outlines the mechanism outlined in the SLB handbook issued by MoUD for assessing public transport services in any city. It illustrates the methodology for evaluating public transport services using a Level of Service (LoS) based model. In this model, the achieved LoS for each component is combined to determine the overall LoS.[1] Additionally, a series of investigative statements are linked to the range of overall LoS achieved post-evaluation, as detailed in Table 1.

*Table 1: SLB for public transport system in India*

| Level of Service (Score) | Presence of Organized Public Transport System in Urban Area (%) (LoS-1) | Extent of Supply Availability of Public Transport (LoS-2) | Service Coverage of Public Transport in the City (LoS-3) | Average waiting time for Public Transport users (minutes) (LoS-4) | Level of Comfort in Public Transport (LoS-5) | % of Fleet as per Urban Bus Specification (LoS-6) |
|---|---|---|---|---|---|---|
| 1 | >= 60 | >= 0.6 | >= 1 | <=4 | <= 1.5 | 75 - 100 |
| 2 | 40- 60 | 0.4 - 0.6 | 0.7- 1 | 4 – 6 | 1.5 - 2.0 | 50 - 75 |
| 3 | 20 – 40 | 0.2 - 0.4 | 0.3 - 0.7 | 6 – 10 | 2.0 - 2.5 | 25 - 50 |
| 4 | < 20 | < 0.2 | < 0.3 | > 10 | >2.5 | <= 25 |
| Calculated LOS = (LoS-1 + LoS-2 + LoS-3 + LoS-4 + LoS-5 + LoS-6) and identify overall LoS as mentioned below | | | | | | |

*Source: SLB Handbook (MoUD, 2009)*

A research study highlighted that in Ethiopia, the performance parameters are divided into two categories as system efficiency and utilization efficiency to investigate the overall service efficiency of city bus transport and to provide equitable bus service to all groups of society in Addis Ababa. (Agarwal et al., 2014) identified some environmental issues and operational issues that affect the performance of public transportation system in Indian cities. The primary operational challenges encompass overcrowding resulting from an insufficient

[1] Ministry of Urban Development. (2009). Service Level Benchmarks for Urban transport at a glance

system, inefficient and economically unsound bus routes, irrational placement of bus stops, inconsistent adherence to service frequency and schedules, traffic congestion, frequent stops leading to increased fuel consumption and vehicle wear and tear, limited fleet size of buses, and a public transport system that lacks appeal primarily due to unsafe and inconvenient vehicles. A research study listed out the following factors to assess the different bus transport systems in Kerala and to identify the merits and demerits of each one in order to gain a better understanding of Kerala public bus transport and the list included comfort, maintenance, and construction, crew behaviour, safety and security, travel time, availability of service, service delivery. (Anderson et al., 2013) found out that the following factors which measure service quality of public transport which includes availability, accessibility, information, time, customer care, comfort, security, environmental impact. (Eboli et al., 2008) identified service availability, service reliability, comfort, safety/security, customer care as indicators for evaluating a transit service.

(Ouali et al., 2020) conducted a study titled “Gender Differences in the Perception of Safety in Public Transport,” which highlighted the prevalent concerns regarding women's safety on public transportation systems, often discussed in media outlets. The researchers developed statistical models to examine gender disparities in safety perception and satisfaction on urban metros and buses using extensive customer satisfaction data from 28 global cities spanning from 2009 to 2018. Their findings revealed a significant gender gap in safety perception, with women being 10% more inclined than men to feel unsafe on metros (6% for buses). This gap was more pronounced for safety perception than overall satisfaction (3% on metros and 2.5% on buses), indicating safety as a crucial component of overall satisfaction. These findings remained consistent across various specifications and were robust even when accounting for city-level and temporal variables. The study also analyzed diverse responses based on socio-demographic characteristics. It indicated that 45% of women felt secure on trains and in metro stations (55% on buses). The gender disparity reflected more nuanced differences in transport perception between genders rather than an inherent network fear. Further analyses investigated the impact of metro features on perceived safety levels, revealing that incidents of violence, larger carriages, and less populated vehicles decreased women's sense of safety. The study utilized annual data from 2009 to 2018 sourced from customer satisfaction surveys among urban metro and railway users. These surveys comprised questionnaires covering various service aspects such as availability, timeliness, information provision, comfort, security, customer service, accessibility, and environment, along with a final question on overall satisfaction. Questionnaires were designed using an online survey tool and translated into local languages as needed. Through data analysis, the researchers constructed regression models to explore the relationships between individual satisfaction factors and overall satisfaction, with safety and travel satisfaction as dependent variables and other questionnaire components as independent variables. The study highlighted that the effects observed varied by age and country, emphasizing that metros significantly influenced individual safety evaluations, with women generally feeling safer on metros compared to buses or other modes of transport. Overall, the study concluded that metros with higher passenger volumes and staff presence contributed to women's sense of safety, while concerns regarding safety on buses were associated with factors like violence and sparse vehicle occupancy.

(Jasti & Ram, 2016) examined a large no. of Indian, Western and European literature on Sustainable service level benchmarking of urban transportation approach and critically reviews the existing benchmark for public transport in India. This study attempts to develop a comprehensive public transport benchmark for Indian cities which integrates environmental and social sustainability aspects otherwise missing in exiting guidelines with a case study of Hyderabad, India. The developed framework consisted of 8 performance indicators with 31 evaluators. These performance indicators are service availability, service reliability, comfort, fare, environmental sustainability, passenger information system, finance/ economic sustainability and social sustainability. Quality of service of bus system of Hyderabad is evaluated using weight based ranking system.

Various methodologies are used to understand the comfort levels associated to user’s ride experience as evaluating comfort is a tricky task. The subjective element depends on users past experience of public transport and their personal opinions of comfort. Behaviors associated with driving such as braking, steering acceleration determine the quality of ride. A study with analysis done on both objective and subjective data through kinematic parameters using smart phones and perception of the passengers about comfort perceived on board was used to evaluate comfort levels. The objective data derived from acceleration values provide an accurate assessment of comfort aspects. was used to define comfort (Eboli, Mazzulla, & Pungillo, 2016). While in another study, the levels of vibrations and noise were quantified. The vibration measurements made on the floor and seat of the buses and acceleration was used for analysis of discomfort. The vibration-based measurements were further understood with measuring discomfort for instance, ability to read a newspaper while on a bus. The postural effects of the movement of the bus were not conducive to the reading activity indicating high levels of discomfort (Prashanth, Saran, & Harsha, 2013).

## 2.1 Exposure to noise inside transit buses

In both developed and developing regions, urban residents express significant concerns regarding traffic noise pollution. With ongoing urbanization, increased car ownership, expansion of roadway capacity, and rising traffic volume, a growing number of urban dwellers are expected to experience heightened exposure to traffic noise pollution in the coming years. Among urban commuters, those utilizing bus transportation systems are directly subjected to noise pollution.

Koushki and Ali (2001) conducted a study aiming to quantify noise pollution levels inside transit buses in Kuwait and investigate passengers' attitudes toward noise exposure. The research involved measuring noise levels inside 115 randomly selected transit buses operating on 12 representative routes in Metropolitan Kuwait during daily commuting hours. The findings revealed generally high noise levels inside transit buses, with equivalent continuous noise levels ranging from 68.2 dBA to 106.7 dBA, and a mean of 79.0 dBA. Approximately 65% of passengers reported being annoyed by the noise inside buses, with nearly 34% expressing significant annoyance.

External sources such as traffic, commercial activities, and construction significantly contributed to noise pollution levels inside buses. A three-way cross-classification analysis was conducted to assess the impact of external noise sources on bus interior noise levels. Although variations in interior noise levels were observed among buses operating on different routes, the study did not provide sufficient evidence to confirm the substantial contribution of external noise sources to noise pollution inside buses. Factors such as the age of the bus engine, bus velocity, road conditions, and traffic flow were identified as potential contributors to variations in interior noise levels, necessitating further investigation.

Nadir et al. (2011) conducted a study in Kerman, Iran, to evaluate noise exposure levels among public transportation bus drivers. The research involved sampling eighty public transportation buses in Kerman during weekday business hours in 2010, with noise exposure measured for 10 minutes in each bus according to standard methods. The study found no significant differences in noise levels among the four bus models tested, with measurements ranging from 65.9 dBA to 79 dBA. These noise levels were deemed acceptable, as they were below the 85 dBA threshold for speech frequencies, indicating no risk of hearing or health-related issues for drivers or passengers.

Mukherjee et al. (2003) investigated noise exposure among drivers and conductors of special state buses in Kolkata, India. The study, conducted over two weeks during winter and summer seasons in 2000, found varying noise exposure levels among different bus routes. Although some routes exceeded the recommended noise exposure standard of 85 dBA, factors such as the condition of selected buses and road congestion influenced noise levels. The study did not extensively discuss factors influencing interior noise pollution levels in buses.

Portela and Zannin (2010) conducted research in Brazil to assess noise pollution levels and analyze factors influencing noise levels in urban buses. The study evaluated 80 buses of four different models and found significant differences in noise levels among the models. Conventional, micro, and articulated buses, particularly those with front-engine designs, produced higher noise levels compared to speedy buses. The study highlighted the influence of engine configuration on noise levels, indicating that drivers operating rear-engine vehicles were exposed to lower noise levels. However, the research did not extensively analyze factors such as bus velocity that could influence noise levels in buses.

## 2.2 **Research Gaps**

Extensive research exists on passenger comfort in traditional public transportation modes, primarily focusing on public buses. The reviewed studies on comfort are mainly centered on crowding and occupancy. As mentioned in sub-section comfort, there are many further aspects of comfort that needs to be investigated. Inclusion of quality attributes categories in the reviewed studies with better focus on reliability. Attributes regarding accessibility, information, customer care,

security, and environmental impact are touched upon in some publications, but without any further elaboration. However, a critical gap exists in our understanding of how public transport buses specifically impact passenger comfort. Due to their distinct operating mechanisms and technological characteristics, these alternative fuel vehicles might present unique advantages or disadvantages concerning passenger comfort parameters. A deeper understanding of these factors is essential to optimize the passenger experience in these evolving public transport solutions.

The current emphasis on promoting EVs and CNG buses for environmental sustainability necessitates a parallel focus on passenger comfort. Integrating these two priorities is crucial to ensure the widespread adoption and success of these sustainable transportation alternatives.

This research addresses this critical gap by investigating passenger comfort specifically within the context of EVs and CNG buses operating in public transportation systems. By analyzing passenger experiences in these two bus types, the study aims to contribute valuable insights for policymakers, transportation planners, and bus manufacturers and also addition of passenger comfort parameters that are missing in the SLB of public transport in India.

### 2.3 Noise Measurement

The unit for measurement of noise is decibels (dB). The measurement of noise helps us to determine the detrimental sound levels and which needs to be controlled with the help of noise reduction. The time weighted average of the sound level in decibels on the scale "A" that is comparable to human hearing is denoted by dB(A) Leq. A “decibel” is a measurement unit for noise. The letter "A" in dB(A). Leq stands for frequency weighting in noise measurements, which correlates to the human ear's (about 40 dB(A) frequency response characteristics. Leq is the noise level's energy mean over a given time period. Figure 3. shows the decibel scale for showing the normal sound level generated from different activities.

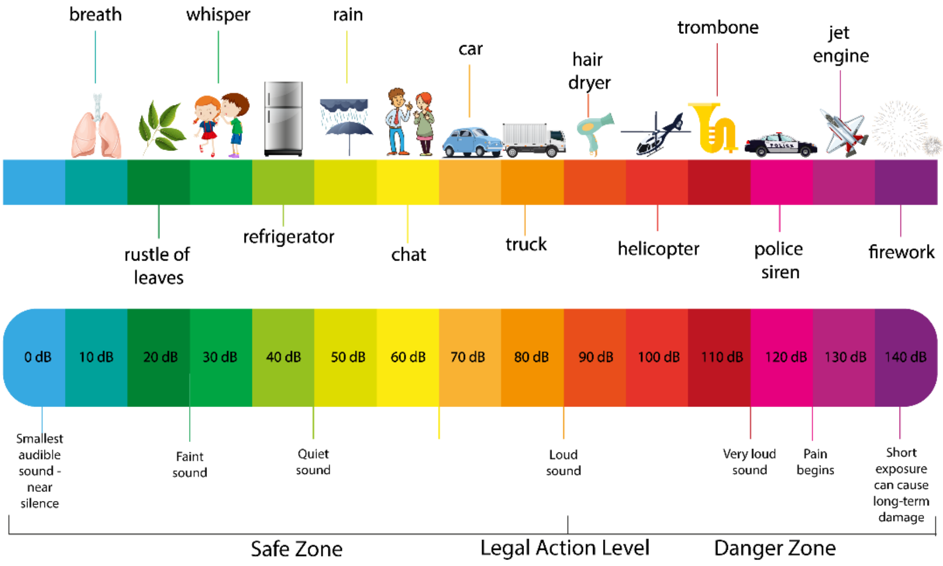


*Figure 4: Occupational Noise Exposure and Standards*

### 2.3.1 Frequency weighting

In most countries, the use of A-frequency-weighting is required to protect workers from noise-induced hearing loss. This weighting is based on historical equal-loudness contours, although it may not be scientifically ideal. However, it remains the standard for most measurements due to its practical advantage of allowing comparison between old and new data. A-frequency-weighting is the only mandated weighting according to international standards, with 'C' and 'Z' weightings being optional. Initially intended for quiet sounds around 40 dB SPL, A-frequency-weighting is now required for all levels. While 'C' frequency-weighting is

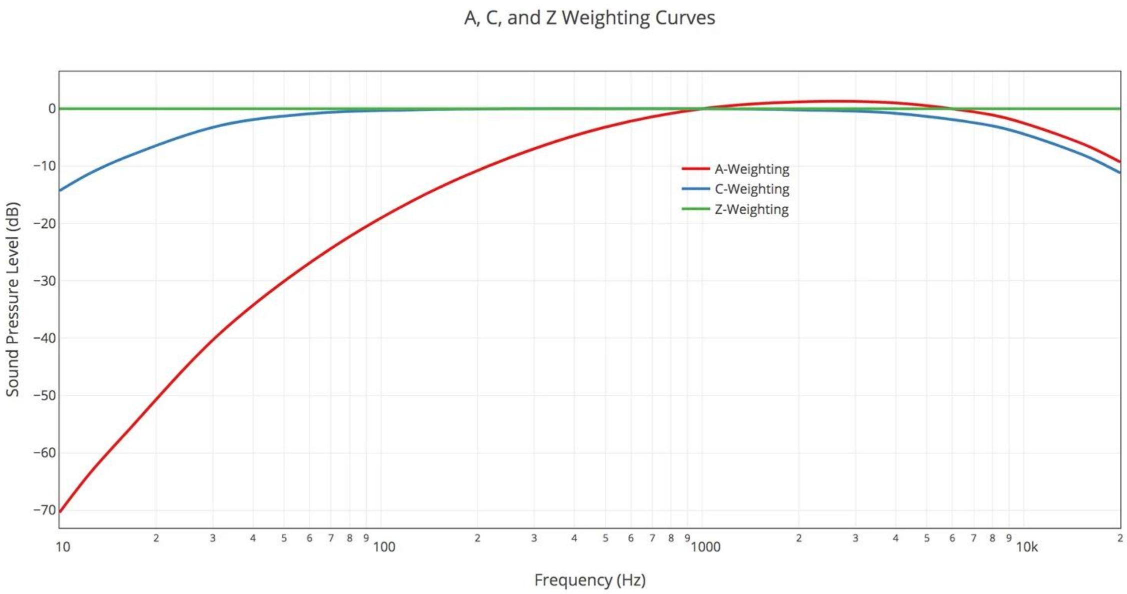


*Figure 5: Graph shows the different frequency weighting of Noise*

still used in some legislation for measuring peak noise values, 'B' frequency-weighting has limited practical use. 'D' frequency-weighting was developed for measuring aircraft noise, particularly for non-bypass jets, but with the discontinuation of the Concorde, which was primarily used for civil aviation, A-frequency-weighting is now standard for all civil aircraft noise measurements as per ISO and ICAO standards.

### 2.3.2 Noise Equivalent Level (Leq)

Leq helps quantify the average sound level over a specific timeframe, accounting for fluctuating noise levels. It is defined as the constant noise level; which over a given time, expands the same amount of energy, as it expanded by the fluctuating levels over the same time

$$\text{Total Leq} = 10\log\left(10^{(Leq1/10)} + 10^{(Leq2/10)} + \ldots.10^{(Leqn/10)}\right)$$

where, Leq is the equivalent continuous linear weighted sound pressure level, determined over a measured time interval Tm.

### 2.3.3 Statistical Noise Levels

L10: The level that is exceeded 10% of the time is L10. 10 % of the time, the sound pressure level of the noise is higher than L10.

L50: The level that is exceeded 50% of the time is called L50. It represents the middle of the noise values statistically. It shows the middle value of the varying noise levels.

L90: The level that is 90% of the time exceeded is L90. 90% of the time, there is more noise than this level.

## 2.4 Tools and Techniques

### 2.4.1 Traceable sound level meter

[2]The traceable sound level meter utilized for data collection of noise levels features a comprehensive set of specifications tailored to ensure accurate and reliable measurements across various environments. With a measurement range spanning from 35.0 to 95.0 dB in the low range and 65.0 to 130.0 dB in the high range, this instrument captures a wide spectrum of sound intensities. Its frequency range spans from 20 Hz to 8 KHz, offering the ability to detect sounds across diverse frequencies. Equipped with both A and C frequency weighting options and 1-

[2] https://www.traceable.com/4335-traceable-sound-level-meter.html

second (Slow) or 125 ms (Fast) time weighting settings, it ensures flexibility in capturing noise characteristics. The instrument incorporates a ½" electrets condenser microphone, enabling precise sound capture. Its calibration is facilitated by an internal oscillator generating a 1 KHz sine wave, adhering to the standards of IEC 61672-1 Class 2 and ANSI S1.4 Type 2 for assured accuracy and consistency. Additionally, the maximum hold function retains noise readings with a decay rate of less than 1 dB per 3 minutes, ensuring prolonged data retention during measurements. This meticulously designed sound level meter serves as a reliable tool for comprehensive noise level assessment across various applications.


*Figure 6: Traceable sound level meter*

2.4.1 Testo 608-H1 Digital Thermo Hygrometer

[3]The Testo 608-H1 Digital Thermo Hygrometer is a versatile instrument designed for accurate measurement and monitoring of temperature and humidity levels in various environments. With its compact and ergonomic design, the 608-H1 is easy to use and suitable for a wide range of applications, including residential, commercial, and industrial settings. This device features a large, easy-to-read digital display that provides clear and precise readings of both temperature and humidity, allowing users to quickly assess environmental conditions. The 608-H1 offers a temperature measurement range from -10°C to +50°C (14°F to 122°F) and a humidity measurement range from 0% to 100% RH, ensuring comprehensive coverage for


*Figure 7: Testo 608-H1 Digital Thermo Hygrometer*

[3] https://www.testo.com/en-IN/testo-608-h1/p/0560-6081

diverse monitoring needs. Equipped with a long-lasting battery, this thermo hygrometer offers continuous operation without the need for frequent battery replacements, enhancing its convenience and reliability for long-term use. Additionally, the Testo 608-H1 is designed with user-friendly functions such as min/max value display, allowing users to track fluctuations in temperature and humidity over time.

### 2.4.2 Mobile Google GPS

Mobile Google GPS utilizes a combination of GPS, accelerometer, and other sensors within smartphones to measure speed accurately. The GPS component tracks the device's location by communicating with satellites, providing real-time coordinates. As the device moves, its position updates continuously, enabling Google's software to calculate speed based on the change in location over time. Additionally, the accelerometer measures changes in velocity, aiding in determining speed by detecting how quickly the device is accelerating or decelerating. Google's algorithms then integrate data from these sensors to provide a reliable estimation of speed. This functionality is extensively used in various Google services, such as Google Maps, where it displays the current speed of the user's vehicle during navigation. However, it's essential to note that while mobile GPS is generally accurate, factors like signal strength, obstructions, and atmospheric conditions can occasionally affect its precision. Overall, mobile Google GPS offers a convenient and accessible means of measuring speed, enhancing navigation experiences and providing valuable information for users on the move.

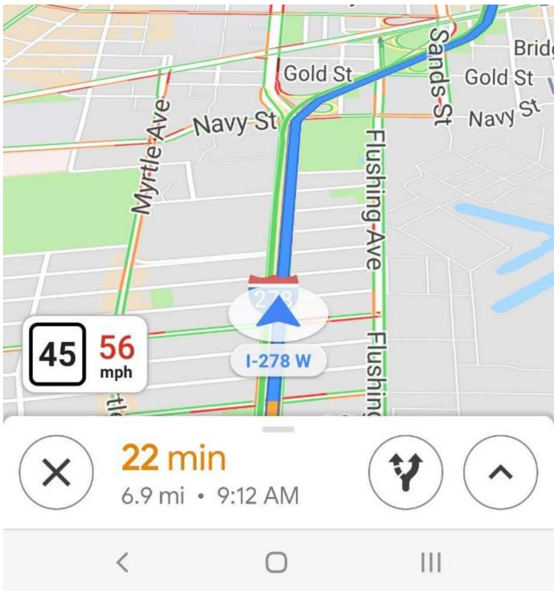

*Figure 8: Mobile Google GPS*

### 2.4.3 Analytic Hierarchy Process (AHP):

[4]The Analytic Hierarchy Process (AHP), developed by Thomas Saaty (1970s), is a robust multi criteria decision-making (MCDM) technique used to address complex scenarios. Its strength lies in its ability to structure a problem hierarchically, incorporating both qualitative and quantitative considerations into the analysis.

**Key Steps in AHP:**

- Problem Decomposition: The decision problem is broken into a hierarchy, starting with the overall goal, followed by criteria, sub-criteria (as needed), and finally, the alternative options being evaluated.
- Pair wise Comparisons: For each level of the hierarchy, decision-makers make pair wise comparisons between elements, indicating their relative importance or preference using Saaty's fundamental scale (values 1-9).
- Priority Derivation: Pair wise judgments are translated into priority vectors, representing the relative weights of elements at each hierarchical level. AHP employs mathematical calculations to derive these priorities.
- Consistency Check: AHP includes a consistency index and ratio, ensuring that the judgments provided by decision-makers exhibit logical consistency.

### 2.4.4 Mann Whitney U Test

The Mann-Whitney U test, also referred to as the Mann-Whitney-Wilcoxon test or Wilcoxon rank-sum test, is a non-parametric statistical method employed for comparing two independent groups. It is utilized when the data do not follow a normal distribution or when the assumptions of other parametric tests such as the t-test are not met. This test finds widespread application in research across diverse disciplines, particularly when dealing with ordinal, interval, or ratio data that are not normally distributed.[5]

[4] https://www.passagetechnology.com/what-is-the-analytic-hierarchy-process
[5] https://statistics.laerd.com/spss-tutorials/mann-whitney-u-test-using-spss-statistics.php

# CHAPTER 3 STUDY AREA

## 3 Site Area

### 3.1 Site Area: The Dynamic Metropolis of Delhi

The focus of this research is the vibrant city of Delhi, officially designated as the National Capital Territory (NCT) of India and encompassing the nation's capital, New Delhi. Geographically, Delhi straddles the Yamuna River, predominantly on the western bank, and shares borders with the states of Uttar Pradesh and Haryana. panning across 1,483 square kilometres, the boundaries of Delhi encapsulate both urban and rural landscapes, with 369.35 square kilometres designated as rural areas. As India's capital, Delhi holds unique significance. Its rapid growth and expansion attract individuals from across the country and the surrounding region. Consequently, planning for Delhi's future must extend beyond its formal boundaries to address the challenges and opportunities presented by its status as a regional hub.

#### 3.1.1 Demographic Profile

The 2001 Census recorded NCT Delhi's population at 13.8 million (138 lakhs), demonstrating a high degree of urbanization with 93.18% of residents living in urban areas – significantly exceeding the national average of 27.81%. During the 1991-2001 period, Delhi's urban population grew at an annual rate of 3.87%. Projections based on current trends estimate the NCTD population to reach 18.2 million (182 lakhs) by 2011 and 22.5 million (225 lakhs) by 2021.

*Table 3: Population Projection 2021*

| Area | Population (In lakh) |
|---|---|
| NCR | 641.38 |
| NCTD | 220-230 |

*Source: NCR Plan – 2021.*

The National Capital Region (NCR) and National Capital Territory of Delhi (NCTD) have stipulated population assignments in the Regional Plan-2021 as follows:

While precise forecasts are challenging, Delhi's population is likely to reach between 22 and 23 million (220 to 230 lakh) by 2021. However, land allocation, infrastructure, and transportation planning should be designed to accommodate the higher end of this projected range (23 million).

### 3.1.2 Drivers of Population: Natural Growth and In-Migration

Delhi's population dynamics are shaped by both natural growth and in-migration. Natural growth has steadily increased, from 55.80% in 1981 to 60.18% in 2001. Conversely, net migration showed a slight decline, from 44.20% in 1981 to 39.82% in 2001. The MPD 2021 anticipates a continued reduction in natural growth and an uptick in migration between 2001 and 2021. The net increase in NCT-Delhi's population is provided in table 3.

*Table 6: Population in NCT- Delhi*

| Year | Addition by Natural Growth | Increase by Migration | Net Increase (in lakh) |
|---|---|---|---|
| 1981 | 12.0 (55.8%) | 9.52 (44.2%) | 21.54 (100%) |
| 1991 | 18.9 (59.2%) | 13.05 (40.8%) | 32.0 (100%) |
| 2001 | 26.66 (60.18%) | 17.64 (39.82%) | 44.30 (100%) |
| 2011 | 24.2 (54.8%) | 20.0 (45.2%) | 44.2 (100%) |
| 2021 | 24.0 (50%) | 24.0 (50%) | 48.0 (100%) |

*Note: Figures (in bracket) indicate percentage to total net increase.*
*Source: Census of India and projections by DDA Sub-Group (MPD- 2021)*

### 3.1.3 Urban Fabric and Noise Zones

As a major urban center, Delhi exhibits dense and diverse development patterns. This study examines different locations within Delhi, classifying them based on their noise zone characteristics, which encompass mixed-use, commercial, residential, and silent zones.

As Delhi comes under urban area, so majority of the locations have a densely-populated and diverse development, with a combination of elements such as major trades, commercial operations, and residential properties. In this paper different locations are studied and they are classified on their Noise zone which includes the combination of Mixed, Commercial, Residential and Silent Zones within the city of Delhi.

Delhi's rapid industrialization, population growth, and extensive infrastructure development have exacerbated noise pollution challenges, particularly from traffic congestion. Despite a slight decrease in congestion due to COVID-19 disruptions, traffic patterns remain a significant contributor to Delhi's noise problems.

Amidst the hustle and bustle of this sprawling metropolis, where the average noise level stands at 81.6 dB, this research focus area is intricately intertwined with the city's dynamic transportation ecosystem. With a formidable fleet size of 7,135 buses, including 2,888 operated by the Delhi Transport Corporation (DTC) and an impressive 1,200 electric vehicles (the largest EV fleet in the country), alongside 3,047 buses managed by Delhi Integrated Multi-Modal Transit System (DIMTS), transportation plays a pivotal role in shaping the fabric of daily life. These buses collectively traverse a staggering cumulative distance of 650,000 kilometres each day, catering to an average daily ridership of 2,986,000 passengers. Notably, within my designated study site, buses emerge as the preferred mode of travel for distances ranging between 8 to 14 kilometres, underscoring their significance in the city's mobility landscape.

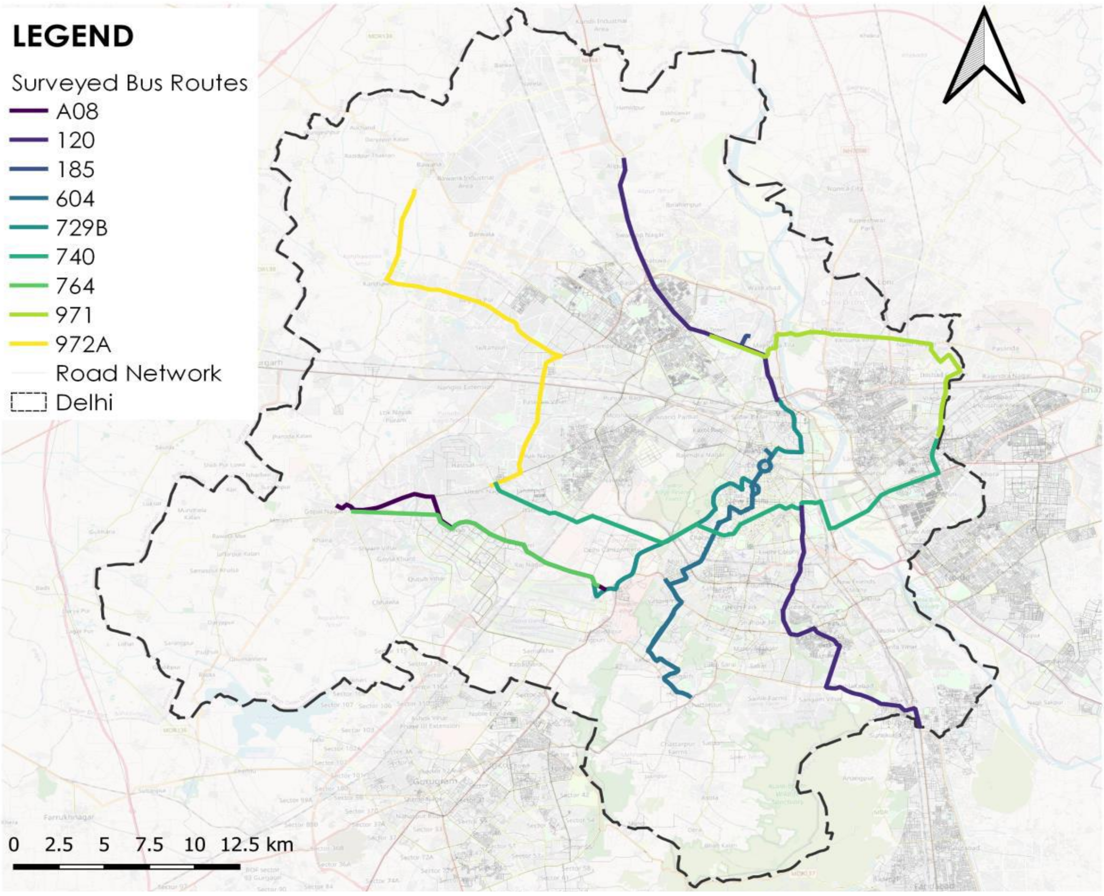


*Figure 10: Surveyed bus route location*
*Source: Author*

A total of 10 route locations have been shortlisted for the monitoring of passenger comfort parameters study, as shown in Figure 8. These routes are selected according to the bus's routes, including both EV and non-EV routes.

## 3.2 Route Selection

Delhi is divided into 11 districts, each encompassing various routes for transportation. These routes cater to both Electric Vehicle (EV) buses and non-EV buses, ensuring comprehensive coverage across the city. From this extensive network, 10 routes were meticulously selected for primary survey purposes. During this survey, instrumental readings pertaining to noise levels, speed, temperature, humidity and passenger count were meticulously recorded at various points along the routes. Furthermore, on board survey questionnaires were administered to bus users, specifically targeting aspects related to passenger comfort. These surveys aimed to gather comprehensive data regarding the performance of both EV and Non-EV buses across diverse environmental conditions and passenger preferences.

*Table 8: Bus routes with origin and destination*

| Route | Bus Type | Origin | Destination | Journey Time (Min.) | Journey Distance (Km) | Average Passenger |
|---|---|---|---|---|---|---|
| 708 | EV | Scindia House | Badarpur | 57 | 22.08 | 56 |
| 185 | EV | BBM Depot II | Kashmere Gate | 20 | 5.86 | 11 |
| 764 | EV | Palam flyover | Najafgarh | 64 | 15.35 | 50 |
| 604 | EV | Chhatarpur | NDLS | 57 | 44.34 | 50 |
| 729B | EV | Kashmere Gate | Airport terminal 1 | 80 | 21.23 | 29 |
| 120 | Non-EV | Narela terminal | Mori gate | 86 | 28.07 | 11 |
| A08 | Non-EV | Najafgarh | Airport T1 | 64 | 24.37 | 6 |
| 740 | Non-EV | Uttam Nagar terminal | Anand Vihar Terminal | 109 | 32.19 | 32 |
| 971 | Non-EV | Anand Vihar terminal | Avantika sector Rohini | 80 | 22.9 | 37 |
| 972A | Non-EV | Uttam Nagar Terminal | Bawana | 96 | 28.86 | 58 |

*Source: Author generated*

Table 4 displays a comprehensive overview of bus routes, detailing the bus type, origin, destination, journey time, journey distance, and the average number of passengers on board during the survey period. Each route is meticulously outlined, including essential information such as the starting and ending points, the duration of the journey, and the distance covered. Moreover, the table provides insights into passenger occupancy levels, offering a snapshot of the average number of individuals utilizing these routes during the survey timeframe.

## 3.3 Data Collection

Survey Design and Implementation: A structured survey was administered to a carefully selected sample of 110 passengers across 10 diverse bus routes (as Shown in the Table 4) in Delhi.

### 3.3.1 Primary Data Collection

**On-board Bus Survey:** A questionnaire survey was conducted on board a selected sample of 110 buses – 53 electric vehicles (EVs) and 57 compressed natural gas (CNG) buses – traversing routes within Delhi NCT. The survey instruments were designed to gather data on the following aspects:

**Passenger Demographics:** Age, gender, travel frequency, etc.

**Trip Purpose**: School, college, business, work, other.

**Income Level**: Bracketed categories for analysis

**Perceived Comfort:** Passengers were asked to rate their comfort on a Likert scale across various dimensions such as noise level, temperature, air quality, vibration, and seat comfort, safety.

**Preference Ratings:** The surveys also captured passenger preferences for different comfort attributes, allowing for an understanding of passenger priorities.

**Device-based Measurements:**

Figure 9 shows that Instruments were deployed on board the buses to collect real-time data on objective comfort parameters at one-minute intervals throughout the journey. These parameters included:

- Noise level (decibels)
- Temperature (°C)
- Humidity (%)
- Speed (km/h)

*Figure 13: Data Collection Process (Instrument based)*
*Source: Author*

The surveyor's location was fixed at the back side of the bus to measure the readings of all the devices (Figure 10). The noise meter was held at a height of 1 meter on a flat platform surface to collect readings of the in-cabin environment of the bus and the users inside. All readings were manually measured at one-minute intervals during various occurrences such as acceleration, deceleration, stops, traffic signals, and jerking for noise, speed, and temperature throughout the bus journey as. shown in Figure 9

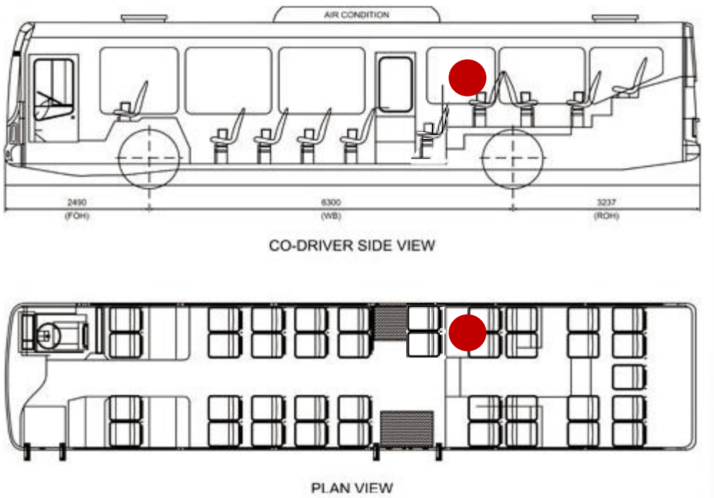


*Figure 14: Location of Observer*
*Source: Author*

### 3.3.2 Secondary Data Collection

To supplement the primary data and gain contextual insights, the study reviewed relevant scholarly articles, reports, and other secondary sources on passenger comfort in public transport, EVs and CNG buses, and Service Level Benchmarking (SLB) in public transportation, and secondary data was sourced from relevant agencies:

**Delhi Transport Corporation (DTC):** Bus routes, ridership data, noise mitigation strategies.

**Delhi Integrated Multi-Modal Transit System (DIMTS):** Insights into transport integration and electric bus plans.

**Regional Transport Office (RTO**): Bus fleet data (types, electric bus registration).

## 3.4 **Sampling**

A purposive sampling strategy was employed to select a representative sample of 110 buses (53 EVs and 57 CNG) operating on routes with varying passenger loads and traffic conditions within Delhi NCT. This approach ensured that the data collected reflected the diversity of experiences on these bus types within the city. Convenience sampling was used to recruit participants on board the selected buses. Passengers who consented to participate were included in the study.

# Chapter 4 DATA ANALYSIS

## 4 Data Analysis

The data was collected on the 10 routes in Delhi. Both questionnaire and instrument-based samples were recorded manually during the survey at one-minute intervals. These data points were then utilized for further analysis and calculation based on formulas, including the Equivalent Noise Level (Leq), L10, L50, L90, Lmin, and Lmax, for all the routes, encompassing both EV and non-EV buses.

The quantitative data collected through the device-based measurements was analyzed using descriptive statistics to obtain measures of central tendency (mean, median) and dispersion (standard deviation) for each comfort parameter (noise level, temperature, humidity, and speed) across both EV and CNG buses.

The passenger survey data was analyzed using a combination of descriptive statistics and inferential statistics. Descriptive statistics were used to summarize passenger demographics, perceived comfort ratings, and preference ratings. Inferential statistics, specifically the Mann-Whitney U test, were employed to compare comfort ratings and preferences between EV and CNG bus users.

The Mann-Whitney U test was employed as a non-parametric method to compare two distinct groups independently, particularly when the data did not adhere to a normal distribution. Its application aimed to ascertain whether there existed statistically notable variances in passenger comfort ratings across different comfort dimensions between users of Electric Vehicles (EV) and Compressed Natural Gas (CNG) buses.

The data on route-wise noise levels collected from the device-based measurements were used to generate noise maps for the selected routes using Geographic Information Systems (GIS) software.

To integrate the various data sources and develop a comprehensive passenger comfort index, the Analytic Hierarchy Process (AHP) was employed.

The AHP is a multi-criteria decision-making tool that facilitates the structuring of complex problems with multiple attributes and criteria. It allows for the incorporation of both objective and subjective factors into the decision-making process.

In this research, the AHP was used to assign weights to different passenger comfort parameters based on their relative importance to overall comfort, informed by the passenger preference ratings and a review of existing literature.

The weighted scores for each comfort parameter measured on board the buses (obtained from both device-based measurements and passenger ratings) were then aggregated to create a composite passenger comfort index for each bus journey.

This index enabled the comparison of overall passenger comfort between EV and CNG buses, accounting for the relative importance of different comfort factors.

## 4.1 Demographics and user profile

The sample collection involved 110 participants, comprising both EV and non-EV users. Each participant was asked to complete a questionnaire, wherein they rated their comfort observations inside buses. Additionally, they were requested to provide ratings indicating their preferences for various parameters affecting passenger comfort within the bus.

### 4.1.1 Age Distribution

The sample population for this study was drawn from a diverse range of age groups. A pie chart (Figure 11) depicts the distribution of participants across four age categories. The youngest age group, those below 18 years old, comprised 19% of the sample. The 19-35-year-old age group represented a larger portion at 36%. Notably, the largest segment of the sample population fell within the 36-60-year-old range, accounting for 38% of participants. The oldest age group, those 61 years old and above, made up the remaining 8% of the sample. This distribution indicates a focus on middle-aged adults, with a smaller representation of both younger and older demographics.

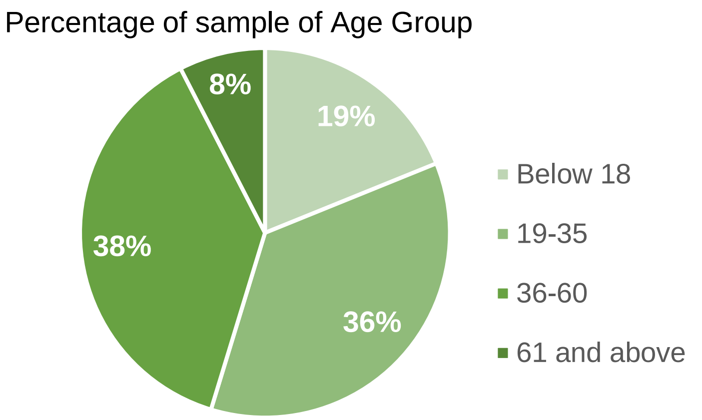


*Figure 15: Age Distribution*
*Source: Author generated*

### 4.1.2 Trip Purpose Distribution

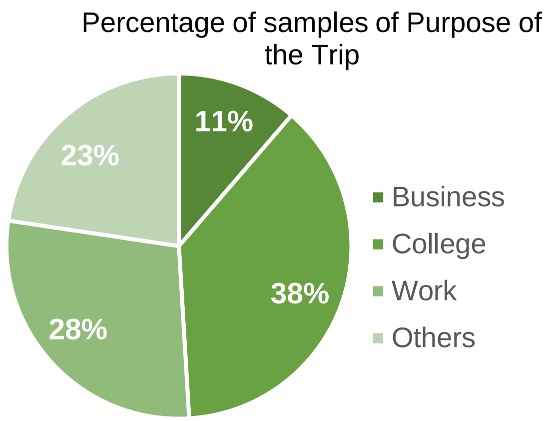


*Figure 16: Trip purpose distribution*
*Source: Author generated*

Figure 12 illustrates the distribution of trip purposes within the collected samples for this thesis. It categorizes trips into four primary purposes: business, college, work, and others. Business trips constitute 11% of the samples, indicating a focus on this specific travel category. College trips account for 38%, highlighting the presence of student participants within the sample population. Work trips are represented by 28% of the samples. Finally, the "other" category captures all remaining trip purposes and encompasses 23% of the samples. This distribution provides insight into the travel behaviours and demographics of the participants included in this study.

### 4.1.3 Trip frequency of the users

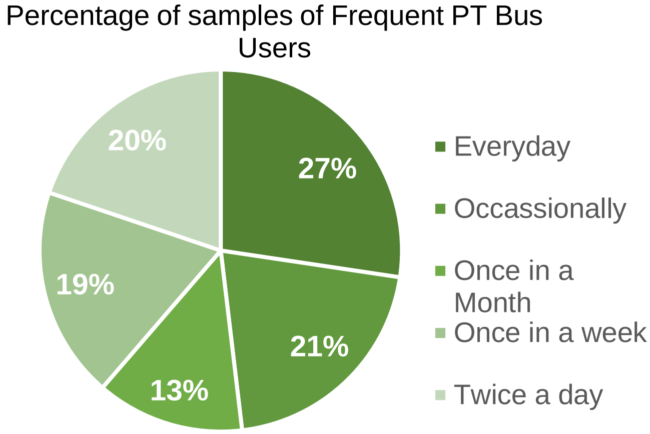


*Figure 17: Trip frequency of the users*
*Source: Author generated*

Figure 13 illustrates the frequency of public bus usage among the samples collected for this thesis. Nearly 27%, of the sampled population falls under the "Everyday" category, indicating they utilize public buses daily. This is followed by the "Once in a Month" category, accounting for 13% of the samples, highlighting a significant portion of weekly users. "Occasionally" users comprise 21% of the pie chart, suggesting a short distance trip or other purpose-based trip user base. Finally, the "Once in a week" category represents the least frequent users, encompassing 19% of the samples. And the remaining 20% encompassing the office based or work-based trip users. This distribution provides valuable insight into the public bus ridership patterns within the study population.

## 4.2 Statistical Analysis - Mann Whitney U test

For statistical analysis, the Mann-Whitney U test was conducted using SPSS software to determine the significance of parameters for both instruments and questionnaires from the user's perspective. This test was chosen as it is suitable for comparing two independent groups when the dependent variable is ordinal or continuous, but not normally distributed.

The Mann-Whitney U test evaluates whether the distributions of scores for two groups are equal or not. In the research, it helped to assess the differences in ratings and preferences between EV and non-EV users regarding comfort parameters inside buses. This analysis helps comprehend the differing rating and preferences of both groups regarding factors impacting passenger comfort.

### For Instrument Measured Parameters

*Table 9: Mann Whitney U test for Instrumental measured parameters*

| Hypothesis Test Summary | | | | | |
|---|---|---|---|---|---|
| | **Null Hypothesis** | **Test** | **Significance. a,b** | **Decision** | **Remark** |
| **1** | The distribution of Noise is the same across categories of Bus Type. | Independent-Samples Mann-Whitney U Test | < 0.001 | Reject the null hypothesis. | The distribution of Noise is not the same across categories of Bus Type. |
| **2** | The distribution of Temperature is the same across categories of Bus Type. | Independent-Samples Mann-Whitney U Test | < 0.001 | Reject the null hypothesis. | The distribution of Temperature is not the same across categories of Bus Type. |
| **3** | The distribution of Humidity is the same across categories of Bus Type. | Independent-Samples Mann-Whitney U Test | 0.000 | Reject the null hypothesis. | The distribution of Humidity is not the same across categories of Bus Type. |
| a. The significance level is .050. | | | | | |
| b. Asymptotic significance is displayed. | | | | | |

*Source: Author generated*

The Mann-Whitney U test in Table 5 was conducted to compare instrumental parameters, such as noise, temperature, and humidity, between Electric Vehicle (EV) and Non-Electric Vehicle (Non-EV) buses. The analysis revealed that all instrumental parameters exhibited statistically significant differences between the two categories of buses, as the significance values were less than 0.05.

Consequently, we reject the null hypothesis and accept the alternate hypothesis that the distribution of noise, humidity, and temperature is not the same across categories of bus type. This implies that there are significant disparities in these parameters between EV and Non-EV buses.

This finding has significant implications for the assessment and comparison of EV and Non-EV buses. The observed differences in noise, humidity, and temperature levels suggest potential variations in passenger comfort, environmental impact, and operational characteristics between the two types of buses.

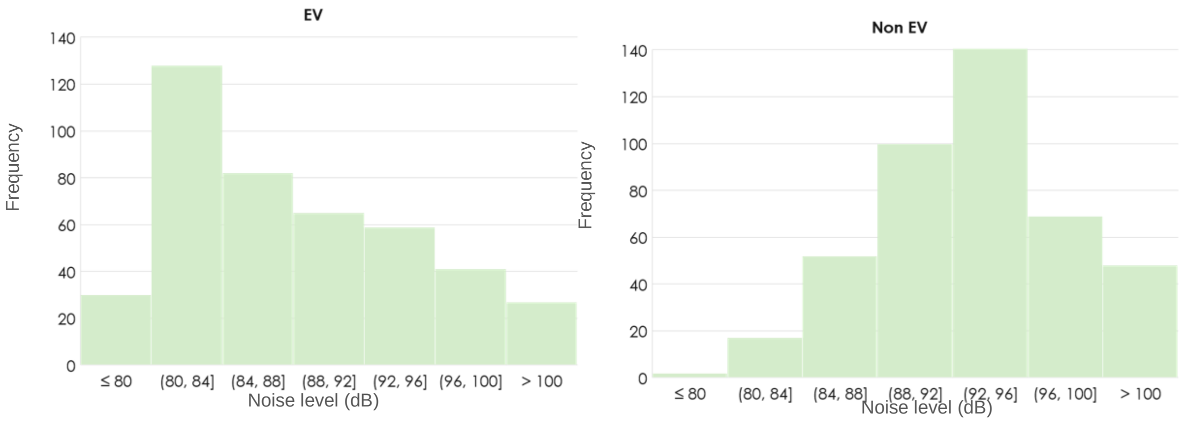


*Figure 19: Noise frequency comparison between EV and Non-EV*
*Source: Author generated*

The above Figure 14 shows that in EV buses more noise reading observed below 80 dB and the skewness of the graph is towards lower noise level as compared to Non-EV (CNG).

*Table 10: Mann Whitney U test for users perspective rating*

| Hypothesis Test Summary | | | | |
|---|---|---|---|---|
| | **Null Hypothesis** | **Test** | **Sig.a, b** | **Decision** |
| 1 | The distribution of Temperature is the same across categories of Bus Type. | Independent-Samples Mann-Whitney U Test | 0.408 | Retain the null hypothesis. |
| 2 | The distribution of Seat Availability is the same across categories of Bus Type. | Independent-Samples Mann-Whitney U Test | 0.348 | Retain the null hypothesis. |
| 3 | The distribution of Smoothness is the same across categories of Bus Type. | Independent-Samples Mann-Whitney U Test | 0.146 | Retain the null hypothesis. |
| **4** | **The distribution of Noise is the same across categories of Bus Type.** | **Independent-Samples Mann-Whitney U Test** | **0.013** | **Reject the null hypothesis.** |
| 5 | The distribution of Seat Comfort is the same across categories of Bus Type. | Independent-Samples Mann-Whitney U Test | 0.169 | Retain the null hypothesis. |
| 6 | The distribution of Legroom is the same across categories of Bus Type. | Independent-Samples Mann-Whitney U Test | 0.279 | Retain the null hypothesis. |
| 7 | The distribution of Air Quality is the same across categories of Bus Type. | Independent-Samples Mann-Whitney U Test | 0.444 | Retain the null hypothesis. |
| 8 | The distribution of Safety is the same across categories of Bus Type. | Independent-Samples Mann-Whitney U Test | 0.162 | Retain the null hypothesis. |
| a. The significance level is .050 | | | | |
| b. Asymptotic significance is displayed. | | | | |

*Source: Author generated*

**Parameters of User preference for passenger comfort**

After conducting the Mann Whitney U test in Table 6 to compare various parameters between Electric Vehicle (EV) and Non-Electric Vehicle (Non-EV) buses, it was revealed that the distributions of temperature, seat availability, smoothness, seat comfort, legroom, air quality, and safety were similar across both categories of buses. However, an exception was observed concerning noise levels, where the distribution was found to be dissimilar between EV and Non-EV buses. This conclusion was drawn based on the significance values obtained from the Mann Whitney U test: the significance value for noise was less than 0.05, indicating a statistically significant difference. Thus, we reject the null hypothesis and accept the alternate hypothesis that the distribution of Noise is not the same across categories of Bus Type. Conversely, for all other parameters, including temperature, seat availability, smoothness, seat comfort, legroom, air quality, and safety features, the significance values exceeded 0.05. Therefore, we retain the null hypothesis for these parameters, indicating that there is no statistically significant difference in their distributions between EV and Non-EV buses.

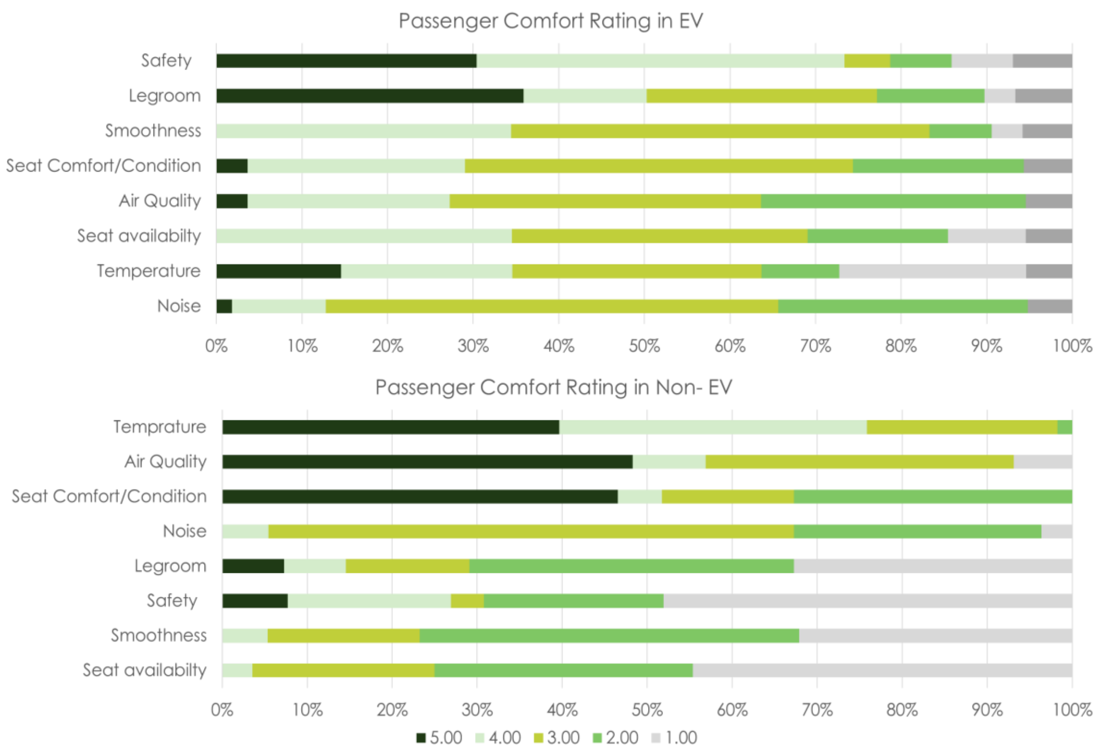


*Figure 20: Graph showing Passenger comfort rating in EV and Non-EV*

Figure 15 is showing the percentage of passengers who are comfortable in a vehicle is based on eight factors:

- Safety
- Legroom
- Smoothness
- Seat comfort/condition
- Air quality
- Seat availability
- Temperature
- Noise

**Passenger Comfort Ratings**

Figure 15 depicts the average passenger comfort ratings for various aspects of a non-electric vehicle (non-EV). These ratings are based on a scale of 1 (Excellent) to 5 (Very Poor). Passengers were asked to evaluate their comfort in terms of eight factors: temperature, noise, safety, smoothness, seat comfort/condition, seat availability, legroom, and air quality.

Temperature: Passengers rated temperature comfort as poor rating in CNG than EV buses, indicating a positive perception of the temperature control within the EV.

Noise: Noise levels within the vehicle received an uncomfortable rating for EV buses, suggesting a negative passenger perception of noise.

Safety: Safety features and overall sense of security in the vehicle garnered a comfort rating in EV buses as there is a police marshal present inside the bus which reflects a positive passenger sentiment regarding safety.

Smoothness: The smoothness of the ride received a comfort rating in both the bus type, indicating a neutral perception of ride quality.

Seat Comfort/Condition: Passengers rated the comfort and condition of the seats are good in EV buses than CNG buses.

Seat Availability: Having enough seats for all passengers was rated as average for comfort, which could indicate a potential issue with crowding factor.

Legroom: The amount of legroom provided in the vehicle was rated as poor rating for comfort in EV buses, suggesting a negative perception of passenger leg space.

Air Quality: The quality of the air inside the vehicle received a poor comfort rating in CNG buses, indicating a negative perception of air quality within the cabin.

### 4.3 Noise Analysis of EV & Non-EV

This analysis in Figure 16 compares the equivalent noise levels generated by electric (EV) and non-electric (non-EV) bus routes. The data highlights considerable noise, with levels ranging from 91.64 dB to 97.91 dB across all routes. Of particular concern are the highlighted routes – EV (764) and non-EV (972A) –

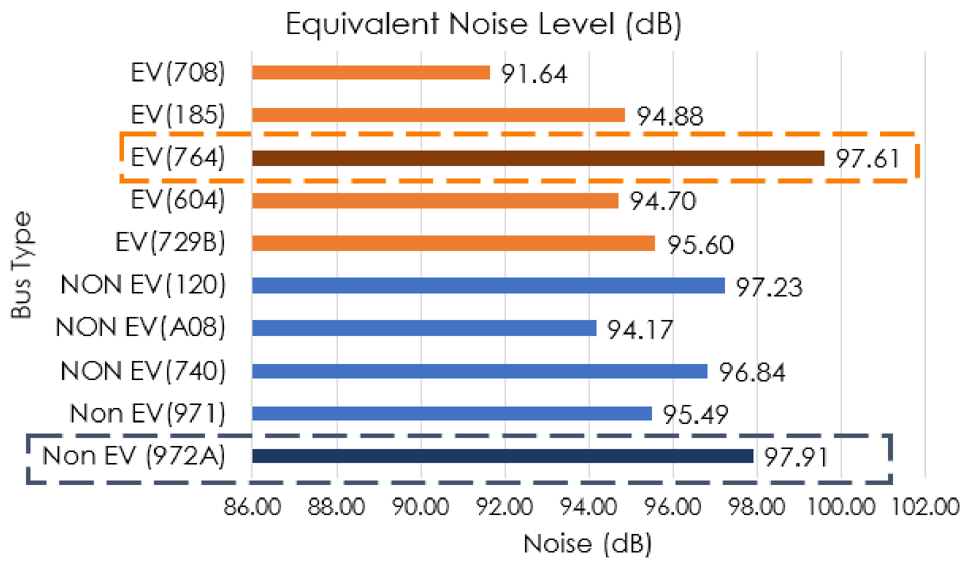


*Figure 23: Route wise equivalent Noise level in EV & Non-EV buses*
*Source: Author generated*

which exhibit the highest recorded noise levels at 97.61 dB and 97.91 dB respectively. This analysis underscores the need to address cabin noise from both electric and non-electric buses, as they can significantly impact the acoustic environment of urban areas.

Table 7 shows the equivalent noise level of electric (EV) and non-electric (non-EV) bus routes. Each route has noise levels listed across seven categories: bus type (EV or Non-EV), Leq (average noise level in dB), L10 (noise level exceeded 10% of the time in dB), L50 (noise level exceeded 50% of the time in dB), L90 (Noise level exceeded 90% of the time in dB), Lmin (minimum noise level in dB), and Lmax (maximum noise level in dB).

Routes 708, 185, 604, 729B, and 764 are all electric buses. Route 764 has the highest noise level among electric buses, at 97.61 dB Leq. Routes 120, A08, 740, and 971 are non-electric buses. Route 972A is the noisiest route overall, at 97.91 dB Leq.

*Table 11: Route wise Noise Equivalent readings*

| Routes | Bus Type | Leq (dB) | L10 (dB) | L50 (dB) | L90 (dB) | Lmin. (dB) | Lmax. (dB) |
|---|---|---|---|---|---|---|---|
| 708 | **EV** | 91.64 | 95 | 89 | 78.92 | 74.1 | 101.8 |
| 185 | **EV** | 94.88 | 99.4 | 89 | 82 | 80.7 | 103 |
| 764 | **EV** | 97.61 | 103.48 | 92.9 | 84.24 | 82 | 110 |
| 604 | **EV** | 94.7 | 100 | 88.9 | 80.8 | 77 | 104 |
| 729B | **EV** | 95.6 | 100.18 | 90.05 | 79.49 | 76.1 | 104 |
| 120 | **NON-EV** | 97.23 | 100.56 | 95.8 | 90.96 | 80.8 | 105.5 |
| A08 | **NON-EV** | 94.17 | 97.78 | 91 | 83.86 | 80 | 102.4 |
| 740 | **NON-EV** | 96.84 | 100.3 | 92.2 | 85.48 | 80.4 | 112.1 |
| 971 | **Non-EV** | 95.49 | 97.13 | 93.35 | 89.44 | 79.4 | 107.5 |
| 972A | **Non-EV** | 97.91 | 102.4 | 92.7 | 85.25 | 82 | 108.2 |

*Source: Author generated*

Figure 17 shows that there are various situations that may affect noise levels, including stopping, gate opening/closing, acceleration, deceleration, turning, honking, jerking, constant running, traffic signals, and horn use. However, the highlighted ones are the reading which shows the noise equivalent level is more in EV than non-EV on these occasion for each route.

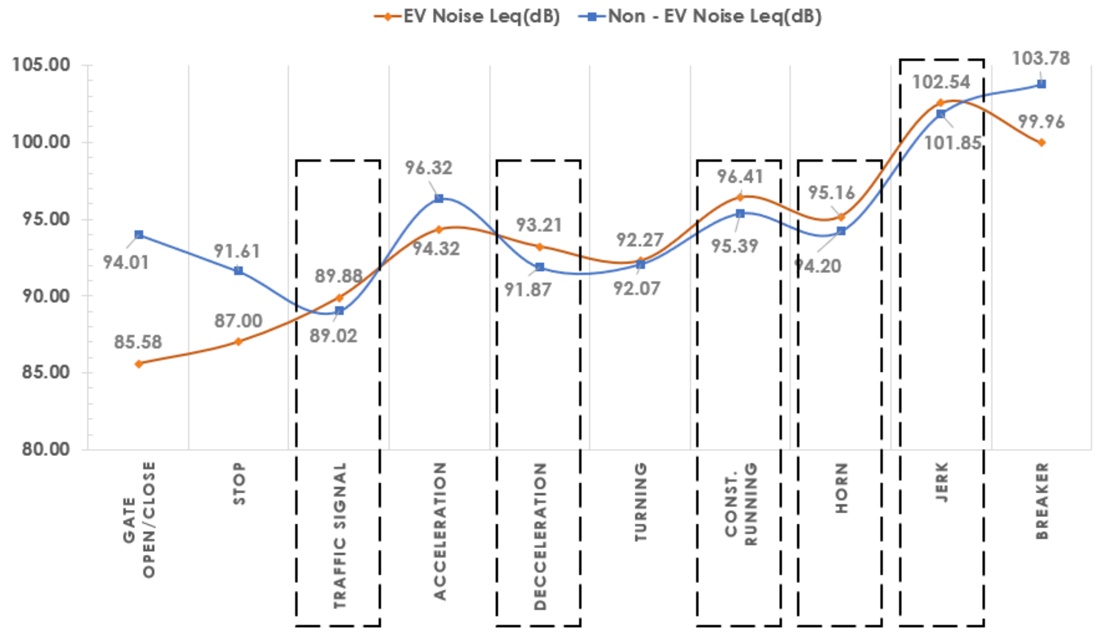


*Figure 26: Figure shows route wise noise equivalent*
*Source: Author generated*

## 4.4 Regression Analysis

Regression analysis was done for the noise and speed for evaluation of EV buses where significant correlation has been observed. It was observed that x and y variable have linear relation whereas “a” and “b” variables had binomial relationship based upon regression analysis. The details of the regression analysis of noise and speed in Different type of buses by the regression model, it tells about the type of relation and the coefficient of determination (R2) are also produced in the study.

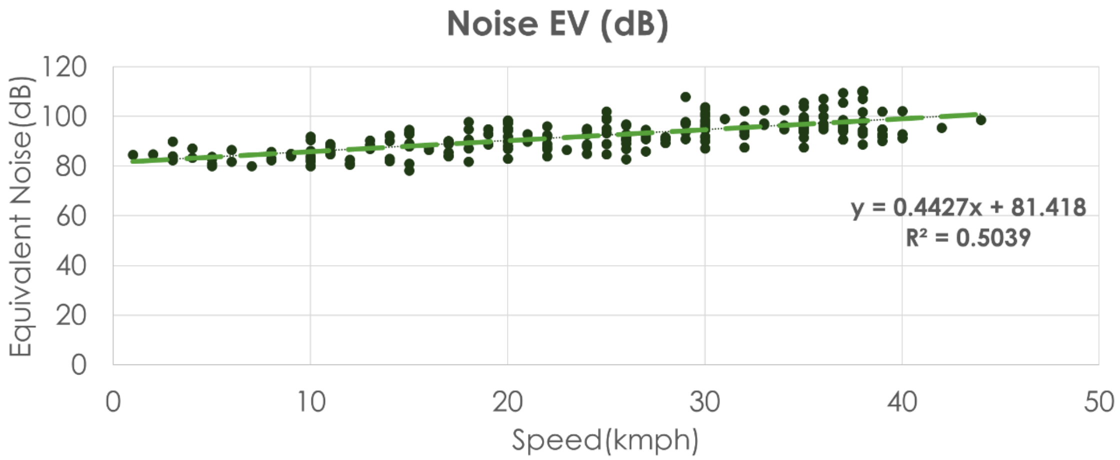


*Figure 27: Graph showing Noise vs Speed relationship*
*Source: Author generated*

Based on the Figure 18, the inferred relationship between the noise level, measured in decibels (dB), and speed is that noise level increases as speed increases. The straight line with a positive slope through the data points suggests a positive correlation. The equation for the line is also provided, which is y = 0.4427x + 81.418, where x is speed and y is Equivalent noise level.

The coefficient of determination ($R^2$) associated with this fit is 0.5039, which is a relatively positive or strong correlation. This means that while there is a positive trend, the data points themselves show a fair amount of scatter.

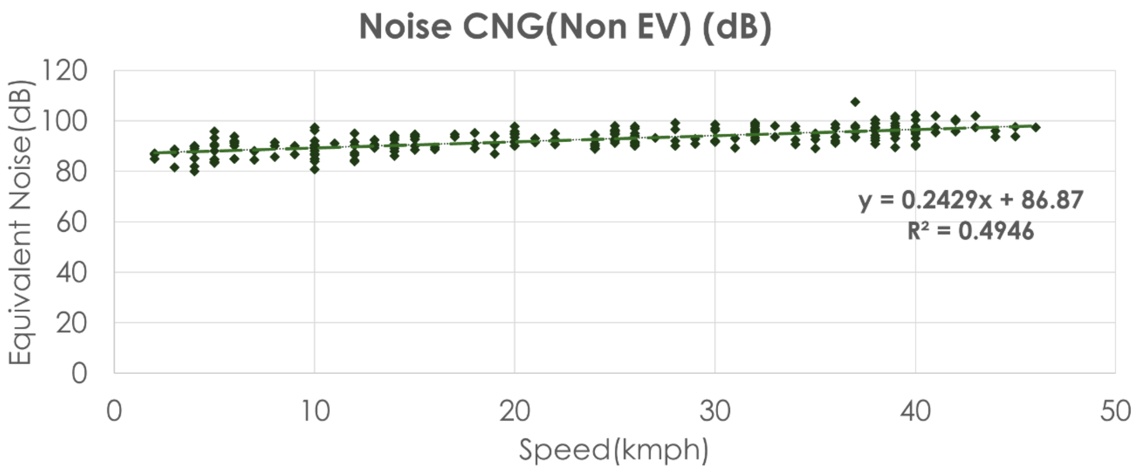


*Figure 28: Graph showing Noise vs Speed relationship*
*Source: Author generated*

Based on the Figure 19, the inferred relationship between the noise level, measured in decibels (dB), and speed is that noise level increases as speed increases. The straight line with a positive slope through the data points suggests a positive correlation. The equation for the line is also provided, which is $y = 0.2429x + 86.87$, where x is speed and y is noise level.

The coefficient of determination ($R^2$) associated with this fit is 0.4946, which is a relatively weak correlation. This means that while there is a positive trend, the data points themselves show a fair amount of scatter and the speed may not be the sole factor affecting the noise level.

Based on the correlation analysis conducted above, it is evident that there is no significant difference in the cabin noise between EV and non-EV buses. This finding indicates that both types of buses exhibit comparable noise levels, suggesting that the introduction of electric vehicles does not inherently lead to a reduction or increase in cabin noise within the bus environment.

Figure 20 shows the noise map generated for all the surveyed routes having the range from 75 decibels (dB) to 112 dB. Areas with the highest noise levels, 105-112 dB, are shown in blue. Areas with the lowest noise levels, 75-85 dB, are shown in yellow.

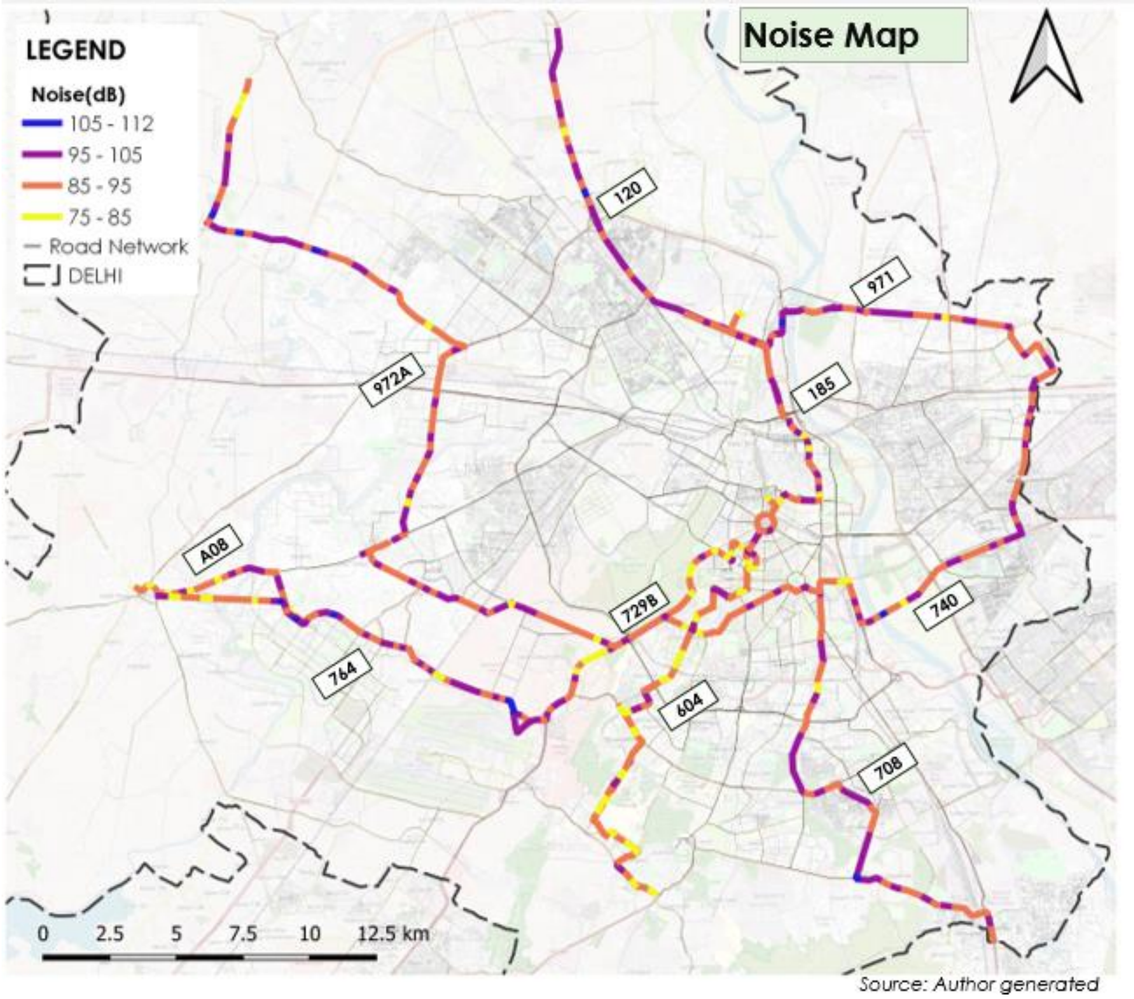


*Figure 29: Noise map of Surveyed Routes in Delhi*

## 4.5 **Weighting of Parameters and Sub parameters**

From the literature we have derive some parameters for the assessment of passenger comfort in public transport. Table 8 illustrates the relative importance weights assigned to each parameter, with values ranging up to a maximum of 5. Similarly, it outlines the normalized weights of each sub-parameter within their respective groups, ensuring a cumulative sum of 1. These weights mirror the data presented in Figures 11 and are utilized in the calculation of the comfort index for benchmarking service levels.

*Table 12: Relative Importance Weight of Parameters and sub parameters*

| Parameters | Mean Weight | Sub Parameters | Mean Weight |
|---|---|---|---|
| **Ride Quality** | **0.20** | Smoothness | **0.321** |
| | | Vibration | **0.344** |
| | | Noise | **0.335** |
| **Accessibility** | **0.19** | Ease of Getting On/Off | **0.36** |
| | | Clear pathways and aisles | **0.30** |
| | | Designated spaces (wheelchairs) | **0.34** |
| **Seating** | **0.21** | Seat Comfort | **0.36** |
| | | Priority seating enforcement (elderly, disabled) | **0.32** |
| | | Charging Points/Ports | **0.33** |
| **Environment** | **0.17** | Temperature | **0.33** |
| | | Air ventilation | **0.32** |
| | | Cleanliness | **0.34** |
| **Security** | **0.23** | Safety | **0.39** |
| | | Presence of staff or security personnel | **0.31** |
| | | Lighting | **0.30** |

*Source: Author generated*

## 4.6 **Analytical Hierarchical Process Analysis**

Taking the weighted mean of the parameters mentioned above for the Analytic Hierarchy Process (AHP) analysis, the first step is to rank them according to their higher weights. Following this, a comparison matrix is constructed considering parameters such as Ride Quality, Accessibility, Seating, Environment, and Security. Subsequently, the steps of AHP are followed systematically to assess the relative importance of these criteria. By applying pairwise comparisons and mathematical calculations, the criteria weights are determined, providing valuable insights into the hierarchy of factors influencing passenger comfort and satisfaction within the bus environment.

### 4.6.1 Criteria Weights for Passenger Comfort Index in Public Transport

The Analytic Hierarchy Process (AHP) was employed to determine the relative importance of various criteria that influence passenger comfort in public transport. The AHP analysis resulted in the following criteria weights, as shown in the Table 9

*Table 13: Normalized Pair wise Matrix*

| Normalized Pair wise Matrix | | | | | | |
|---|---|---|---|---|---|---|
| **Parameters** | **Ride Quality** | **Accessibility** | **Seating** | **Environment** | **Security** | **Criteria Weight** |
| **Ride Quality** | 0.15 | 0.19 | 0.12 | 0.2 | 0.14 | 0.16 |
| **Accessibility** | 0.07 | 0.1 | 0.08 | 0.13 | 0.11 | 0.1 |
| **Seating** | 0.29 | 0.29 | 0.25 | 0.27 | 0.22 | 0.26 |
| **Environment** | 0.05 | 0.05 | 0.06 | 0.07 | 0.09 | 0.06 |
| **Security** | 0.44 | 0.38 | 0.49 | 0.33 | 0.44 | 0.42 |

*Source: Author generated*

**Ride Quality (0.16):** This criterion encompasses factors like smoothness of the ride, acceleration, and vibration. The weight of 0.16 indicates that ride quality is perceived by passengers to be the most important factor influencing their comfort, accounting for 16% of the overall comfort index.

**Accessibility (0.10):** This criterion includes aspects like ease of boarding and disembarking, waiting times, and proximity to stops. The weight of 0.10 suggests that accessibility is considered moderately important for passenger comfort, contributing 10% to the overall comfort index.

**Seating (0.26):** This criterion incorporates features like seat availability, comfort, legroom, and layout. The weight of 0.26 signifies that seating is perceived as the second most important factor affecting comfort, attributing 26% to the overall comfort index.

**Environment (0.06):** This criterion covers factors like temperature, noise level, ventilation, and cleanliness. The weight of 0.06 indicates that the environment is considered the least important factor influencing comfort, contributing only 6% to the overall comfort index.

**Security (0.42):** This criterion encompasses feelings of safety and security while using public transport. The weight of 0.42 highlights that security is considered the third most important factor affecting comfort, attributing 42% to the overall comfort index.

*Table 14: Consistency Index Calculation*

| | |
|---|---|
| **Lamda max.** | 5.06 |
| **Consistency Index** | 0.0158 |
| **Consistency Ratio** | C.I / R. I |
| | 0.0141 |
| **R.I (Random Index)** | 1.12 (for n=5) |
| **C.I** | 0.0141<<0.1 |

*Source: Author generated*

The consistency of the pairwise comparisons within the AHP analysis was evaluated. As shown in Table 10, the Consistency Ratio (CR) of 0.0141 is well below the recommended threshold of 0.1. This value is obtained by dividing the Consistency Index (CI) of 0.0158 by the Random Index (RI) of 1.12 (for n=5 criteria). This low CR indicates a good level of consistency in the expert judgments used to determine the relative importance of passenger comfort criteria. This level of consistency strengthens the reliability of the derived criteria weights, which will be used to construct the passenger comfort index for public transport The final equation for passenger comfort assessment is

**R.Q X 0.16 + A X 0.1 + S X 0.26 + E X 0.06+ S.S X 0.42**

#### 4.6.2 K-Mean Clustering

By the use of K mean Clustering benchmarking has done with the help of 50 Samples through SPSS software. Figure 21 illustrates the clustering of parameters and provides the final index sum for the passenger comfort level of service. (Figure20)

**Final Cluster Centers**

| | Cluster 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Ride_Quality | .253 | .278 | .296 | .355 |
| Accessibility | .166 | .169 | .180 | .212 |
| Seating | .376 | .457 | .513 | .633 |
| Environment | .102 | .114 | .101 | .121 |
| Security | .644 | 1.185 | .847 | 1.148 |
| Index_Sum | 1.541 | 2.203 | 1.937 | 2.468 |

*Figure 31: K mean clustering output table*
*Source: Author generated*

### 4.7 **Developing a Passenger Comfort Benchmark**

The passenger comfort index created using AHP will offer a comprehensive tool to evaluate and compare the comfort levels provided by EVs and CNG buses. This index can be used by transport agencies and policymakers to assess the performance of public transport routes and identify areas for improvement.

By assessing the ratings of EV and Non-EV it was found out that EV has LOS 4, whereas Non-EV Level of service stands lower rating LOS 2.

*Table 15: Benchmarking with other parameters of passenger comfort*

| **Level of Service** | **Benchmarking** |
|---|---|
| **LOS 1** | <=1.54 |
| **LOS 2** | 1.55 - 1.94 |
| **LOS 3** | 1.95 – 2.20 |
| **LOS 4** | 2.21 – 2.45 |
| **LOS 5** | >2.45 |

*Source: Author generated*

# CHAPTER 5 RECOMMENDATIONS

## 5 Recommendation

### 5.1 Issues Identified

The analysis suggests a notable disparity in noise levels between the EV and CNG bus systems in Delhi. Despite controlled temperatures inside the buses, user preferences vary significantly between the two. The Service Level Benchmark (SLB) reveals a gap concerning passenger comfort parameters, where only passenger load is considered, neglecting other aspects assessed in the research. This highlights the need to address this gap in the SLB by incorporating additional comfort parameters identified in the study.

### 5.2 Interventions

#### 5.2.1 Policy Based Interventions

**Targeted Improvement Plans:** Develop targeted improvement plans for noise, seat comfort, Safety,

**Investment in Infrastructure:** Advocate for investments in infrastructure upgrades, such as improved bus shelters with seating, lighting, and protection from the elements, to enhance passenger comfort at boarding points.

**Fleet Renewal:** Recommend fleet renewal initiatives to replace older vehicles with newer models featuring advanced comfort features, quieter engines, better suspension systems, and improved climate control.

**Collaboration with Stakeholders:** Foster collaboration between transport authorities, operators, manufacturers, urban planners, and other stakeholders to develop holistic solutions for improving passenger comfort in public transport. Leverage partnerships to access expertise, resources, and funding opportunities.

**Pilot Programs and Innovation**: Implement pilot programs to test innovative solutions for enhancing passenger comfort, such as retrofitting existing vehicles with noise-reducing materials, installing ergonomic seating prototypes, or integrating smart technologies for real-time monitoring of comfort conditions.

**Public Awareness Campaigns:** Launch public awareness campaigns to raise awareness about the importance of passenger comfort in public transport and encourage behavioral changes among passengers, such as prioritizing courtesy and respecting fellow travelers' comfort.

**Incentive Mechanisms**: Introduce incentive mechanisms to reward operators and drivers who consistently maintain high standards of passenger comfort, such as performance-based contracts or recognition programs.

**Regulatory Reforms:** Advocate for regulatory reforms to establish minimum standards for passenger comfort in public transport and enforce compliance through regular inspections, audits, and penalties for non-compliance.

#### 5.2.2 Technology Based interventions

**Smart Noise-Canceling Technology:** Install smart noise-canceling technology within vehicle cabins to actively reduce ambient noise levels and create a quieter and more peaceful environment for passengers.

**Biophilic Design Elements:** Incorporate biophilic design elements such as living green walls, natural lighting, and indoor plants within vehicle cabins to create a connection with nature and improve air quality while enhancing passenger comfort.

### 5.3 Addition of Passenger Comfort Parameters in SLB

A comprehensive index can be made including both Passenger load and other parameters of Passenger comfort. The recommended Index and benchmark for Passenger comfort (excluding Passenger Load) is

R.Q. means Ride Quality, A means Accessibility, S means Seating, E means Environment and S.S means Safety security inside the buses.

*Table 17: Benchmarking with other parameters of passenger comfort*

**R.Q X 0.16 + A X 0.1 + S X 0.26 + E X 0.06+ S.S X 0.42**

| LEVEL OF SERVICE | BENCHMARKING |
|---|---|
| LOS 1 | < = 1.54 |
| LOS 2 | 1.55-1.94 |
| LOS 3 | 1.95-2.20 |
| LOS 4 | 2.21-2.45 |
| LOS 5 | > 2.45 |

*Source: Author generated*

| Indicators to calculate City-wide Level of Service (LoS) of Public Transport Facilities | | | | | | |
|---|---|---|---|---|---|---|
| **Level of Service** | **1. Presence of Organized Public Transport System in Urban Area (%)** | **2. Extent of Supply Availability of Public Transport** | **3. Service Coverage of Public Transport in the city** | **4. Average waiting time for Public Transport users** | **5. Level of Comfort in Public Transport** | **6. % of Fleet as per Urban Bus Specification** |
| 1 | > = 60 | > = 0.6 | >= 1 | < = 4 | < = 1.5 | 75 - 100 |
| 2 | 40 - 60 | 0.4 - 0.6 | 0.7- 1 | 4 - 6 | 1.5 - 2.0 | 50 - 75 |
| 3 | 20 - 40 | 0.2 - 0.4 | 0.3 - 0.7 | 6 - 10 | 2.0 - 2.5 | 25 - 50 |
| 4 | < 20 | < 0.2 | < 0.3 | > 10 | > 2.5 | < = 25 |

| Service level Benchmark (SLB) | Area to be covered | Primary Survey Required |
|---|---|---|
| Public Transport facilities | Key public transport corridors along the city | • Boarding Alighting at major bus stops of identified routes<br>• Passenger count inside the bus on identified routes |

SLBs for Urban Transport- MoUD, Government of India

| | | | |
|---|---|---|---|
| | **5. Level of Comfort in Public Transport** | | |
| a) | Identification of key nodes / traffic origin points | No. | With help of city maps, routes of all public transport corridors should be plotted. Identify the key routes of public transport in the city (R1, R2, .... Rn) which covers the whole city. |
| b) | Passenger count on bus at key identified routes | No. | Passenger count survey should be carried out on bus of each identified route during morning & evening peak hour in both directions. If there is more than one type of bus then count to be done for each bus type. |
| c) | Seats available in the bus | | Count the number of seats available in a bus of each type on each identified route. |
| d) | **Passenger comfort- Load factor (passengers per seat)** | 1/2/3/4 | **Calculate= [b / c]** for each route for each bus type and calculate the average load factor of all routes and compute LoS as mentioned in indicator 5 i.e. Level of Comfort in Public Transport |
| | **6. % of Fleet as per Urban Bus Specifications** | | |
| a) | Total number of buses in the city | No. | Calculate the total number of buses in the city |
| b) | Total number of buses as per urban bus specifications in the city | No. | Calculate the total number of buses as per urban bus specification (Urban bus specifications given on website :urbanindia.nic.in" |
| c) | **% of Fleet as per Urban Bus Specifications** | % | **Calculate [b / a * 100 ].** Compute LoS as mentioned in indicator 6 i.e. % of Fleet as per Urban Bus Specifications |

*Figure 33: Service level Benchmarking of Public transport India*
*Source: MoUD*

Figure 22 represents the Service Level Benchmark (SLB), illustrating six indicators for benchmarking the service level of public transport. Within these indicators, the fifth one pertains to passenger comfort. Currently, passenger comfort in public transport is solely evaluated based on the passenger load factor (passengers per seat). However, by integrating additional parameters identified in the research—such as ride quality, accessibility, seating, security, and environment—into the fifth indicator, the SLB would comprehensively address passenger comfort, fulfilling a crucial aspect of service evaluation.

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# ANNEXURE

## Questionnaire

योजना एवं वास्तुकला विद्यालय, भोपाल
School of Planning and Architecture, Bhopal
An Institute of National Importance, Ministry of Education, Government of India

Department of Transport Planning
(Transport Planning Logistic Manangement)

**Demographic Questions**

**Bus Number ____________** **Bus Type ______** **Time ________**

**A. Gender ______ Age_______ Origin______________ Destination________________**

**B. Educational Qualification**
1) 10TH
2) 12TH
3) Bachelor
4) Master
5) Doctorate and others

**C. Purpose of the trip**
1) School
2) College
3) Business
4) Work
5) Others

**D. Income**
1) Below 20K
2) 20k – 40 k
3) 40k – 60 k
4) Above 60k

**E. How frequently do you use DTC buses**
1) First time
2) Twice a day
3) Everyday
4) Once in a week
5) Once in a month
6) Occasionally

**Please answer the following questions considering your experiences traveling on buses within Delhi.**

1. **How would you rate the overall temperature inside Delhi buses?**
   - **1 - Far too cold (uncomfortably chilly)**
   - **2 - Slightly too cold**
   - **3 - Just right**
   - **4 - Slightly too warm**
   - **5 - Far too warm (uncomfortably hot)**
2. **How often do you find yourself standing for most of your journey due to a lack of available seats on Delhi buses?**
   - **1 - Always**
   - **2 - Very often**
   - **3 - Sometimes**
   - **4 - Rarely**
   - **5 - Never**
3. **Delhi bus rides can sometimes be bumpy. Rate the typical smoothness of your bus journeys.**
   - **1 - Extremely rough (constant jolts and vibrations)**
   - **2 - Very bumpy**
   - **3 - Average (some bumps and jolts)**
   - **4 - Mostly smooth**
   - **5 - Exceptionally smooth**
4. **How would you describe the general noise level inside Delhi buses?**
   - **1 - Unbearably loud**
   - **2 - Distractingly loud**
   - **3 - Moderate**
   - **4 - Relatively quiet**
   - **5 - Very quiet**
5. **How would you rate the condition of seats on Delhi buses in terms of cleanliness and overall upkeep?**

- **1 - Very poor (stains, noticeable damage)**

Note: This survey is a part of our academic programme only. The survey form consists of a few questions and the answers provided by you will solely be used for academic/study purpose.
नोट: यह सर्वेक्षण केवल हमारे शैक्षणिक कार्यक्रम का एक हिस्सा है। सर्वेक्षण फॉर्म में कुछ प्रश्न होते हैं और आपके द्वारा दिए गए उत्तरों का उपयोग केवल अकादमिक/अध्ययन के उद्देश्य के लिए किया जाएगा।

योजना एवं वास्तुकला विद्यालय, भोपाल
School of Planning and Architecture, Bhopal
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Department of Transport Planning
(Transport Planning Logistic Manangement)

- **2 - Somewhat worn and dirty**
- **3 - Average (signs of use, but generally clean)**
- **4 - Well-maintained and mostly clean**
- **5 - Excellent condition**

6. **Do you find the legroom on Delhi buses to be sufficient for your comfort?**
    - **1 - Extremely cramped**
    - **2 - Very limited legroom**
    - **3 - Slightly cramped**
    - **4 - Adequate for short journeys**
    - **5 - Sufficient even for longer journeys**
7. **In your experience, how would you describe the air quality within Delhi buses?**
    - **1 - Stuffy and stagnant**
    - **2 - Slightly stuffy**
    - **3 - Average**
    - **4 - Good air circulation**
    - **5 - Excellent ventilation**
8. **How safe do you feel in terms of personal security (pickpocketing, harassment, etc.) when traveling on Delhi buses?**
    - **1 - Very unsafe**
    - **2 - Somewhat unsafe**
    - **3 - Neither safe nor unsafe**
    - **4 - Somewhat safe**
    - **5 - Very safe**

**Rank the importance of the parameters**

| **Passenger Comfort Factor** | **Preference Ranking (1-5)** |
|---|---|
| Smoothness of ride | |
| Noise levels | |
| Vibration levels | |
| Availability of seats | |
| Seat comfort | |
| Temperature | |
| Air circulation/ventilation | |
| Overall cleanliness | |
| Ease of getting on/off | |
| Feeling of safety and security | |
| Clear pathways and aisles | |
| Designated spaces (wheelchairs) | |
| Priority seating enforcement (elderly, disabled) | |
| Charging Points/Ports | |
| Safety | |
| Presence of staff or security personnel | |
| Lighting | |

Note: This survey is a part of our academic programme only. The survey form consists of a few questions and the answers provided by you will solely be used for academic/study purpose.
नोट: यह सर्वेक्षण केवल हमारे शैक्षणिक कार्यक्रम का एक हिस्सा है। सर्वेक्षण फॉर्म में कुछ प्रश्न होते हैं और आपके द्वारा दिए गए उत्तरों का उपयोग केवल अकादमिक/अध्ययन के उद्देश्य के लिए किया जाएगा।

| starting time | | | | deboarding station | | | | A- Acc.<br>D- Deacc.<br>J- Jerking<br>C- Constant Speed | | S- Stop<br>B- Sudden Break<br>G1- Gate Open<br>G2- Gate Close | | **Outside Temp.** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| bus number | | | | bus type | | | | | | | | Boarding | Deboarding |
| boarding station | | | | end time | | | | | | | | | |
| Min elapsed | Spd (kmph) | Noise (db) | Temp.© | H % | No. of passengers | Occasion | Min elapsed | Spd (kmph) | Noise (db) | Temp.© | H % | No. of passengers | Occasion |
| 1 | | | | | | | 28 | | | | | | |
| 2 | | | | | | | 29 | | | | | | |
| 3 | | | | | | | 30 | | | | | | |
| 4 | | | | | | | 31 | | | | | | |
| 5 | | | | | | | 32 | | | | | | |
| 6 | | | | | | | 33 | | | | | | |
| 7 | | | | | | | 34 | | | | | | |
| 8 | | | | | | | 35 | | | | | | |
| 9 | | | | | | | 36 | | | | | | |
| 10 | | | | | | | 37 | | | | | | |
| 11 | | | | | | | 38 | | | | | | |
| 12 | | | | | | | 39 | | | | | | |
| 13 | | | | | | | 40 | | | | | | |
| 14 | | | | | | | 41 | | | | | | |
| 15 | | | | | | | 42 | | | | | | |
| 16 | | | | | | | 43 | | | | | | |
| 17 | | | | | | | 44 | | | | | | |
| 18 | | | | | | | 45 | | | | | | |
| 19 | | | | | | | 46 | | | | | | |
| 20 | | | | | | | 47 | | | | | | |
| 21 | | | | | | | 48 | | | | | | |
| 22 | | | | | | | 49 | | | | | | |
| 23 | | | | | | | 50 | | | | | | |
| 24 | | | | | | | 51 | | | | | | |
| 25 | | | | | | | 52 | | | | | | |
| 26 | | | | | | | 53 | | | | | | |
| 27 | | | | | | | 54 | | | | | | |

## Service Level Benchmarks for urban transport at a Glance by MoUD



# Section 1:

# SERVICE LEVEL BENCHMARKS

## *1.1 PUBLIC TRANSPORT FACILITIES*

It indicates the city-wide level of services provided by public transport systems during peak hours (8 to 12 noon & 4 to 8 pm). Public Transport systems will only include rail, or organized bus based systems. Public Transport systems are characterized by - Fixed origins and destinations; Fixed routes and schedules; Fixed stoppage points; and Fixed fares. Public Transport therefore does not include Intermediate Public Transport (IPTs) such as shared RTVs, auto-rickshaws, three-wheelers, tempos, shared taxi or other such vehicles providing point-to-point services.

1. **Presence of Organized Public Transport System in Urban Area:** Within the first year, all JnNURM cities to establish Organized Public Transport System and by second year all 2 lakh plus population cities (as per 2001 census) to establish the same.
2. **Extent of Supply / Availability of Public Transport:** Within the first two years, all million plus cities but less than 4 million to increase public transit supply to service level 3 or above. All 4 million plus cities to increase supply to service level 2 or above.
3. **Service Coverage of Public Transport in the city (Bus route network density):** All million plus cities but less than 4 million to increase their public transit coverage at least supply to service level 3 or above. All 4 million plus cities to increase the service coverage to service level 2 or above.
4. **Average waiting time for Public Transport users:** All million plus cities to maintain average waiting time for public transport users to be a maximum of 12 minutes or below within 2 years.
5. **Level of Comfort in Public Transport (Crowding):** In all million plus cities, with in 2 years, the level of service should be 3 or above
6. **Percentage Fleet as per Urban Bus Specifications:** All million plus cities to have atleast 25% of their fleet as per urban bus specifications by the end of first year.

**Regulatory Mechanism for Periodic Revision of Fares:** There would be periodic revision of fares based on changes in the prices of indices. Such periodic revision is proposed to be carried out, every year. The formula to be used for such revision would be as follows:

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**FN = 0.4 [FPN – FPO] + 0.3 [CPIN – CPIO] + 0.3 [AMCN – AMCO] + FO**

Where,
FN - New Fare
FO – Old Fare
FPN – New Fuel Price
FPO – Old Fuel Price
CPIN – New Consumer Price Index
CPIO – Old Consumer Price Index
AMCN – AMC Rate/km
AMCO - Old AMC Rate/km

| Indicators to calculate City-wide Level of Service (LoS) of Public Transport Facilities | | | | | | |
|---|---|---|---|---|---|---|
| **Level of Service** | **1. Presence of Organized Public Transport System in Urban Area (%)** | **2. Extent of Supply Availability of Public Transport** | **3. Service Coverage of Public Transport in the city** | **4. Average waiting time for Public Transport users** | **5. Level of Comfort in Public Transport** | **6. % of Fleet as per Urban Bus Specification** |
| 1 | > = 60 | > = 0.6 | >= 1 | < = 4 | < = 1.5 | 75 - 100 |
| 2 | 40 - 60 | 0.4 - 0.6 | 0.7- 1 | 4 - 6 | 1.5 - 2.0 | 50 - 75 |
| 3 | 20 - 40 | 0.2 - 0.4 | 0.3 - 0.7 | 6 - 10 | 2.0 - 2.5 | 25 - 50 |
| 4 | < 20 | < 0.2 | < 0.3 | > 10 | > 2.5 | < = 25 |

| Data Requirement to Calculate the Level of Service of Public Transport Facilities | | | |
|---|---|---|---|
| **S.no** | **Data required for calculating the indicator** | **Unit** | **Remarks** |
| **1. Presence of Organized Public Transport System in Urban Area** | | | |
| a) | Calculate the total number of buses in the city | No. | Total number of buses operating on road |
| b) | Calculate the total number of buses under the ownership of STU/SPV or under concession agreement. | No. | Organized Public Transport may be identified as that which is run by a company or SPV formulated specifically for the operation of public transport within the city or under concession agreement. The intercity bus services would not be included as part of urban public transport operations |
| c) | **Presence of Public Transport System in Urban Area (%)** | **%** | **Calculate= [b / a]*100**. Compute LoS as mentioned in indicator 1 i.e. Presence of Public Transport System in Urban Area (%) |
| **2. Availability of Public Transport** | | | |
| a) | No of Buses/ train coaches available in a city on any day | No. | Number of public transport vehicles operating in the city, which may be lower than the number of vehicles owned by the utility or that authorized to ply. Daily average values over a time period of a month may be considered. (1 train coach is equivalent to 3 buses). |
| b) | Total Population of the city | No. | Current population should be considered. Past census figures should be used as base, and annual growth rate should then be used to arrive at current population. |
| c) | **Availability of Public transport /1000 population.** | **Ratio** | **Calculate= [a / b].** Compute LoS as mentioned in indicator 2 i.e. Availability of Public Transport |

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| | | | |
|---|---|---|---|
| **3. Service Coverage of Public Transport in the city** | | | |
| a) | Total length in road kms of the corridors on which public transport systems ply in the city. | Road kms | Total length of the public transport corridor within the urban limits should be considered. Corridors along which the service frequency is one hour or less should only be considered. Public transport systems may be road or rail or water based, and include public or private transport service providers. |
| b) | Area of the urban limits of the city. | Area in sq. kms | Area of the urban limits should be considered. This may corresponds the urban limits demarcated by the development authority / metropolitan area, or any other such urban planning agency which need to be covered by public transport. This need not be restricted to municipal boundaries. |
| c) | **Service Coverage** | **road kms / sq. km** | **Calculate = [a / b].** Compute LoS as mentioned in indicator 3 i.e. Service coverage of public transport system in a city. |
| **4. Average waiting time for Public Transport users** | | | |
| a) | Identify bus stops for survey within the city | No. | With help of city map, plot all public transport routes and bus stops (both direction) using GIS and GPS. |
| b) | Average headway of buses/route | No. | Make the complete list of bus stops in a serial number (1,2,3….N) |
| | | | • Out of the total number of bus stops (N), a sample of (n) bus stops need to be collected for the purpose of survey, as follows:<br>○ > 4 million – 10%<br>○ 1 – 4 million – 25%<br>○ <1 million – 50%<br>• To select the actual stops to be surveyed, stratified random sampling is recommended as follows:<br>○ Select 1st bus stop between 1 to 5 randomly from the list identified above<br>○ To select the next bus stop, skip N/nth bus stops from the list<br>• Repeat the exercise for all the bus stops |
| | | Min | • Collect the data of route wise headway (in min) for buses at each of the identified bus stop during morning and evening peak hour.<br>• From the data collected, calculate the average headway for that particular route. Repeat the exercise for all selected routes<br>• Calculate the average waiting time of passenger for each route as half of the average headway for that particular route. |
| | | | Make frequency distribution table for each of the LoS class interval (indicator 4). Find out the median of the frequency distribution which defines the average waiting time. Find out LoS corresponding to that median value for the table (indicator 4). |
| c) | **Average waiting time for Public Transport users** | 1 / 2 / 3 / 4 | Compute LoS as mentioned in indicator 4 i.e. Average waiting time for Public Transport users |

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| **5. Level of Comfort in Public Transport** | | | |
|---|---|---|---|
| a) | Identification of key nodes / traffic origin points | No. | With help of city maps, routes of all public transport corridors should be plotted. Identify the key routes of public transport in the city (R1, R2, …. Rn) which covers the whole city. |
| b) | Passenger count on bus at key identified routes | No. | Passenger count survey should be carried out on bus of each identified route during morning & evening peak hour in both directions. If there is more than one type of bus then count to be done for each bus type. |
| c) | Seats available in the bus | | Count the number of seats available in a bus of each type on each identified route. |
| d) | **Passenger comfort- Load factor (passengers per seat)** | 1/2/3/4 | **Calculate= [b / c]** for each route for each bus type and calculate the average load factor of all routes and compute LoS as mentioned in indicator 5 i.e. Level of Comfort in Public Transport |
| **6. % of Fleet as per Urban Bus Specifications** | | | |
| a) | Total number of buses in the city | No. | Calculate the total number of buses in the city |
| b) | Total number of buses as per urban bus specifications in the city | No. | Calculate the total number of buses as per urban bus specification (Urban bus specifications given on website :urbanindia.nic.in" |
| c) | **% of Fleet as per Urban Bus Specifications** | % | **Calculate [b / a * 100 ].** Compute LoS as mentioned in indicator 6 i.e. % of Fleet as per Urban Bus Specifications |

| **Overall Level of Service of Public Transport facilities City wide** | | |
|---|---|---|
| **The calculated level of Service (LoS) of Public Transport facilities = ($LoS_1 + LoS_2 + LoS_3 + LoS_4 + LoS_5 + LoS_6$) and identify overall LoS as mentioned below** | | |
| **Overall LoS** | **Calculated LoS** | **Comments** |
| 1 | < 12 | The City has a good public transport system which is wide spread and easily available to the citizens. The system provided is comfortable. |
| 2 | 12 - 16 | The City has public transport system which may need considerable improvements in terms of supply of buses/ coaches and coverage as many parts of the city are not served by it. The frequency of the services available may need improvements. The system provided is comfortable. |
| 3 | 17 - 20 | The City has a public transport system which may need considerable improvements in terms of supply of buses / coaches and coverage as most parts of the city are not served by it. The frequency of the services available needs improvements. The system provided is not comfortable as there is considerable over loading. |
| 4 | 21 - 24 | The city has poor or nil organized public transport system |

| **Reliability of measurement** | |
|---|---|
| **Reliability Scale** | **Description of method** |
| Lowest level of reliability (D) | Based on some information collated from secondary sources. |
| Intermediate level(C ) | Only information collected from city authorities / different agencies without any checks. |
| Intermediate level (B) | Only surveys are undertaken |
| Highest/preferred level of reliability (A) | All the data for above mentioned performance parameters is collected/measured as mentioned above. Field observers should be properly trained, data formats provided, and observations be properly tabulated. Actual surveys are undertaken which are either carried out by or verified by the independent agencies. |

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## Thesis Sheets

# BACKGROUND

## Passenger Comfort

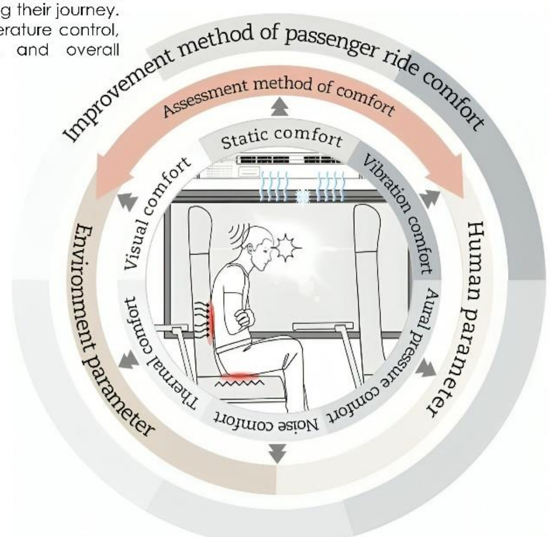
Passenger comfort in public transport refers to the degree **of satisfaction, convenience**, and **well-being experienced** by passengers during their journey. It encompasses various factors such as seating comfort, temperature control, air quality, noise levels, cleanliness, safety, accessibility, and overall convenience.

**Passenger Load**

**Ride Comfort**
Acceleration, jerk, vibration, Noise Levels

**Thermal Comfort**
Temperature, Humidity, Air quality

**Visual Comfort**
Lighting




## Service level Benchmarking

A comprehensive framework to measure and monitor urban transport performance in India - established in 2011 by the Ministry of Urban Development, GOI.

INDICATORS

1. Presence of Organized Public Transport System in Urban Area (%)
2. Extent of Supply Availability of Public Transport
3. Service Coverage of Public Transport in the city
4. Average waiting time for Public Transport users
5. Level of Comfort in Public Transport
6. % of Fleet as per Urban Bus Specification

### Future Mobility Trends

**Draft EV policy of Delhi (2018)** targets that 25% of all new vehicles registrations be EVs by 2023.

**UBBL (2019)** mandates provision of charging bays in buildings at 20% of their parking capacity.

MPD-2041 will have to acknowledge emerging paradigms of Electric Vehicles and App-based Mobility which are a positive trend in facilitating the shift from private mobility to shared mobility

## Why Passenger Comfort?

| | |
|---|---|
| Customer Satisfaction | Accessibility |
| Increased Ridership | Environmental Benefits |
| Health and Well-being | Economic Impact |
| Productivity | Competitive Advantage |
| Safety | Quality of Life |

### Noise

Noise is an unwanted sound that can affect animal and human behaviour. Not all noise is pollution. The WHO classifies noise above 65 dB as pollution. Noise is detrimental at 75 dB and agonizing at 120 dB. In 2018, the WHO limited traffic noise to 53 dB for health reasons

| Duration | WHO/EPA (dB) | OSHA (dB) | NOISH199 (dB) |
|---|---|---|---|
| 8h | 75 | 90 | 85 |
| 4h | 78 | 95 | 88 |
| 2h | 81 | 100 | 91 |
| 1h | 84 | 105 | 94 |
| 30 min | 87 | 110 | 97 |
| 15 min | 90 | 115 | 100 |
| 7 min 30 s | 93 | | 103 |
| 3 min 45 s | 96 | | 106 |
| 1 min 53 s | 99 | | 109 |
| 56s | 102 | | 112 |
| 28s | 105 | | 115 |
| 14s | 108 | | 118 |
| 7s | 111 | | 121 |
| 4s | 114 | | 124 |

US National Institute for Occupational Safety and Health (NIOSH)
US Occupational Safety and health Administration (OSHA)

*Source: Yao et al. Journal of Otolaryngology - Head and Neck Surgery (2017) 46:62*

| 1 | SUHAIL MASOOD 2022MTPLM013 | M.PLAN THESIS 2023-24 | PASSENGER COMFORT ASSESSMENT: COMPARING ELECTRIC AND CNG BUSES IN DELHI | Seal & Sign | DEPARTMENT OF TRANSPORT PLANNING | योजना एवं वास्तुकला विद्यालय, भोपाल School of Planning and Architecture, Bhopal |
|---|---|---|---|---|---|---|

# INTRODUCTION

## RESEARCH NEED:

The research need is to revise the indicators of service level benchmarking in order to improve the passenger comfort in public transport.

## AIM:

To enhance the passenger comfort in EVs and CNG buses.

## OBJECTIVES:

01 To identify the parameters influencing passenger comfort in public transport.

02 To assess passenger comfort in public transport, comparing experiences between electric vehicle (EV) and CNG bus users.

03 To evaluate parameters of passenger comfort in public transport, examining differences between EV and CNG users.

04 To develop recommendations for integrating passenger comfort in urban transportation planning and policy-making.

## SCOPE AND LIMITATIONS:

This research focuses on particular parameters of passenger comfort in public transport such as noise levels, passenger count, temperature, humidity, and speed.
The Study is limited to the selected 10 routes.
Passenger comfort indicator have passenger load as a parameter, therefore, it is not considered in the study.
The research is limited to the in cabin environment of the buses.

## RESEARCH OUTCOME

The outcome of the research is service level benchmarking for passenger comfort in public transport.

**Total no. of samples collected- 110**

**Sample Characteristics**

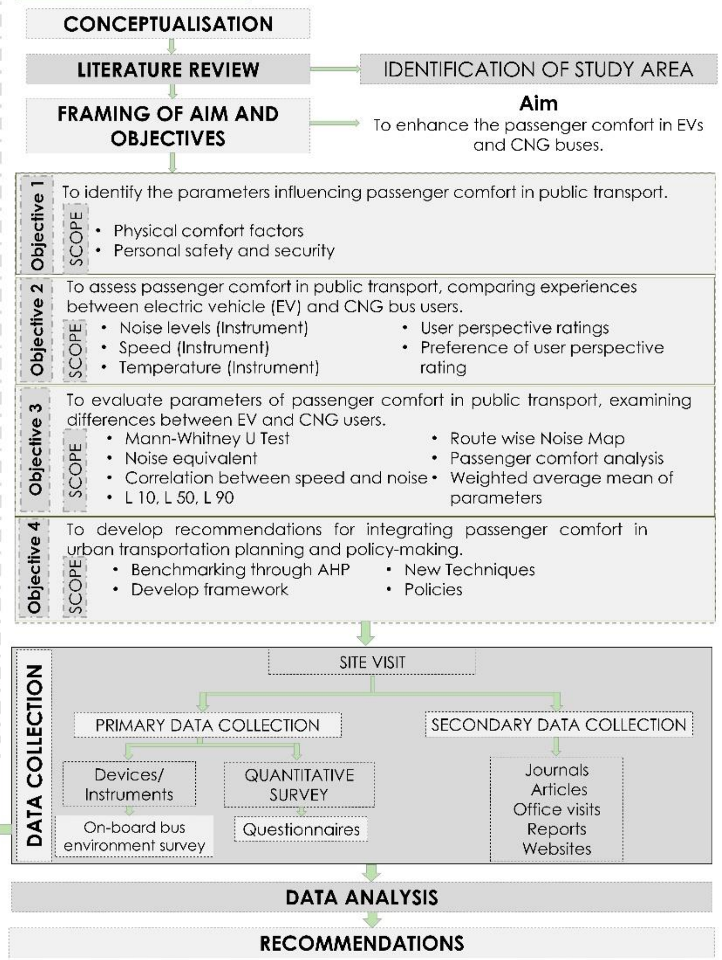
- **EV Bus Users** (53)
- **CNG Bus Users** (57)

**Sampling Methods**

**Non-Probability Sampling** → Convenience Sampling

Sampling Strategy

## METHODOLOGY:




| 2 | SUHAIL MASOOD 2022MTPLM013 | M.PLAN THESIS 2023-24 | PASSENGER COMFORT ASSESSMENT: COMPARING ELECTRIC AND CNG BUSES IN DELHI | Seal & Sign | DEPARTMENT OF TRANSPORT PLANNING | योजना एवं वास्तुकला विद्यालय, भोपाल School of Planning and Architecture, Bhopal |
|---|---|---|---|---|---|---|

## LITERATURE

| Title | Location | Year | Authors | Parameters | Key Findings |
|---|---|---|---|---|---|
| Exposure to noise inside transit buses in Kuwait: measurements and passenger attitudes | Kuwait, UAE | 2001 | Parviz a. Koushki et al. | Noise levels, routes, bus count, journey time, speed, health impact, demographics | - Quantifies Kuwait transit bus noise Levels. - Presents Passenger attitudes on noise exposure and impact. |
| LEVEL-OF-SERVICE CONCEPT APPLIED TO PUBLIC TRANSPORTATION | Texas, USA | 1981 | Diane Bullard et al. | Accessibility, travel time, directness, delay, frequency, reliability, passenger density, comfort (including noise) | - Identifies 8 level-of-service indicators with definitions and values.<br>- Develops weighting technique to reflect indicator importance. |
| LEVEL-OF-SERVICE CONCEPT FOR EVALUATING PUBLIC TRANSPORT | | 1950 | Hermann Botzow | Comfort factors (density, acceleration, jerk, temperature, airflow, noise) | - Proposes system to evaluate service variables across transport modes.<br>- Aims to improve existing systems and design based on desired service levels. |
| Measuring Comfort in Public Transport: A case study for İstanbul | Istanbul, Turkey | 2016 | Şükrü İmrea, Dilay Çelebi | Comfort , Noise, Crowd,Area | The comfort level of public transport systems can vary significantly based on factors like crowd density during peak hours, potentially leading to higher private car usage due to convenience and comfort. |
| Noise levels inside passenger cars | Mosul, Iraq | 1978 | S. M. J. ALX, S. P. SARNA | Noise levels, Comfort, speeds, Salford Criterion ('quiet', 'noticeable', etc.) | - Discusses car noise problems, focusing on levels in 5 models in Mosul. - Covers sources, transmission, frequency, control, and acceptable levels. |
| Noise annoyance is related to the presence of urban public transport | | 2009 | Jakovljevic B et al. | Survey (5861 adults), noise measurements, analysis | - Daytime public transport increased noise annoyance. - Noise-sensitive people chose quieter areas. - Noise annoyance linked to lower quality of life. |
| An Investigation on Occupational Noise Exposure in Kerman Metropolitan Bus Drivers | Kerman, Iran | 2012 | Farshad Nadri et al. | Noise exposure in 4 bus models (out of 80 sampled) | - Noise levels below 85 dBA, considered safe for drivers and passengers. |
| A review of passenger ride comfort in railway: assessment and improvement method | | 2022 | Yong Peng, Jiahao Zhou, Chaojie Fan, Zhifa Wu, Wenjun Zhou, Dayan Sun, Yating Lin, | sources of discomfort, including static comfort, vibration comfort, noise comfort, aural pressure comfort, thermal comfort and visual comfort | Researchers suggest employing various methods for vibration comfort evaluation to account for the complexity of vibration signals. |
| The Effect of Noise on the Comfort of Passengers Inside the Tramway and Its Impact on Traffic Congestion in the Urban Area | Algeria | 2018 | Mouloud Khelf, Salim Boukebbab | Noise levels, passenger annoyance, mode choice, comfort, congestion | - Main noise sources: rail, rolling stock, traction system. - Tram noise increases with speed. - Passenger numbers and behavior also affect noise. |
| Noise Exposure for Bus Drivers in an Iowa City Transit System | Iowa, USA | 2008 | P. Zannin | Noise exposure levels, radio use, window status, route types | - Iowa City bus drivers didn't exceed 85 dBA due to short shifts. - Noise exposure varied between routes, some exceeding guidelines. - Highlights need to manage noise exposure for driver health. |
| Vulnerability of bus and truck drivers affected from vehicle engine noise | West Bengal, India | 2014 | Naba Kumar Mondal et al. | Noise, age, BMI, driving experience, vehicle age, humidity, blood pressure, pulse rate | - Engine noise linked to blood pressure changes, BMI affected, back pain reported. - Humidity affects digestion, noise impacts pulse rate. - Results align with prior research on noise pollution's health effects. |

### Parameters Considered are:

- **Ride Quality**
- **Accessibility**
- **Environment**
- **Safety**

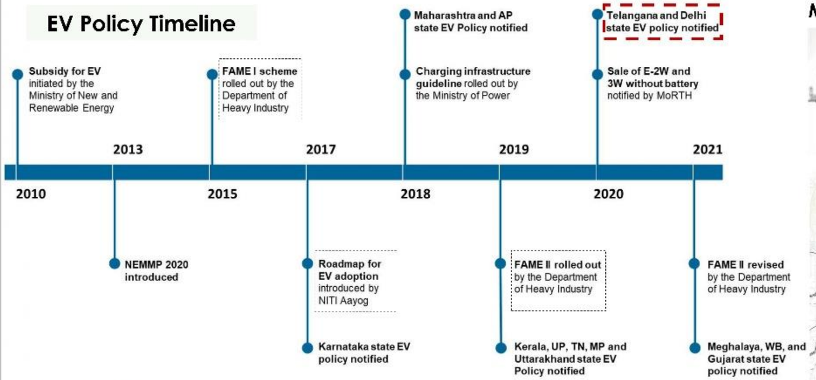
- Smoothness
- Vibration
- Noise
- Ease of Getting On/Off
- Clear pathways and aisles
- Designated spaces (wheelchairs)
- Seat Comfort
- Priority seating enforcement (elderly, disabled)

- Charging Points/Ports
- Temperature
- Air ventilation
- Cleanliness
- Safety
- Presence of staff or security personnel
- Lighting

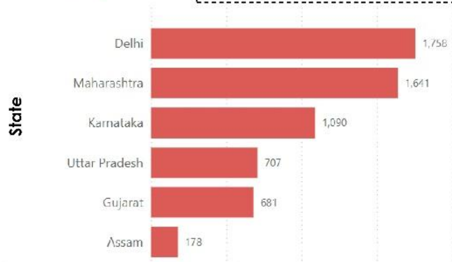
| 3 | SUHAIL MASOOD 2022MTPLM013 | M.PLAN THESIS 2023-24 | PASSENGER COMFORT ASSESSMENT: COMPARING ELECTRIC AND CNG BUSES IN DELHI | Seal & Sign | DEPARTMENT OF TRANSPORT PLANNING | योजना एवं वास्तुकला विद्यालय, भोपाल School of Planning and Architecture, Bhopal |
|---|---|---|---|---|---|---|

# STUDY SELECTION

## EV Policy Timeline




Delhi state EV Policy Notified in 2020 by *Govt. of NCT of Delhi*




Delhi has Maximum Ev bus fleet size comparing with other states of India (FY 2020-24)

## Study Area Profile

**Area of Study –** New Delhi
**Population –** 33,807,403
**Delhi Boundary area -** 1483 Km2 of which 369.35 sq.Km (rural) and 1113.65 sq.km

- The average noise level in **Delhi is 81.6 dB** ( 4th in Indian Cities)

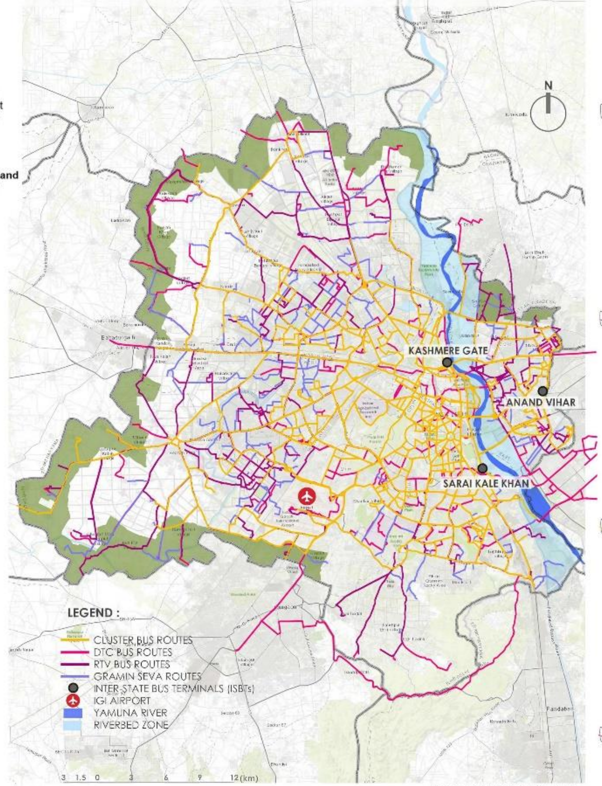
Delhi has a fleet size **of 7,135 buses**

- **2,888 buses** under the Delhi Transport Corporation (DTC)
- **1200 EV** (1st in EV Fleet Size)
- **3,047** under DIMTS

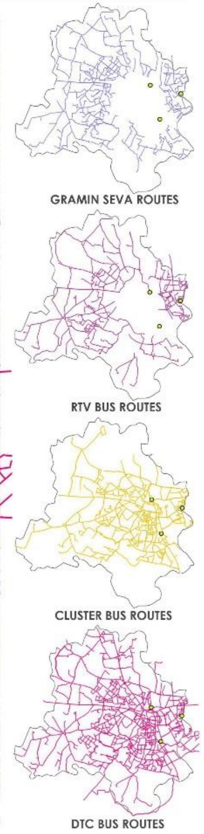
The buses cover a cumulative **distance 6,50,000 km per day**, with an average daily ridership of **29,86,000 passengers**
The bus is a preferred mode choice for distances between **8-14 km.**

## Mode share for motorized trips 2018


Map 7 Map of Bus Routes (DTC + Cluster), RTV Routes, and Gramin Seva routes within NCT




Source: DIMTS; Analysis: NIUA

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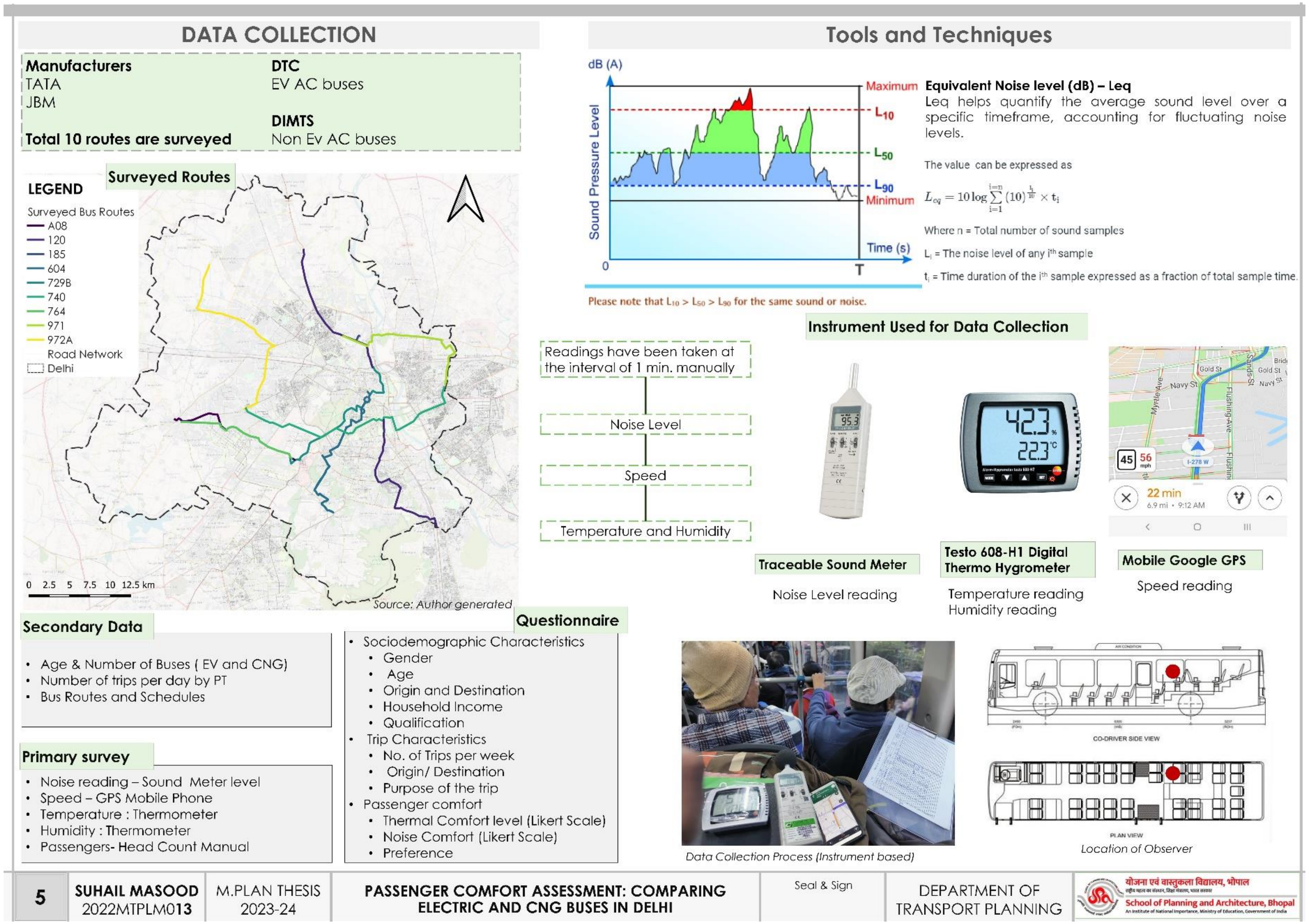
|---|---|---|---|---|---|---|


DATA COLLECTION
Manufacturers
TATA
JBM
Total 10 routes are surveyed
DTC
EV AC buses
DIMTS
Non Ev AC buses
Surveyed Routes
LEGEND
Surveyed Bus Routes
A08
120
185
604
729B
740
764
971
972A
Road Network
Delhi
0 2.5 5 7.5 10 12.5 km
Source: Author generated
Secondary Data
Age & Number of Buses ( EV and CNG)
Number of trips per day by PT
Bus Routes and Schedules
Primary survey
Noise reading – Sound Meter level
Speed – GPS Mobile Phone
Temperature : Thermometer
Humidity : Thermometer
Passengers- Head Count Manual
Questionnaire
Sociodemographic Characteristics
Gender
Age
Origin and Destination
Household Income
Qualification
Trip Characteristics
No. of Trips per week
Origin/ Destination
Purpose of the trip
Passenger comfort
Thermal Comfort level (Likert Scale)
Noise Comfort (Likert Scale)
Preference
Tools and Techniques
dB (A)
Sound Pressure Level
Maximum
L10
L50
L90
Minimum
Time (s)
0
T
Please note that L10 > L50 > L90 for the same sound or noise.
Equivalent Noise level (dB) – Leq
Leq helps quantify the average sound level over a specific timeframe, accounting for fluctuating noise levels.
The value can be expressed as
$L_{eq} = 10 \log \sum_{i=1}^{i=n} (10)^{\frac{L_i}{10}} \times t_i$
Where n = Total number of sound samples
$L_i$ = The noise level of any $i^{th}$ sample
$t_i$ = Time duration of the $i^{th}$ sample expressed as a fraction of total sample time.
Instrument Used for Data Collection
Readings have been taken at the interval of 1 min. manually
Noise Level
Speed
Temperature and Humidity
Traceable Sound Meter
Noise Level reading
Testo 608-H1 Digital Thermo Hygrometer
Temperature reading
Humidity reading
Mobile Google GPS
Speed reading
Data Collection Process (Instrument based)
CO-DRIVER SIDE VIEW
PLAN VIEW
Location of Observer
5
SUHAIL MASOOD
2022MTPLM013
M.PLAN THESIS
2023-24
PASSENGER COMFORT ASSESSMENT: COMPARING ELECTRIC AND CNG BUSES IN DELHI
Seal & Sign
DEPARTMENT OF TRANSPORT PLANNING
योजना एवं वास्तुकला विद्यालय, भोपाल
School of Planning and Architecture, Bhopal

# ANALYSIS

## Mann Whitney U Test

**Hypothesis Test Summary**

| | Null Hypothesis | Test | Significance.a,b | Decision | Remark |
|---|---|---|---|---|---|
| 1 | The distribution of Noise is the same across categories of Bus Type. | Independent-Samples Mann-Whitney U Test | < 0.001 | Reject the null hypothesis. | The distribution of Noise is not the same across categories of Bus Type. |
| 2 | The distribution of Temperature is the same across categories of Bus Type. | Independent-Samples Mann-Whitney U Test | < 0.001 | Reject the null hypothesis. | The distribution of Temperature is not the same across categories of Bus Type. |
| 3 | The distribution of Humidity is the same across categories of Bus Type. | Independent-Samples Mann-Whitney U Test | 0.000 | Reject the null hypothesis. | The distribution of Humidity is not the same across categories of Bus Type. |

a. The significance level is .050.
b. Asymptotic significance is displayed.

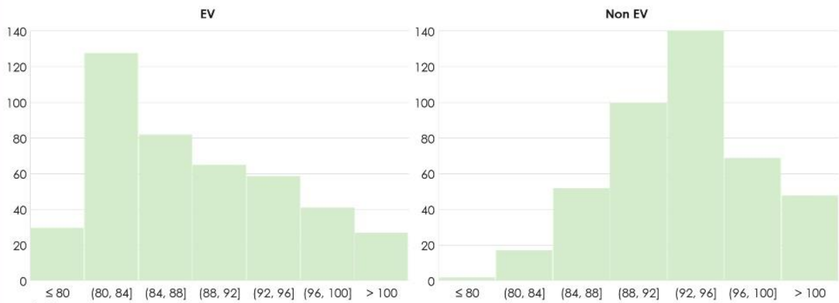
**Hypothesis Test Summary**

| | Null Hypothesis | Test | Sig.a,b | Decision |
|---|---|---|---|---|
| 1 | The distribution of Temperature is the same across categories of Bus Type. | Independent-Samples Mann-Whitney U Test | 0.408 | Retain the null hypothesis. |
| 2 | The distribution of Seat Availability is the same across categories of Bus Type. | Independent-Samples Mann-Whitney U Test | 0.348 | Retain the null hypothesis. |
| 3 | The distribution of Smoothness is the same across categories of Bus Type. | Independent-Samples Mann-Whitney U Test | 0.146 | Retain the null hypothesis. |
| 4 | The distribution of **Noise** is the same across categories of Bus Type. | Independent-Samples Mann-Whitney U Test | **0.013** | **Reject the null hypothesis.** |
| 5 | The distribution of Seat Comfort is the same across categories of Bus Type. | Independent-Samples Mann-Whitney U Test | 0.169 | Retain the null hypothesis. |
| 6 | The distribution of Legroom is the same across categories of Bus Type. | Independent-Samples Mann-Whitney U Test | 0.279 | Retain the null hypothesis. |
| 7 | The distribution of Air Quality is the same across categories of Bus Type. | Independent-Samples Mann-Whitney U Test | 0.444 | Retain the null hypothesis. |
| 8 | The distribution of Safety is the same across categories of Bus_Type. | Independent-Samples Mann-Whitney U Test | 0.162 | Retain the null hypothesis. |

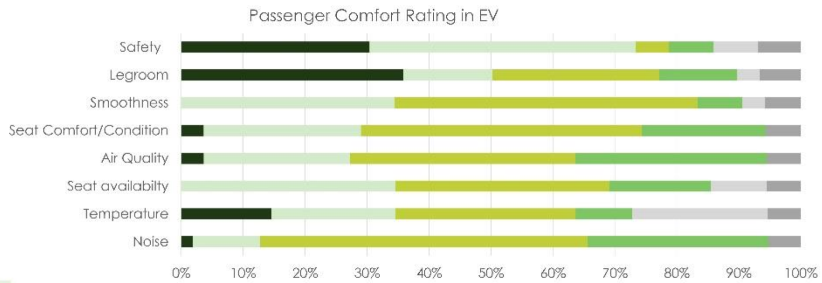
a. The significance level is .050.
b. Asymptotic significance is displayed.

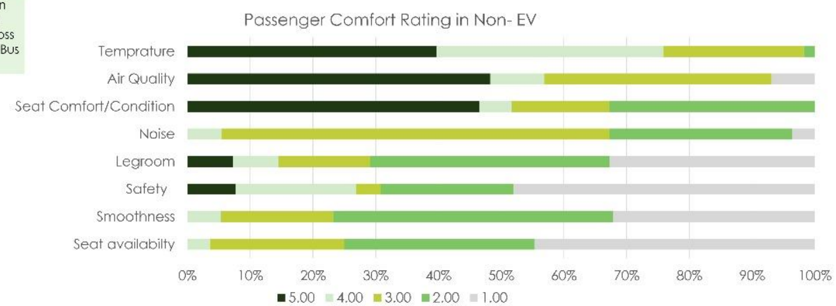
The distribution of **Noise** is not the same across categories of Bus Type.

### Questionnaire Sample Test




**Inferences**
In Ev buses more noise reading observed below 80 dB and the skewness of the graph is towards lower noise level as compared to Non EV (CNG)

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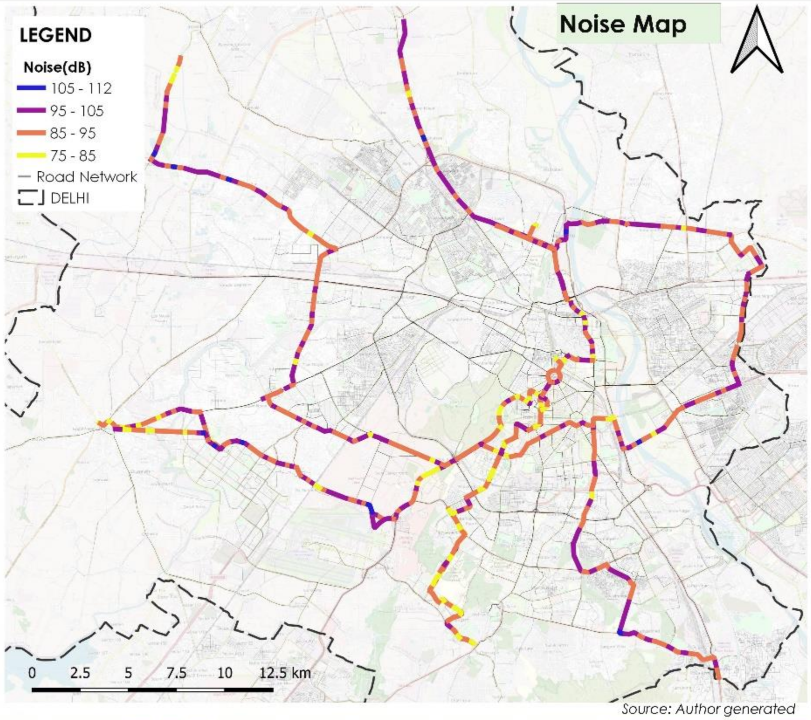
|---|---|---|---|---|---|---|

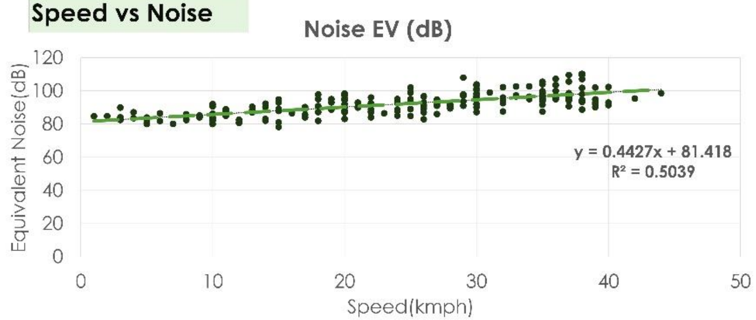
# INSTRUMENT BASED ANALYSIS

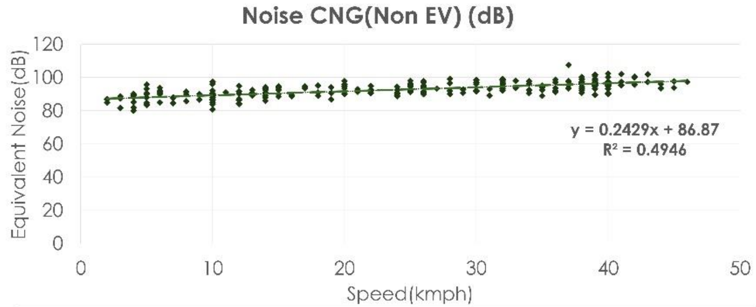
## Noise Map




*Source: Author generated*

## Speed vs Noise




**Inferences:**
The R-squared value for EV is higher than the R-squared value for CNG(non-EV). The relationship between speed and noise for Ev and CNG are strongly corelated.

| Routes | Bus Type | Leq (dB) | L10 (dB) | L50 (dB) | L90 (dB) | Lmin. (dB) | Lmax. (dB) | Journey Time (Min.) | Journey Distance (Km) | Average Passenger | Min. Temperature © | Max. Temperature© | Min. Humidity | Max. Humidity |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 708 | EV | 91.64 | 95 | 89 | 78.92 | 74.1 | 101.8 | 57 | 22.08 | 56 | 20 | 27.7 | 34.9 | 64.9 |
| 185 | EV | 94.88 | 99.4 | 89 | 82 | 80.7 | 103 | 20 | 5.86 | 11 | 24.4 | 26.6 | 52.3 | 64.4 |
| 764 | EV | 97.61 | 103.48 | 92.9 | 84.24 | 82 | 110 | 64 | 15.35 | 50 | 24.5 | 26.1 | 32.4 | 47.5 |
| 604 | EV | 94.7 | 100 | 88.9 | 80.8 | 77 | 104 | 57 | 44.34 | 50 | 23.7 | 27.2 | 23.2 | 53.4 |
| 729B | EV | 95.6 | 100.18 | 90.05 | 79.49 | 76.1 | 104 | 80 | 21.23 | 29 | 25.9 | 29.4 | 37.7 | 64.3 |
| 120 | NON EV | 97.23 | 100.56 | 95.8 | 90.96 | 80.8 | 105.5 | 86 | 28.07 | 11 | 25.7 | 28.3 | 25.8 | 47.2 |
| A08 | NON EV | 94.17 | 97.78 | 91 | 83.86 | 80 | 102.4 | 64 | 24.37 | 6 | 20.1 | 39.7 | 26 | 43.1 |
| 740 | NON EV | 96.84 | 100.3 | 92.2 | 85.48 | 80.4 | 112.1 | 109 | 32.19 | 32 | 15.7 | 29.7 | 31.6 | 61.6 |
| 971 | Non EV | 95.49 | 97.13 | 93.35 | 89.44 | 79.4 | 107.5 | 80 | 22.90 | 37 | 24.6 | 29.2 | 32.3 | 46.4 |
| 972A | Non EV | 97.91 | 102.4 | 92.7 | 85.25 | 82 | 108.2 | 96 | 28.86 | 58 | 22.6 | 56.7 | 21.4 | 29 |

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|---|---|---|---|---|---|---|

# PASSENGER COMFORT RATING ANALYSIS

| Parameters | Mean Weight | Sub Parameters | Mean Weight |
|---|---|---|---|
| Ride Quality | 0.20 | Smoothness | 0.321 |
| | | Vibration | 0.344 |
| | | Noise | 0.335 |
| Accessibility | 0.19 | Ease of Getting On/Off | 0.36 |
| | | Clear pathways and aisles | 0.30 |
| | | Designated spaces (wheelchairs) | 0.34 |
| Seating | 0.21 | Seat Comfort | 0.36 |
| | | Priority seating enforcement (elderly, disabled) | 0.32 |
| | | Charging Points/Ports | 0.33 |
| Environment | 0.17 | Temperature | 0.33 |
| | | Air ventilation | 0.32 |
| | | Cleanliness | 0.34 |
| Security | 0.23 | Safety | 0.39 |
| | | Presence of staff or security personnel | 0.31 |
| | | Lighting | 0.30 |

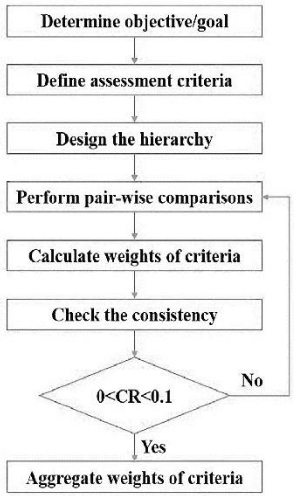
## Comparison Pair wise Matrix

| | Ride Quality | Accessibility | Seating | Environment | Security |
|---|---|---|---|---|---|
| Ride Quality | 1 | 2 | 0.5 | 3 | 0.33 |
| Accessibility | 0.5 | 1 | 0.33 | 2 | 0.25 |
| Seating | 2 | 3 | 1 | 4 | 0.5 |
| Environment | 0.33 | 0.5 | 0.25 | 1 | 0.2 |
| Security | 3 | 4 | 2 | 5 | 1 |
| Sum | 6.83 | 10.5 | 4.08 | 15 | 2.28 |

## Normalized Pair wise Matrix

| Parameters | Ride Quality | Accessibility | Seating | Environment | Security | Criteria Weight |
|---|---|---|---|---|---|---|
| Ride Quality | 0.15 | 0.19 | 0.12 | 0.2 | 0.14 | 0.16 |
| Accessibility | 0.07 | 0.1 | 0.08 | 0.13 | 0.11 | 0.1 |
| Seating | 0.29 | 0.29 | 0.25 | 0.27 | 0.22 | 0.26 |
| Environment | 0.05 | 0.05 | 0.06 | 0.07 | 0.09 | 0.06 |
| Security | 0.44 | 0.38 | 0.49 | 0.33 | 0.44 | 0.42 |

## AHP PROCESS




## Weighted Sum value matrix

| Parameters | Ride Quality | Accessibility | Seating | Environment | Security | Weighted Sum | Criteria Weight | W/C |
|---|---|---|---|---|---|---|---|---|
| Ride Quality | 0.16 | 0.2 | 0.13 | 0.19 | 0.14 | 0.81 | 0.16 | 5.06 |
| Accessibility | 0.08 | 0.1 | 0.09 | 0.12 | 0.1 | 0.49 | 0.1 | 5.02 |
| Seating | 0.32 | 0.3 | 0.26 | 0.25 | 0.21 | 1.34 | 0.26 | 5.1 |
| Environment | 0.05 | 0.05 | 0.07 | 0.06 | 0.08 | 0.31 | 0.06 | 5.03 |
| Security | 0.48 | 0.39 | 0.52 | 0.31 | 0.42 | 2.13 | 0.42 | 5.11 |
| | | | | | | | | 5.064 |

| | |
|---|---|
| Lamda max. | 5.06 |
| Consistency Index | 0.0158 |
| Consistency Ratio | C.I / R.I |
| | 0.0141 |
| R.I (Random Index) | 1.12 (for n=5) |
| C.I | 0.0141<<0.1 |

**R.Q X 0.16 + A X 0.1 + S X 0.26 + E X 0.06+ S X 0.42**

### K Mean Clustring

By the use of K mean Clustering benchmarking has done with the help of 110 Samples.

**R.Q – Ride Quality**
**A – Accessibility**
**S – Seating**
**E – Environment**
**S - Security**

| LEVEL OF SERVICE | BENCHMARKING |
|---|---|
| LOS 1 | < = 1.54 |
| LOS 2 | 1.55-1.94 |
| LOS 3 | 1.95-2.20 |
| LOS 4 | 2.21-2.45 |
| LOS 5 | > 2.45 |

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|---|---|---|---|---|---|---|

# RECOMMENDATION

| Indicators to calculate City-wide Level of Service (LoS) of Public Transport Facilities | | | | | | |
|---|---|---|---|---|---|---|
| Level of Service | 1. Presence of Organized Public Transport System in Urban Area (%) | 2. Extent of Supply Availability of Public Transport | 3. Service Coverage of Public Transport in the city | 4. Average waiting time for Public Transport users | 5. Level of Comfort in Public Transport | 6. % of Fleet as per Urban Bus Specification |
| 1 | > = 60 | > = 0.6 | >= 1 | < = 4 | < = 1.5 | 75 - 100 |
| 2 | 40 - 60 | 0.4 - 0.6 | 0.7- 1 | 4 - 6 | 1.5 - 2.0 | 50 - 75 |
| 3 | 20 - 40 | 0.2 - 0.4 | 0.3 - 0.7 | 6 - 10 | 2.0 - 2.5 | 25 - 50 |
| 4 | < 20 | < 0.2 | < 0.3 | > 10 | > 2.5 | < = 25 |

| Service level Benchmark (SLB) | Area to be covered | Primary Survey Required |
|---|---|---|
| Public Transport facilities | Key public transport corridors along the city | • Boarding Alighting at major bus stops of identified routes<br>• Passenger count inside the bus on identified routes |

SLBs for Urban Transport- MoUD, Government of India

| 5. Level of Comfort in Public Transport | | | |
|---|---|---|---|
| a) | Identification of key nodes / traffic origin points | No. | With help of city maps, routes of all public transport corridors should be plotted. Identify the key routes of public transport in the city (R1, R2, .... Rn) which covers the whole city. |
| b) | Passenger count on bus at key identified routes | No. | Passenger count survey should be carried out on bus of each identified route during morning & evening peak hour in both directions. If there is more than one type of bus then count to be done for each bus type. |
| c) | Seats available in the bus | | Count the number of seats available in a bus of each type on each identified route. |
| d) | **Passenger comfort- Load factor (passengers per seat)** | 1/2/3/4 | **Calculate= [b / c]** for each route for each bus type and calculate the average load factor of all routes and compute LoS as mentioned in indicator 5 i.e. Level of Comfort in Public Transport |
| **6. % of Fleet as per Urban Bus Specifications** | | | |
| a) | Total number of buses in the city | No. | Calculate the total number of buses in the city |
| b) | Total number of buses as per urban bus specifications in the city | No. | Calculate the total number of buses as per urban bus specification (Urban bus specifications given on website :urbanindia.nic.in" |
| c) | **% of Fleet as per Urban Bus Specifications** | % | **Calculate [b / a * 100 ].** Compute LoS as mentioned in indicator 6 i.e. % of Fleet as per Urban Bus Specifications |

**Service Level Benchmark (AHP)** – A comprehensive index can be made including both Passenger load and other parameters of Passenger comfort. The recommended Index and benchmark for Passenger comfort (excluding Passenger Load) is :

Ride Quality X 0.16 + Accessibility X 0.1 + Seating X 0.26 + Environment X 0.06+ Safety/Security X 0.42

| LEVEL OF SERVICE | BENCHMARKING |
|---|---|
| **LOS 1** | < = 1.54 |
| **LOS 2** | 1.55-1.94 |
| **LOS 3** | 1.95-2.20 |
| **LOS 4** | 2.21-2.45 |
| **LOS 5** | > 2.45 |

**1.Targeted Improvement Plans:** Develop targeted improvement plans for noise, seat comfort, Safety,

**2.Investment in Infrastructure:** Advocate for investments in infrastructure upgrades, such as improved bus shelters with seating, lighting, and protection from the elements, to enhance passenger comfort at boarding points.

**3.Fleet Renewal:** Recommend fleet renewal initiatives to replace older vehicles with newer models featuring advanced comfort features, quieter engines, better suspension systems, and improved climate control.

**4.Training and Capacity Building:** Provide training and capacity building programs for transport personnel, including drivers, maintenance staff, and customer service representatives, focusing on customer care, communication skills, and vehicle maintenance to enhance passenger comfort.

**5.Collaboration with Stakeholders:** Foster collaboration between transport authorities, operators, manufacturers, urban planners, and other stakeholders to develop holistic solutions for improving passenger comfort in public transport. Leverage partnerships to access expertise, resources, and funding opportunities.

**6.Pilot Programs and Innovation**: Implement pilot programs to test innovative solutions for enhancing passenger comfort, such as retrofitting existing vehicles with noise-reducing materials, installing ergonomic seating prototypes, or integrating smart technologies for real-time monitoring of comfort conditions.

**7.Public Awareness Campaigns:** Launch public awareness campaigns to raise awareness about the importance of passenger comfort in public transport and encourage behavioral changes among passengers, such as prioritizing courtesy and respecting fellow travelers' comfort.

**8.Incentive Mechanisms**: Introduce incentive mechanisms to reward operators and drivers who consistently maintain high standards of passenger comfort, such as performance-based contracts or recognition programs.

**9.Regulatory Reforms:** Advocate for regulatory reforms to establish minimum standards for passenger comfort in public transport and enforce compliance through regular inspections, audits, and penalties for non-compliance.

## Other interventions

**1. Smart Noise-Canceling Technology:** Install smart noise-canceling technology within vehicle cabins to actively reduce ambient noise levels and create a quieter and more peaceful environment for passengers.
**2.Biophilic Design Elements:** Incorporate biophilic design elements such as living green walls, natural lighting, and indoor plants within vehicle cabins to create a connection with nature and improve air quality while enhancing passenger comfort.

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