Inclusive Approach Towards Understanding Wayfinding by People with Vision Impairments in Mumbai Suburban Railway

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Dedicated
to

My Grandparents

Lt. Shri Vishwanath Dhanuka & Lt. Smt. Bhagwati Dhanuka

My Father

Lt. Shri Sushil Kumar Dhanuka

My Mother

Mrs. Vimla Dhanuka

Approval Sheet

The thesis entitled **'Inclusive Approach Towards Understanding Wayfinding by People with Vision Impairments in Mumbai Suburban Railways'** is approved for the Degree of Philosophy.

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Abstract

The study delves into the intricacies of wayfinding within the Mumbai Suburban Railways, one of the world's most extensive and densely populated commuting systems. It aims to investigate the wayfinding encounters of sighted individuals and those with visual impairments. The primary objective of the study is to evaluate the existing wayfinding support system to train commuters, discerning the factors hindering or aiding wayfinding activities. This doctoral research, rooted in behavioural design, emphasizes comprehensively understanding the wayfinding experience within the rail commuting system, encompassing individuals with varying visual capabilities.

Wayfinding is finding one's way using spatial information in an environment. Spatial information is gathered using perceptual and cognitive processes. It is a cognitive decision-making process that consists of a sequence of mental processes to complete a task (Arthur & Passini, 1992; Passini, 1984).

Past research has consistently highlighted vision as the primary factor influencing wayfinding (Passini, 1988; Golledge, 1999). However, research on wayfinding in rail commuting is scarce, particularly for individuals with vision impairments. Much of the current literature predominantly represents the wayfinding context of developed nations. However, the context of economically developing countries like India significantly differs based on factors like social dynamics, urban congestion, and infrastructural and technological landscape.

We used the type 2 design research methodology framework proposed by Blessing & Chakrabarti (2009) to identify the nature of the study and outcome. The methods adopted in this empirical and evidence-based research were derived mainly from the field of Environment-Behavior research (Zeisel, 2006; Sommer & Sommer, 2002) and usability research (Hertzum 2006, 2010; Sauro 2012, 2013, 2014; Neilsen, 1994, 1995).

This qualitative wayfinding research conducted in the economically developing world represents a noteworthy contribution to the existing knowledge of wayfinding. The study elucidates the merits and drawbacks of the current wayfinding assistance Mumbai Suburban Railways provides. These assessments encompass external factors such as the built environment, signage design, rail services, and issues related to overcrowding. Additionally,

the research delves into the impact of individual strategies, including social wayfinding, sensory cues, personal mobility aids, and personal escorts, on participants' wayfinding experiences and performance, offering valuable insights gleaned from empirical research. Studying wayfinding across the spectrum of vision and intersectional variables of familiarity, gender, and literacy differences is a unique aspect of our study.

The wayfinding problem severity matrix, which stemmed from empirical research, informs the order of priority in addressing wayfinding problems based on critical, moderate, and minor impacts as perceived by the commuters, which is another noteworthy contribution. The matrix is one of its kind to involve users, particularly those with vision impairments, in informing them of the order of priority in addressing wayfinding problems.

Lastly, the guidelines were proposed to address the wayfinding problems that emerge from the ground research act as design support for wayfinding design development. They are developed and presented using a robust three-layered framework of wayfinding stages, design principles and enabling aspects.

Keywords: Mumbai Suburban Railways, Vision impairment, Wayfinding, Inclusion

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Abbreviation & Terms

MLTCS	Mumbai Local Train Commuting System
VI	Vision Impairment
PVIs	People with vision impairments
NV	No vision
LV	Low Vision
S	Sighted
PwDs	People with Disabilities
NSG	Non-suburban
SG	Suburban
AR	Augmented Reality
TGSI	Tactile Surface Indicator
IF	Severity Impact Factor
PF	Problem Frequency
ETA	Electronic Travel Aids
RF	Radiofrequency
MI	Mobility impairment
HIC	High-Income country
LMIC	Low and Middle-income country
VA	Visual acuity

…….

Sahayaks: Help desk Officials

Yatri: Passengers

Madad: Help

Lechal: A haptic footwear developed by Ducere Technologies in India, aids visually impaired individuals in navigation.

Chapter 1 Introduction

1.1 Motivation

This thesis deals with the wayfinding needs of people with vision impairments (PVIs) in Mumbai Suburban Railways, also called Mumbai Local Train Commuting System (MLTCS). This suburban rail commuting system serves 7.4 million commuters daily in India's financial hub and boasts the world's highest passenger density among urban railway systems (Gardas et al., 2013). Despite being the most crowded public environment, rail commuting in India is still the most dependable and economical mode of commuting both intercity and within the city. They are the oldest, fastest, affordable, and irreplaceable means of daily commuting, supporting the livelihoods of millions of commuters, including people with impairments. In the economically developing world, people with impairments suffer a high incidence of poverty, perpetuated by a lack of access to socio-economic opportunities. Mumbai's Suburban rail commuting system plays a vital role in alleviating poverty if it supports the mobility needs of people with impairments through an empathetic and inclusive wayfinding system design approach. Unfortunately, to date, attempts made in the direction of development focus on most travellers who are non-disabled, thus ignoring those with special needs such as mobility, sensory and cognitive impairments (Raheja & Tyagi, 2016).

Indian literature on accessibility explains the needs of people with impairments, emphasizing the 'physical accessibility' in public transportation (Nagaveni & Thirumalraja et al., 2021; Raheja & Tyagi, 2018; Raheja & Tyagi, 2016; Devi et al., 2013; Banerji et al., 2007). Hence, developing guidelines and implementing measures in the rail commuting system is limited to architectural changes to make navigation possible in public buildings. There is yet no well-developed body of knowledge that explains the 'cognitive accessibility' of the built environment, particularly in the Indian rail commuting context. Cognitive accessibility is about making buildings not just easy to navigate but easy to wayfind. Passini & Proulx (1988) describe wayfinding as a process involving cognition, behaviour and strategic movement planning from point A to B. It is a mental process of collecting information from the built environment to reach the desired destination. An oriented individual is considered a person who knows where they are, where they go and what they need to do to get where they want to go.

Wayfinding in rail commuting systems in India is daunting, as one must negotiate a fast-moving, extraordinarily dynamic and bustling environment. The current rail commuting environments, particularly Mumbai Suburban Railways, have not made significant progress in addressing the wayfinding needs of commuters due to the lack of understanding of ground-level issues that can only come from foundational field research.

Vision plays a primary role in providing plentiful information to Wayfinder. Arthur & Passini (1992) and Golledge (1993;1999) declare that *'visual impairments are the most obvious and most severe perceptual impairments affecting wayfinding'*. India is home to an estimated 25% of the world's population with visual impairments (Institute for Health Metrics and Evaluation, 2021). Still, our knowledge of wayfinding of people with vision impairments (VI) is primarily built on the work done in the world's economically developed countries. However, the real-world wayfinding challenges people with vision impairments face in rail transit environments of economically developing countries like India provide unique insights that add to the world's already known. Therefore, addressing wayfinding behaviour and concerns requires action relevant to India's socio-economic and environmental context.

1.2 Background

The 17 Goals of the 2030 Agenda for Sustainable Development were adopted by 193 nations, including India, in September 2015 at the UN Summit. They officially came into force on 1st January 2016. While ambitious and universal, they have, in principle, charted a path for nations to achieve fair, equitable, inclusive, and environment-friendly development.

Goal 9 of the SDG goal states to 'build resilient infrastructure, promote inclusive & sustainable industrialization and foster innovation. Develop quality, reliable, sustainable and resilient infrastructure, including regional and trans-border infrastructure, to support economic development and human well-being, focusing on affordable and equitable access for all.' (WNTA, 2017).

To meet this goal, the Department of Empowerment of Persons with Disabilities (DEPwD) India launched the Accessible India Campaign (*Sugamya Bharat Abhiyan*) in 2015 as a nationwide campaign that aims to make a barrier-free environment for people with disabilities all over the country. It seeks to enable persons with disabilities to gain universal access, equal opportunity for development, independent living and participation in an inclusive society in all aspects of life. For creating universal accessibility for Persons with Disabilities, the campaign has been divided into three verticals: Accessibility of the Built Environment, Transport system accessibility and Accessibility of the Information and Communication Technology (ICT) ecosystem (DEPwD*,* 2015*;* WNTA, 2017).

One of the objectives and targets envisioned under the Accessible India campaign is to conduct an accessibility audit of at least 50 important government buildings and convert them into fully accessible buildings by July 2016 in 50 country cities (DEPwD*,* 2015). Among government buildings, railway stations in every city are recognised as one such building typology that needs to be made universally accessible. Under the Accessible India Campaign, the Department aims to make 10% of government-owned public transport carriers and 50% of railway stations accessible by March 2018 (DEPwD**,** 2015). The critical challenge in front of the government is to collect data on the accessibility features required to make stations and trains accessible for people with disabilities (PwDs), as there are no prior benchmarks. A nationwide audit program has been launched to assess public buildings on Access to Information, Infrastructure, and Services (Raheja & 2016). Eighteen organizations were empanelled as access auditors, and 48 cities, including Mumbai, were selected for this

campaign to assess public buildings (DEPwD, 2015). Since then, several access audits have been executed to identify the barriers that limit the full participation of people with disabilities in public buildings.

The doctoral work fits into a larger ambit of Goal 9 of SDGs, 2030. Its goal is to enhance understanding of the wayfinding experiences of individuals with vision impairments by conducting empirical research on the wayfinding behaviours and challenges commuters face using the Mumbai local train system. The motivation for this thesis is to add knowledge on the wayfinding of commuters with and without vision impairments in one of the world's most crowded and uncontrolled mass commuting systems, Mumbai Suburban Railways, India.

1.3 Inclusive Design Thinking

In the latter half of the 20th century, the design field embraced a medical model of disability, distinguishing between 'general' and 'special' needs. The former catered to able-bodied, educated people, while the latter addressed those outside this norm, such as children, the elderly, and people with disabilities. This approach, though pragmatic, focused on solving problems rather than upholding rights, resulting in stigmatizing environments. Criticism of medical model has led to a shift of design towards inclusion, emphasizing universality over fragmented solutions for specific groups (Hanson, 2004). Recognizing that many are excluded from different aspects of society, socially, physically and digitally, enables actionable steps toward inclusive design by understanding the reasons behind such exclusion.

The perception of disability has evolved from solely a health issue to one deeply influenced by context. Disability is now recognized as a multifaceted phenomenon arising from the interplay between an individual's bodily characteristics and societal environment, leading to physical, cognitive, and social exclusion when these interactions are mismatched, leading to social exclusion. Exclusion can be temporary and situational (Microsoft Design, 2016). Take the continuum of vision, for instance: someone with blindness experiences a permanent disability and cannot access visual signage. In contrast, someone with an eye injury faces a temporary one and cannot access the visual signage until the eye heals. Additionally, an individual with full vision might encounter a situational disability when navigating crowded spaces and struggling to find or view the signage. As people move through different

environments, their abilities can fluctuate significantly. Inclusive design operates within a spectrum of interconnected abilities, bridging diverse individuals facing similar circumstances. While designing for those with permanent disabilities may initially appear limiting, designing for spectrum can cater to a much wider audience. Recognizing the continuum from permanent disabilities to situational impairments prompts us to realize how design can innovatively reach a broader audience (Microsoft Design, 2016). There has been a significant evolution in the design paradigm where the focus to benefit the ‘majority’ has shifted to ‘heterogeneity’. This shift in thinking has led researchers, designer, architects, government organizations, NGOs, educators, and citizens to respond, acknowledge and appreciate this shift.

Previously, when crafting policies, guidelines, and design interventions for groups like individuals with vision impairments in extensive built environments such as rail commuting systems, there was a tendency to view them as "minority user groups." This approach often led to implementing specialized solutions tailored solely to their needs. However, this approach missed recognizing shared challenges and needs with the sighted world that could be effectively addressed through an integrated design approach or universal solutions.

The thesis investigates how a change in the level of vision affects wayfinding. Mapping changes in wayfinding due to the severity of vision impairment will help to seek ways to design approaches that may lead to joint and unique solutions. Furthermore, In the Indian context, verbal communication and human assistance (escorting) by strangers play an integral role in social wayfinding for all commuters irrespective of abilities, gender, economic status, and language differences, including able-bodied, sighted population, help us to explore the possibility of strengthening co-existence, interdependence and social inclusion.

1.4 Research Objectives & Questions

Inclusive design prioritizes people from the outset. When experiences fall short of meeting people's needs, they instinctively adapt. Understanding these adaptations unlocks invaluable insights. Empathy is pivotal across diverse design disciplines, highlighting the importance of immersing ourselves in individuals' experiences. This process enables us to pinpoint barriers and recognize the common motivations shared by all individuals.

This study examines the wayfinding scenario of a rail commuting system from the lens of people who represent three different levels of vision: No Vision (NV), Low Vision (LV) and

Sight. The overarching theme guiding this enquiry is providing an **'inclusive approach to wayfinding design'.**

The principal objectives of the study are to:

O1. Understand how the current rail commuting system fulfills the wayfinding needs of different levels of vision.

O2. Prioritize wayfinding concerns in station use and train travel based on the severity assessment.

O3. Create design support to improve the wayfinding experience and performance of people with different levels of vision at Mumbai Suburban Railways.

To address the above objectives, this study has developed a multiple-stage research strategy that involves the following research questions:

RQ1. How does the existing scenario of the commuting system affect the wayfinding *experiences* of people with different levels of vision?

RQ2. How does the existing scenario of the commuting system affect the wayfinding *performance* of people with different levels of vision?

RQ3. What is the *order of priority* of wayfinding problems faced by people with different levels of vision?

RQ4. What design support may improve the wayfinding experience and performance of people with different levels of vision?

The work done in the thesis is divided into two parts. Part A has three empirical studies that address RQ1, RQ2, and RQ3, and Part B has worked to develop design support for RQ4.

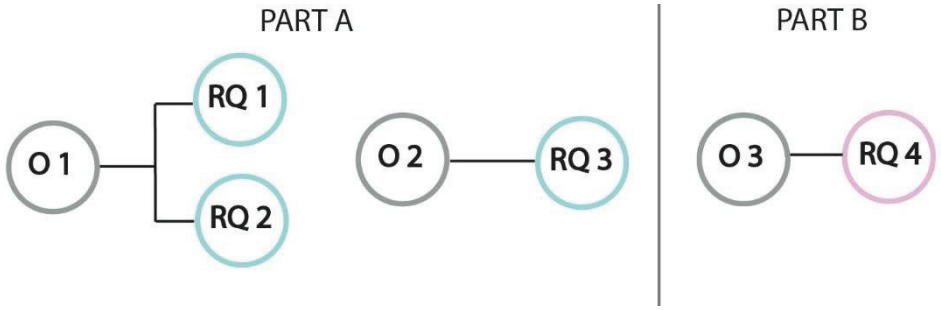


Figure 1.1: Research Questions and Objectives interlinkage.

1.5 Methodology

We used the type 2 design research methodology framework proposed by Blessing & Chakrabarti (2009) to identify the nature of the study and outcome (Figure 1.2). The *Research Clarification* stage involves literature analysis and preliminary field studies to get a focused approach to the wayfinding research. This is followed by a *Descriptive stage* that involves empirical data collection and analysis to develop a detailed and comprehensive description of the existing wayfinding situation for the rail commuting system.

Further, as part of the *initial Predictive stage, using assumptions, experiences,* and synthesis, the wayfinding design support system is proposed as design guidelines. These guidelines are suggestive and show how the findings from the empirical research could be used to improve the existing wayfinding situation with a design action. The methods adopted in the field studies conducted at the research clarification and descriptive stage were derived mainly from the methods used in Environment-Behavior research (Zeisel, 2006; Sommer & Sommer, 2002) and usability evaluation studies (Hertzum 2006, 2010; Sauro 2012, 2013, 2014; Neilsen, 1994, 1995). Figure 1.3 depicts the research methodology followed through a diagrammatic representation.

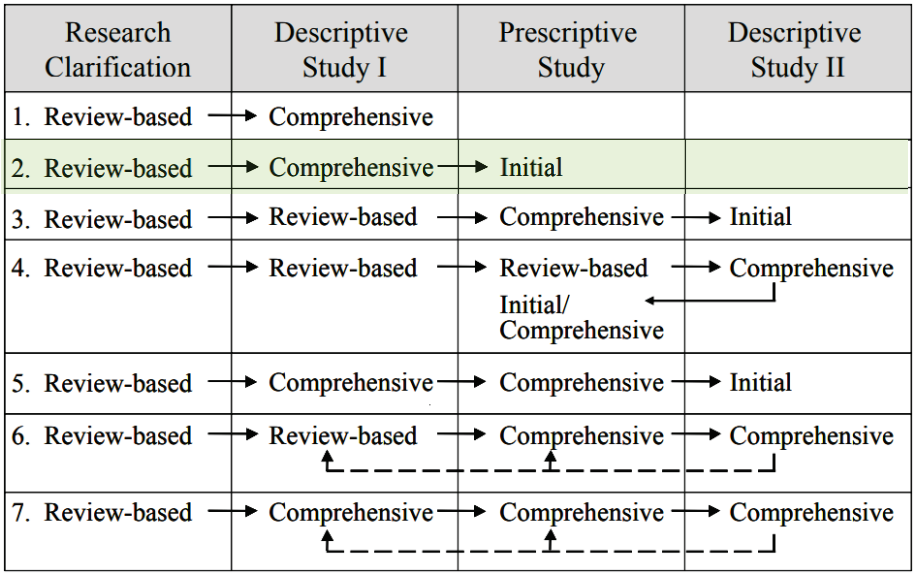


Figure 1.2 Types of Design Research Projects (Blessing & Chakrabarti, 2009)

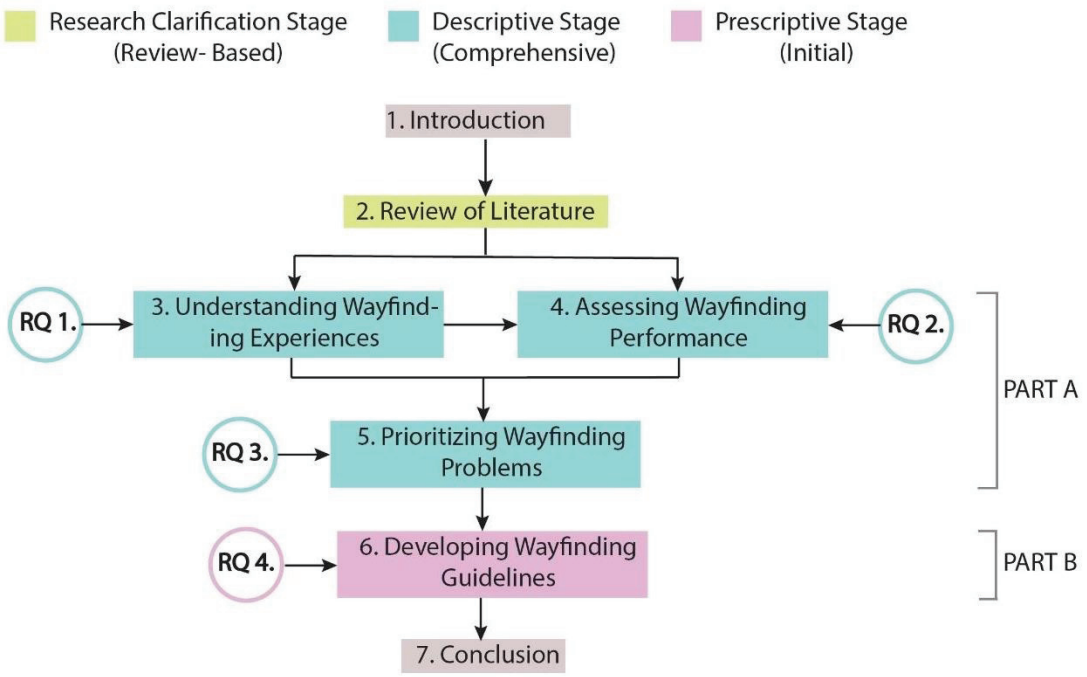


Figure 1.3 Research Methodology and Thesis Chapter Organization

1.5.1 Research Clarification Stage (Review-based)

"In the Research Clarification (RC) stage, the researchers try to find evidence or at least indications that support their assumptions in order to formulate a realistic and worthwhile research goal" (Blessing & Chakrabarti, 2009).

During the research clarification phase, deviating from the proposed methodology by Blessing & Chakrabarti (2009), our initial step at the research clarification stage involved conducting field research to understand Mumbai Local Train Commuting (MLTCS). This was necessary due to the scarcity of published user-centered empirical research on the Mumbai Suburban Railway. Three field studies were done for research clarification.

(i) Interviews with people with mobility and vision impairments and other railway stakeholders (Appendix A1)

(ii) Observation study on travel behaviour of all commuters in Mumbai Suburban Railway (Appendix A2)

(iii) Railway station spatial layout analysis using annotated drawings (Appendix A3)

Additionally, the literature review enhanced the initial description of the situation by identifying influencing factors and deepening the understanding of wayfinding, particularly in rail commuting systems. Unique challenges associated with vision impairment in India were explored, revealing gaps in research on uncontrolled public spaces, social interactions, and crowd influence on wayfinding, especially in low- and middle-income countries like India. This doctoral research focuses on the Mumbai Suburban Railway, recognizing its complexity and significance for individuals with and without visual impairments, leading to focused research questions on wayfinding.

1.5.2 Descriptive Stage (Comprehensive)

After having a clear goal and focus, there was a need to find enough evidence to understand how the existing scenario of Mumbai Suburban Railways fulfils the wayfinding needs of commuters with *different* levels of vision. At this stage of the descriptive study, primary research was conducted with three interlinked studies to address the research questions.

(i) Study 1: Understanding Wayfinding Experiences in Mumbai Suburban Railways

The first study used a semi-structured interviewing method to describe the participants' past wayfinding. An interview guide was made to drive the conversations with the participants. Probes were used to elicit responses from the participants (Robinson, 2023). The findings from the interviews were consolidated to comprehend the reasons for participants' preference to travel by local trains, wayfinding challenges, and wayfinding support systems. In addition to this, feedback was taken from the participants on what would help improve the station wayfinding experiences for them. The study helped to get a general idea about various aspects of the Mumbai Suburban Rail commuting system that enable or disable commuters with different levels of vision.

(ii) Study 2: Assessing Wayfinding Performance in a model station

A station walkthrough study was conducted to compare and assess the wayfinding performance of commuters in a real-life railway station building. In this phase, twenty-two participants representing all three levels of vision from Study 1 were asked to perform a sequential wayfinding task in a large-scale station building. The performance was measured against

observable quantitative measures. Participants' cognitive thought process wayfinding decision-making during the wayfinding was analyzed using qualitative environmental- behavioral research methods. This study helped to validate most wayfinding challenges reported in Study 1 through a real-life site-specific study. Further, it helped to objectively measure and compare participants' performance against measurable criteria to establish the impact of existing wayfinding system design on their wayfinding experience.

(iii) Study 3: Prioritizing wayfinding problems based on Severity Assessment

Severity assessments are crucial in usability evaluations, guiding designers, planners, and policymakers in prioritizing and addressing problems effectively. This study developed a prioritization system for wayfinding concerns, determining their impact on commuters' experiences. Usability evaluation methods, including ranking, rating, and structured interviewing, were employed to categorize concerns into critical, moderate, and minor categories based on severity. Validation was conducted with thirty new participants across different vision levels. The severity matrix assigned numerical values to wayfinding problems based on severity level, facilitating prioritization and resource allocation. This research stage was used to elaborate on the initial description of the knowledge developed during the research clarification stage. The novelty of this study is the involvement of commuters with and without vision impairments in the severity assessment process.

1.5.3 Prescriptive Stage (Initial)

In the Prescriptive Study (PS), at its initial stage, the increased understanding of the existing wayfinding situation was instrumental in representing the vision of how addressing problems would lead to the realization of the desired, improved situation. The systematic development of design support in the form of design guidelines for wayfinding was proposed. They were developed based on an in-depth understanding of the existing wayfinding situation for the desired situation and user preferences stated during all three field studies. The primary research helped to identify the limitations of the wayfinding systems by studying the wayfinding scenario in detail. The national and international official guidelines were reviewed to understand how they holistically address the wayfinding problems experienced by people with and without vision impairments. The research in the final phase presents the wayfinding

design guidelines in a way that can be used in applied design situations. These proposed aspects are intended to create a developmental framework for architects, designers and facility managers to design a user-friendly and inclusive wayfinding system. The wayfinding design considerations are prepared for the wayfinding task hierarchy. They are a response to the information requirement of commuters who differ in their level of vision for each journey stage. The guidelines are specific and generalized based on the participant's level of vision and other rail-based commuting systems because of the amplified breadth and depth of the present research. They are developed to offer choices to people for assisted and independent wayfinding depending on their ability, experience of use and psychological comfort. They address the wayfinding needs of train commuters based on personal factors such as level of vision, familiarity, and gender differences.

1.6 Scope of work

The Mumbai Suburban Railway, characterized by its dense population, hurried commuter culture, extensive network, and frequent services, persists as Mumbai's top transportation choice despite its age and overcrowding. It poses a challenging wayfinding environment for all commuters, especially those with vision impairments or limited familiarity. While the empirical research primarily focuses on the Mumbai Suburban Railway, its insights can apply to other rail commuting systems (suburban and non-suburban), metro and monorail.

The research is limited to studying the individual and group differences in wayfinding based on the level of vision. Within the vision impairment (VI) group, people with complete vision loss and low vision were included. Furthermore, a representative group of individuals with sighted people were included in the research to draw comparisons and highlight information deficits for the VI group. The study is limited to independent adults and senior citizens who are independent travellers while exploring the impact of other human factors, such as familiarity levels and gender, on wayfinding experiences.

This research delves into the current state of wayfinding within rail transit commuting systems, aiming to understand its effects on the behaviour (including performance and strategy used) and perceptions of commuters who differ in the level of vision, familiarity, and gender. Studying wayfinding cognition was beyond the scope of this research. Employing

environmental and behavioural research methodology, the study examines individuals' behaviour and emotions during their interactions with the environment. Methods include behavioural observation, tracking and mapping in real-world settings, retrospective verbal reports, and interviews. Further, usability research methods incorporating rating and ranking techniques were used to prioritize wayfinding problems. Computational methods and virtual simulations were not part of the scope of this research.

The issues identified from empirical and evidence-based research were arranged in the order of severity, indicating priority for address based on commuters' perceptions gathered through usability research ranking and rating techniques. We understood that the reliability of severity assessment increased with user involvement over expert usability specialists. The resultant, quantified wayfinding problem severity matrix helps prioritize them for future address based on their perceived negative impact on wayfinding.

Further, the wayfinding guidelines were formed using a systematic travel chain framework that addresses all wayfinding task requirements of people with different levels of vision, familiarity, and gender. They do not prescribe rigid design standards but instead offer adaptable strategies to enhance the wayfinding of Mumbai's local train system. The guidelines propose to modify the existing station and train physical and digital infrastructure and human services, further strengthening social wayfinding by considering train commuters' behaviour, needs, and abilities. Moreover, they offer insights that could inform the design and development of new rail-based commuting infrastructures. While primarily focusing on interior wayfinding, they apply to different station types, including terminals and interchanges. Targeting users with no vision, low vision, and sight, the guidelines provide both standard and specific recommendations, refraining from specifying percentages of visual impairment. Qualitatively, the guidelines aim to inspire design solutions to improve wayfinding experiences for all users, serving as a foundation for future research on design approaches and design solutions.

1.7 Relevance of the Research

Past research on wayfinding for people with vision impairments is limited to studying them as a segregated group. Hence, the design guidelines and interventions proposed were

never socially inclusive. The present research addresses this notable gap by researching people on a spectrum of vision, familiarity, and gender difference, hoping that it will guide design solutions that foster co-existence and interdependence.

The review of the existing studies shows that minimal empirical studies have been conducted on wayfinding behaviour and challenges in rail commuting globally, particularly for PVIs. It is important to note that when India is the second most populous country in the world, home to over 20 percent of the world's blind population, yet there is hardly any research done on wayfinding from the perspective of people with vision impairments in public environments. Economically developed countries have made considerable strides in enhancing transport accessibility for individuals with disabilities, mainly adhering to standardized guidelines with some local adaptations. However, in economically developing nations like India, the wayfinding design is limited due to a lack of research and inclusive guidelines on public environments.

The present research is foundational work that addresses this gap and highlights the unique social context of wayfinding, its relevance and its impact on the world's most extensive and populated rail commuting system. Furthermore, research conducted in such a complex socio-physical environment adds unique insights into wayfinding challenges and behaviour to the existing international wayfinding literature.

The research is expected to catch the attention of researchers in design, architecture, social work and environmental behaviour research. They offer a framework suitable for designers, architects, railway planners, administrators, policymakers, social workers, and anyone striving to create a welcoming and inclusive environment for wayfinding in the rail commuting system. The practitioners may like to implement the findings to design and further test them for efficacy.

1.8 Organization of the Chapters

This chapter introduces the research with motivation, background, key objectives, and research questions that propel the study. It describes the methodology adopted in the research and its scope and relevance in design and research.

Chapter two traces the evolution of wayfinding since the 1960s, highlighting the factors that led to the advancements made in economically developed and developing countries.

Furthermore, the review highlighted aspects that made wayfinding in Indian conditions unique. Having vision impairment makes the wayfinding process even more challenging. The review of existing empirical studies highlighted notable gaps in the current literature on limited research on the wayfinding of people with vision impairments in uncontrolled overcrowded public environments, particularly rail-based computing systems in the world and how research in Indian conditions will offer a unique perspective to the existing knowledge on wayfinding.

Chapter three delves into the wayfinding hurdles and strategies discussed by participants, drawn from their past experiences of commuting on local trains. This insight is gathered through semi-structured interviews. Additionally, the feedback provided by participants regarding enhancements to the wayfinding experience at stations is considered.

In chapter four, an additional empirical investigation is detailed, aimed at comprehending how individuals with diverse levels of vision wayfinding in Mumbai Local Train Commuting System and how the current state of the commuting infrastructure impacts their wayfinding performance. This study is designed to collect evidence and analyze data regarding the wayfinding process, behaviours, and performance inside one of the railway stations of the Mumbai Suburban Railways network. The following objectives drive the study: 1) To compare the wayfinding performance of people with different levels of vision and 2) To identify the limitations of the existing commuting system that lead to difficulty in wayfinding task execution.

Chapter five presents a system of prioritization of wayfinding problems identified in Chapters 3 and 4 to determine which issues have a more severe impact on commuter wayfinding than others based on commuter's assessment. The study helped to identify the most critical concerns common or specific to user groups based on three levels of vision: no vision, low vision and sighted people. The study led to the formulation of the wayfinding problem severity matrix, which may be used to inform the action plan or the design implementation strategy, considering commuter's order of priority in addressing wayfinding problems.

Chapter six presents wayfinding guidelines that aim to make the Mumbai Suburban Rail commuting system socially inclusive of the needs of people based on differences in personal factors such as level of vision, level of familiarity, and gender differences. The design guidelines are proposed for different wayfinding stages of the computing system. They are both

generic and specific to focused user groups. They are developed based on the insights from studies in chapters three, four and five.

Chapter seven concludes the research work with a summary and implications of the present research. It summarizes answers to all the research questions raised and discusses this research study's strengths, limitations, and impact. The chapter also presents future research directions.

The Review of the literature is divided into two parts. Part A to the first three research questions is presented in Chapter 2, and Part B leads to the fourth research question presented in Chapter 6 (Figure 1.4).

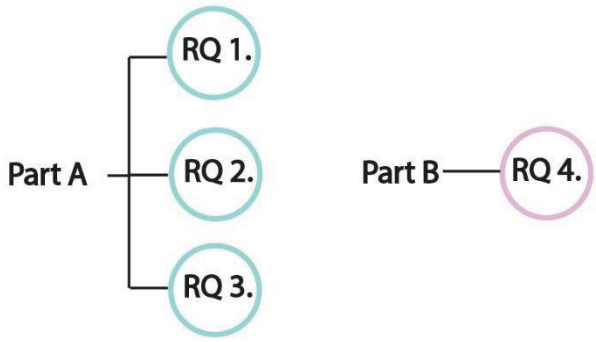


Figure 1.4 Organization of Literature Review

1.9 Terminology

Since India signed and ratified the UNCRPD in 2007, Persons with Disabilities or PwDs has been the accepted official term for a social group that is discriminated against by society due to physical or mental impairments (UNCRPD, 2007). Throughout the thesis, the author has used the terminology of people with disabilities (PwDs) and disabled people to refer to such a section of society.

In this thesis people with blindness and low vision are referred to collectively as people with vision impairments. Further, people with blindness are referred to as having no vision, and those with vision are referred to as people with sight and sighted people.

Handicap coach is a terminology used in Mumbai for the reserved coach in every Mumbai local train reserved for people with disabilities, senior citizens, pregnant women and cancer patients in India till 2015. Later, the coach is referred to as disabled friendly coach. Hence, the

work done in the thesis till 2015 uses the terminology of Handicap when referring to the coach for people with disabilities. In the later part of the thesis, the Handicap coach is replaced by disabled friendly coach or a coach reserved for people with disabilities.

Chapter 2 Review of Literature

2.1 Organization of Literature Review

The literature review chapter aims to build and synthesize a knowledge base of current research based on the research themes: 'Experience of wayfinding in large public buildings by people with different levels of vision.' Research gaps in the existing knowledge will be identified in this chapter. It will help to formulate the Research Question/s.

Section 2.2 maps the evolution and critical development of wayfinding since the 1960s. It will illustrate how parameters such as technology, cognitive psychology, urban design principles, accessibility and inclusivity have driven the evolution of wayfinding. This evolution has moved beyond conventional static signage to embrace a diverse range of physical and digital tools, reflecting a dedication to user-centered design and the seamless integration of technology.

Infrastructure, accessibility, economic development, sociocultural aspects, and technology significantly affect wayfinding design. A comparative analysis between high-income and low-middle-income countries based on these factors is explored in section 2.3 to understand how they affect wayfinding practices and experiences. HICs typically have a well-developed infrastructure, prioritized accessibility features, advanced technological solutions, and organized urban planning, collectively facilitating smoother wayfinding for residents and

visitors alike. Conversely, LMICs often face challenges from limited infrastructure, inadequate accessibility measures, restricted access to technology, socioeconomics impacting wayfinding methods, and less organized urban planning. These disparities highlight the importance of considering context-specific approaches and addressing the unique challenges LMICs face to enhance wayfinding experiences in such countries.

Section 2.4 presents factors that are unique to wayfinding in India (one of the LMICs). India presents a distinct scenario of wayfinding and related challenges grounded in cultural diversity, urban complexity, the emergence of digital solutions, reliance on informal landmarks, and human assistance. Very little research has been conducted on the wayfinding experiences of people in public places. This highlights a critical need for in-depth research tailored to the Indian context. Such research should include contextual inquiry conducted in real public places to gain comprehensive insights into the experiences of wayfinders.

Section 2.5 discusses disability studies from the perspective of models. Models of disability and functioning serve as tools for defining impairment and, more recently, functioning. Governments and society use these models to develop policies and strategies that address the needs of individuals who experience functional loss due to health conditions, disease, or injury. While they offer a framework for understanding impairment, disability, and functioning, they remain subjects of debate and contention.

While architectural elements and wayfinding systems in large-scale public buildings are typically designed for "average" users, many individuals deviate from this norm due to impairments, temporary health conditions, or situational factors. Vision emerges as a critical variable in facilitating wayfinding, with its absence posing significant challenges, particularly for individuals with visual impairments, as discussed in **section 2.6**. The section further highlights the unique challenges associated with vision impairment in India and their effect on the wayfinding ability of PVIs. Vision impairment poses significant challenges globally, with countries like India facing particularly pronounced impacts due to their large population size, limited access to financial resources, and limited access to expensive personal wayfinding aids. The close correlation between illiteracy and higher rates of blindness highlights the critical importance of education, particularly in braille literacy, which limits access to braille signage. Moreover, the transition to digital literacy presents new challenges, as many wayfinding digital platforms still need to be made available to visually impaired individuals. Stereotypes, prejudice, and stigma contribute to the discrimination and exclusion experienced by people with

disabilities and their families, exacerbating social exclusion and dependency on family support networks for outdoor mobility—further, overcrowded environments hindering navigation and challenges in unfamiliar or changing environments. Notably, the unique challenges faced by individuals with vision impairments in India highlight the need for tailored approaches to wayfinding design in public environments.

Section 2.7 examines empirical research on wayfinding in public environments, identifying gaps in research on uncontrolled public spaces, especially for people with vision impairments (VI) globally. It highlights the lack of studies on the influence of social interactions and crowds on wayfinding, particularly in low- and middle-income countries (LMICs) like India. Rail and metro systems are complex wayfinding environments, with limited empirical research worldwide exploring challenges and facilitators for individuals with and without vision impairments. Wayfinding research needs to be addressed in rail commuting systems in India. Existing studies had separate and exclusive focus on architectural, signage, and social aspects of wayfinding, missing out on the interrelationship between these factors. Although existing studies advocate implementing a universal design philosophy in improvising old and building new commuting systems, studies have yet to study commuter diversity based on the level of vision. Rail commuting presents a more challenging environment for individuals with vision impairments due to its age and more extensive and chaotic nature than metro systems. This doctoral research recognizes the Mumbai Suburban Railway as an ideal setting for studying wayfinding challenges due to its complexity stemming from factors like high population density, extensive network coverage, frequent service, and historical significance and dependency for daily commuting by people with and without visual impairments.

Section 2.8 presents the research gaps, and **Section 2.9** presents research objectives and questions.

2.2 Wayfinding

Research on wayfinding spans various disciplines, including urban design (Lynch, 1960), geography (Golledge, 1999), cognitive psychology (Downs & Stea, 1973; Downs & Stea, 1977), architecture (Arthur & Passini, 1992), virtual environments (Vila et al., 2003), graphic design (Berger, 2005), and augmented reality (Goldiez et al., 2007) and beyond.

The understanding of wayfinding has evolved significantly from the 1960s to the 2020s. Here is a brief overview of the key developments:

(i) *1960s-1970s*: Wayfinding primarily focused on environmental psychology and cognitive mapping. Researchers like Kevin Lynch introduced concepts such as legibility, imageability, and the mental mapping of urban environments in his influential book "The Image of the City" (1960). Stea (1969) referred to these mental images as cognitive maps, emphasizing their hierarchical and bounded relationship. The interest of the researchers later shifted from the study of the product (the cognitive map) to the study of the process (cognitive mapping) in the late 1970s. Golledge (1999) noted that cognitive map depth and breadth increase with familiarity with surroundings. Attention is drawn to complex, large-scale public buildings, which can lead to slower development of cognitive maps and representational inaccuracies (Stea, 1969).

(ii) *1980s-1990s*: The 1980s saw an increased interest in signage systems and their role in aiding navigation. Human factors and ergonomics became integral to wayfinding studies during this period. The importance of intuitive design and user-centered approaches was given to understand and study the wayfinding process. In another seminar work, Romedi Passini and Paul Arthur focused on building-oriented wayfinding in their collaborative work "Wayfinding: People, Signs, and Architecture" (Arthur & Passini, 1992). They synthesized research on architectural layout, signage, and environmental cues, emphasizing the importance of wayfinding in building design. Acknowledging that everyone can face difficulties in wayfinding regardless of ability, they addressed general wayfinding problems experienced by diverse groups within buildings. Passini and Proulx (1998) describe wayfinding as *'a user-oriented process encompassing cognition, behavior, and strategic planning. It involves gathering information from the environment to navigate from point A to B, incorporating past and present experiences.* Whether in constructed or natural surroundings, wayfinding remains a fundamental aspect of our spatial interaction. It encompasses finding a path from one location to another and is intimately linked to the physical environment in which it occurs.

Passini (1984) proposed a framework explaining that people look for spatial clues, termed environmental information. Information from spatial clues is through the senses and understood through cognition. The wayfinding process is a decision-making process (Figure

2.1) that consists of a sequence of operations to complete a task. Decision plans depend upon the nature of the environmental information available (sensory and memory-based). Passini (1984) described three distinct wayfinding capabilities: (a) cognitive mapping or information-generating ability, (b) a decision-making ability that allows one to plan actions and structure them into an overall plan, and (c) a decision-executing ability that transforms decisions into behavioural actions.

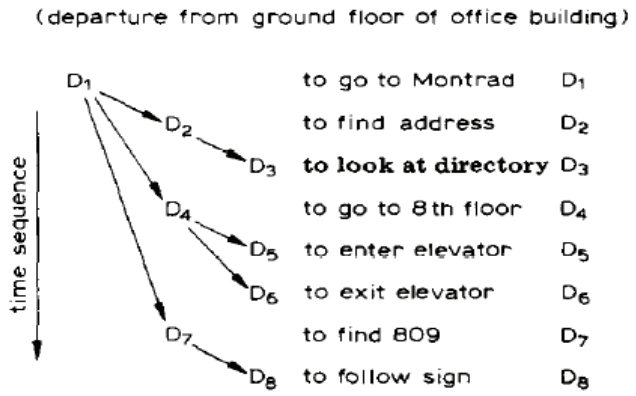


Figure 2.1 Decision diagram showing the hierarchical structure (Passini, 1980).

In the 1990s, wayfinding primarily relied on physical signage, maps, and landmarks. However, with the advent of digital mapping tools, GPS navigation systems, and smartphone applications, individuals now have access to real-time, personalized navigation assistance. These technologies have revolutionized how people find indoors and outdoors, providing step-by-step directions and dynamic routing based on current conditions. Understanding human cognition and perception has deepened, leading to insights into how individuals process spatial information and make wayfinding decisions. This knowledge has informed the design of wayfinding systems that are more intuitive and user-friendly, considering factors such as mental mapping, landmark recognition, and route memorization (National Research Council, 1986). It remains a crucial aspect of human navigation, drawing upon sensory information, cognitive processes, and past experiences to guide individuals from one point to another. The wayfinding activity becomes complex in public large-scale environments.

(iii) *2000s-2010s*: With the rise of digital technology, wayfinding expanded beyond physical signage to include digital and mobile solutions. GPS navigation systems, smartphone apps, and

interactive maps have revolutionized how people navigate indoor and outdoor environments. User experience (UX) design principles became central to developing digital wayfinding tools (Giudice & Legge, 2008; Woodwill, 2006; Cerri et al., 2017; Cardillo & Caddemi, 2019).

Wayfinding has also become more inclusive, emphasizing designing for diverse user needs, including those with disabilities. There is now a greater emphasis on creating inclusive and accessible environments for all individuals, including those with disabilities. Wayfinding design now considers universal design principles, ensuring that wayfinding systems accommodate diverse needs and preferences. This includes tactile signage, audible cues, and clear visual communication, making wayfinding easier for everyone, regardless of physical, sensory or cognitive abilities (McIntyre, 2011; Folska, 2012).

(iv) *2020s*: The 2020s have seen a further integration of technology into wayfinding, with advancements in augmented reality (AR) (Yoon et al. 2019), artificial intelligence (AI) (Adler-Milstein & Dhaliwal, 2021), and the Internet of Things (IoT) (Afif et al., 2021) leading to more personalized and context-aware navigation experiences. In the 2020s, there is a growing recognition of the importance of user feedback and engagement in the design process. Designers now involve end-users in developing wayfinding systems, conducting usability studies and gathering input to create solutions tailored to the target audience's specific needs and preferences. This human-centered approach ensures that wayfinding systems are intuitive, effective, and responsive to the needs of the people using them.

The evolution of wayfinding, shaped by technological advancements, insights from cognitive psychology, principles of urban design, and a growing emphasis on accessibility and inclusivity, has transitioned from traditional static signage to a more comprehensive array of physical and digital tools. This shift highlights the importance of user-centric design and seamless integration of technology. Spanning from the 1960s to the present, the study of wayfinding has seen significant progress, resulting in the development of sophisticated and user-friendly systems that improve mobility, accessibility, and overall user experience in both indoor and outdoor settings. The complexity of the wayfinding process varies depending on several factors, including infrastructure, accessibility priorities, economic development, socio-cultural considerations, urban planning strategies, and levels of technology adoption.

2.3 Factors contributing to the difference in Wayfinding between High Income (HIC) and Low Middle-Income Countries (LMIC)

In this section, the factors influencing wayfinding will be explored further, with a comparative analysis between high-income and low-middle-income countries. Wayfinding in High-Income Countries (HICs) and Low- and Middle-Income Countries (LMICs) can differ in several ways due to the following factors:

(i). Infrastructure: HICs typically have well-developed public transportation systems and options, including extensive road networks and signage. In contrast, many LMICs have limited infrastructure, including poorly maintained roads, inadequate public transportation, and inconsistent signage (Maunder et al., 2004).

(ii). Accessibility: HICs often prioritize accessibility for individuals with disabilities, with features such as ramps, elevators, and tactile paving. In LMICs, accessibility infrastructure may be lacking, making navigation challenging for individuals with disabilities (Venter et al., 2003; Mashiri et al., 2005).

(iii). Technology: HICs have more advanced technological solutions for wayfinding, such as GPS navigation systems, smartphone apps, and digital maps. In contrast, LMICs have limited access to technology and rely more on social methods of wayfinding, such as verbal directions (Nagraj et al., 2021).

(iv). Socioeconomic factors: Socioeconomic factors can influence wayfinding practices. For example, in some LMICs like India, people may rely more on local knowledge and social networks for wayfinding (Ahmed, 2015). At the same time, HICs have a greater reliance on formal signage and technological tools.

(v). Urban planning: Urban planning practices can vary significantly between HICs and LMICs, impacting the layout of cities and the ease of navigation. HICs may have more organized and grid-like city layouts, while LMICs may have more informal and chaotic urban environments (Nagraj et al., 2021).

In conclusion, the disparities between high-income countries (HICs) and low- and middle-income countries (LMICs) across various factors significantly influence wayfinding

practices and experiences. HICs typically boast well-developed infrastructure, prioritised accessibility features, advanced technological solutions, and organized urban planning, collectively facilitating smoother navigation for residents and visitors alike. Conversely, LMICs often face challenges from limited infrastructure, inadequate accessibility measures, restricted access to technology, socioeconomics impacting navigation methods, and less organized urban planning. These disparities highlight the importance of considering context-specific approaches and addressing the unique challenges LMICs face to enhance wayfinding experiences in such countries. The following section presents unique factors that make wayfinding in India (one of the LMICs) unique worldwide.

2.4 Wayfinding in India

Wayfinding in India presents characteristic challenges stemming from its diverse cultural, geographical, and infrastructural landscape. Here are some key aspects that make wayfinding in India distinctive:

(i) Cultural and language diversity: India is known for its rich cultural diversity, with numerous languages, dialects, customs, and traditions. This diversity extends to wayfinding, where signage and sensory cues may vary significantly across regions, reflecting local languages and cultural norms (Patil, 2008).

(ii)Rapid urbanization and overcrowded public environments: India is undergoing rapid urbanization, expanding and developing cities. This rapid growth can result in inconsistent infrastructure, frequent construction activities, and changing landmarks, impacting wayfinding efforts (Venter et al., 2003; Maunder et al., 2004; Mashiri et al., 2005). Further, Indian cities often exhibit high population densities, chaotic traffic conditions, and intricate street layouts. Wayfinding in urban areas can be challenging due to crowded streets and public transport, limited signage, and a lack of standardized addressing systems, especially in older parts of cities (Nagraj et al., 2021).

(iii)Reliance on human assistance: People in India heavily rely on asking for directions from locals or seeking assistance from passersby, especially in areas with limited signage or digital navigation tools. Human interaction is vital in wayfinding and fostering community engagement and social connections (Patil, 2008; Ahmed, 2015; Nagraj et al., 2021). Human

assistance in India is still the preferred way of wayfinding because, as a society, Indians have always depended on giving and receiving help. As a result, signage systems were and still are scarce, especially in older parts of the cities and transport commuting systems. Cultural and linguistic diversity, lower literacy in the country and overcrowded public environments have led to sustaining the culture of asking and giving help in Indian cities.

(iv)Informal landmarks: In many Indian cities and rural areas, landmarks such as temples, markets, trees, or prominent buildings serve as crucial wayfinding aids. These informal landmarks significantly guide individuals through the urban or rural landscape, not a formal signage system (Ahmed, 2015).

(v)Emerging digital solutions: With the increasing penetration of smartphones and digital technologies, there is a growing trend towards adopting digital navigation apps and platforms in India. In recent years, high digital technology and smartphone penetration have occurred even among lower-income groups in India, yet disparities persist. Challenges include limited internet access, especially in rural areas, digital literacy gaps, affordability concerns, and language barriers. Disparities in access to quality smartphones and reliable internet services persist, affecting the digital inclusion of marginalized communities, including people with disabilities.

While wayfinding focuses on the cognitive process and finding one's way within a space, accessibility encompasses the design and provision of inclusive environments and resources that facilitate navigation and participation for people of all abilities. The focus on accessibility in built environments is limited to removing structural barriers in India (Raheja, 2016; Raheja & Sinha, 2016; Collective For Spatial Alternatives & Indian Center for Human Rights Law, 2017). Removal of cognitive barriers associated with wayfinding in built environments has been neglected for a very long time as there are very few published studies focusing on wayfinding behaviour and challenges in the Indian context (Nagraj et al., 2021; Raheja & Sinha, 2018; Ahmed, 2015; Patil, 2008).

The disparities between high-income countries (HICs) and low- and middle-income countries significantly influence wayfinding practices and experiences, as discussed in section 2.3. The solutions proposed in these contexts often rely heavily on advanced technology, which may not be applicable or suitable for LMICs like India, as discussed in section 2.3. Consequently, without adequate research, policies and guidelines may fail to account for the unique challenges faced by wayfinders in India. This oversight can result in design solutions

that do not effectively align with the country's social realities and built environmental aspects. Wayfinding in India presents distinct challenges, including cultural diversity, urban complexity, the emergence of digital solutions, reliance on informal landmarks, and human assistance. To effectively address these challenges, there is a critical need for in-depth research specifically tailored to the Indian context. Such research should include contextual inquiry conducted in real public places to gain comprehensive insights into the experiences of wayfinders. Carlson et al., 2010 state that wayfinding experience and performance are affected by the dynamic interplay between the wayfinder's characteristics and the environment. To conduct wayfinding research, knowing which wayfinder's characteristics affect the wayfinding experience and performance the most is essential. The following sections identify such wayfinder attributes from the literature review.

Having a disability can significantly affect wayfinding, the process of navigating and orienting oneself in an environment. Creating accessible environments incorporating multiple sensory cues (tactile, visual, and auditory) and ensuring physical accessibility can significantly improve wayfinding for people with disabilities.

The major work in environmental design is done from the architectural perspective of removal of physical barriers to promote accessibility to people with disabilities in public buildings (Vardia et al., 2018; Chaurasia et al., 2017; Raheja & Suryawanshi, 2014). However, wayfinding research and design for people with disability is an under-researched area in India to date.

As a first step, the following section reviews the models as they explain the society's general perception, belief and behaviour, which influences policy making. These models expose how society can enable or limit access to employment, public buildings such as public transport, etc., for individuals with disabilities. They also shed light on underlying societal attitudes, perceptions, and biases. As societal views on disability and functional loss have evolved, so have these models reflecting these changes. By examining the development and application of these frameworks, we gain a clearer understanding of the shifting perspectives on disability over time.

2.5 Disability Models

Preliminary assessment of different models of disability is crucial, as Smart (2004) emphasizes, because they provide definitions of disability and inform policy development and implementation. Disability studies gained prominence in the 1970s, mainly due to the self-organization of people with disabilities and a growing recognition of disability as a human rights issue. The model's approach has been instrumental in advancing a rights-based perspective, empowering disabled individuals to actively participate in decision-making related to education, employment, and policies governing access to public spaces in India over the past few decades. In many parts of the world, the participation of disabled people in all aspects of public life has become a reality over the last thirty years (Anand, 2016).

In Western research, the shift from the 'medical' to the 'social' model has sparked new approaches to understanding disability as a social and political experience (Morris, 2001). Historical accounts of disability in Europe and the USA have helped to reclaim personal and community identities, challenging historical injustices and striving to end marginalization (Turner & Stagg, 2006).

In India, disability history developed in three areas: advocating for necessary services, broader medical history, and religious interpretations of disability (Buckingham, 2011). Religion plays a key role in shaping the understanding and treatment of disability (Kaur & Arora, 2019). Post-1960s, India's disability rights movement gained momentum, culminating in significant legislative measures such as the Persons with Disabilities Act of 1995, which responded to collective demands for equality and inclusion (Chakraborty, 2009).

The Religious Model of disability varies across different religions, influencing how disability is understood and how individuals are treated. Religion plays a crucial role in shaping these perspectives (Kaur & Arora, 2019). As the oldest model, it appears in many religious traditions (Retief & Letsosa, 2018). In Hinduism, disability is often seen through karma and reincarnation, where disabilities are believed to result from sins committed in a past life (Kaur & Arora, 2019; Karna, 1999). In contrast, Islam and Christianity emphasize that all humans, regardless of ability, are inherently valuable, viewing disability as an opportunity for compassion and service (Hajira Shanaz, 2023). The Charity Model frames people with disabilities (PWDs) as dependent and in need of pity, portraying them as victims in need of

assistance. Critics argue it reinforces harmful stereotypes, depicting PWDs as helpless (Duyan, 2007).

The Charity or the Philanthropic Model views people with disabilities (PWDs) as victims of their impairment who require pity and assistance. This model portrays their situation as tragic, suggesting that PWDs need special services and institutions due to their perceived differences (Duyan, 2007). Unlike the moral/religious model, the charity model promotes the humane treatment of PWDs (Henderson & Bryan, 2011). However, many in the disability community criticize this model for reinforcing stereotypes of PWDs as helpless, dependent, and incapable of contributing to society. It emphasizes providing welfare and support but excludes PWDs from mainstream development (Spark, 2022). In India, the state's attitude has always been one of charity and welfare since the colonial period. After independence, the Indian state embraced social welfare as a key responsibility, aiming to promote the well-being of marginalized groups, including children, women, individuals from scheduled castes and tribes, and people with disabilities (Billimoria, 1985).

The Medical Model of disability, which gained prominence by the 1960s, views disability as a physical or mental impairment treated as a "medical condition." It defines disability as a deviation from the norm, leading to perceptions of people with disabilities as "deficient" or "incomplete." This model emphasizes the need for treatment, rehabilitation, and correction (Twardowski, 2022). It focuses on biological factors, sets medical standards for treatment and legal evaluation, and advocates for healthcare investment to support people with disabilities (Sanabria, 2022). The model has influenced medical rehabilitation by focusing on curing or managing disabilities through medical professionals. The evolution of prosthetics and assistive aids as different therapeutic interventions were developed to help PwDs perform daily activities with the help of artificial limbs (Mohit, 2000). However, insights from existing research strongly suggest that the notion of the individual as distinct from the “social” is intrinsic to the critique of the medical model (Anand, 2016).

Nagi’s Disablement Model (1965) introduced the environment to understanding disability, exploring factors within family, community, and society that influence it. However, the model's view of the environment was limited, considering it relevant only when activity limitations interact with external demands. The model still primarily attributes disability to medical conditions and impairments (Brandt & Pope, 1997).

The social model of disability developed out of the disabled people's movement in Europe and the USA in the 1970s and 1980s. The Social Model, introduced by Oliver (1981) and expanded by the Union of the Physically Impaired against Segregation (UPIAS) (1976), argues that disability results from social and environmental barriers, not impairments themselves. These barriers stem from society's failure to offer appropriate services and to fully integrate the needs of disabled people into its social framework (Oliver, 1990, 2004). These obstacles are both physical and ideological, embedded in discriminatory and disempowering practices and structures that hinder disabled individuals from achieving full social participation and citizenship (Kroger, 2009).

While the Medical Model aims to "repair" individuals, the Social Model emphasizes adapting environments to remove barriers and promote inclusion. The UN Convention on the Rights of Persons with Disabilities (2006) reflects this shift, encouraging policies focusing on social participation and accessibility. The Social Model promotes rights, reduces stigma, and fosters inclusive design to ensure individuals with disabilities can freely participate in society and make independent choices. The model advocated for a robust minority identity and called for improved services and facilities for individuals with disabilities, including higher benefits, expanded educational and employment opportunities, and greater access to public amenities. The government's hesitation in developing and implementing a comprehensive disability policy reflects the prevailing socio-cultural assumptions about disability in India, where a religio-moral-medical model continues to dominate (Ghosh, 2016).

In contrast, the United Nations Convention on the Rights of Persons with Disabilities (2007) explicitly affirms that states have a proactive and vital role in promoting, protecting, and ensuring the full and equal enjoyment of all human rights and fundamental freedoms by persons with disabilities, while also upholding respect for their inherent dignity. The convention defines persons with disabilities as those with long-term physical, mental, intellectual, or sensory impairments, who, in interaction with various barriers, may face challenges in fully participating in society on an equal footing with others. Based on the principle that all human beings possess inherent dignity, which guarantees the enjoyment of human rights, persons with disabilities are unequivocal rights holders. The emphasis is, therefore, not on the impairment itself but on the societal barriers that impede the realization of rights. In addition to physical obstacles, this approach highlights various social, behavioral, and stereotype-based barriers that contribute to and perpetuate the exclusion of persons with disabilities.

Thus, defining disability remains a complex and evolving issue, as both practitioners and scholars continue to debate the best ways to conceptualize and address disability and impairment (Das, 2008). While the medical condition or impairment often serves as the foundation for a range of social interpretations, increasing attention is being paid to the sociocultural, religious, and linguistic contexts that shape the way people with impairments or disabilities are understood (Ghosh, 2016).

The Cultural Model explores how cultural factors shape the understanding of disability. Disability is a socially constructed experience, with meanings varying across cultures and contexts (Snyder & Mitchel, 2005; Waldschmidt, 2017). British sociologist Tom Shakespeare emphasized the need to research cultural representations of people with disabilities as early as 1994. The theoretical framework for a cultural model of disability was initiated by Snyder and Mitchel in 2005. The cultural model of disability is based on assumptions regarding the cultural determinants of understanding disability (Waldschmidt, 2017). There is no universal definition of disability; its understanding can change over time and across different cultures. The cultural model explores personal autonomy and independent living concepts within specific cultural contexts and related discourses. It also examines the interdependence between able-bodied and disabled individuals in daily life and its implications for autonomy.

The International Classification of Functioning, Disability and Health (ICF) framework, 2001, integrates medical and social models of disability by acknowledging the interplay of biological, individual, and social factors in shaping function and disability. It highlights the environment's role in the social construction of disability, noting that while social barriers contribute to participation restrictions, the physical environment is intrinsically linked to functional performance. The model strongly advocates enabling physical environments to foster social and political change towards more inclusive societies. Built environments have historically been designed for the general population without considering the needs of diverse populations with a range of physical functions (Mintz, 2021). It calls for changes to unresponsive environments to improve participation and inclusivity. Under this model, societies use principles of Inclusive Design to maximize accessibility for everyone, including disabled people (Masala & Petretto, 2008).

The nature of our study finds social and ICF models more suitable for conducting research in the area of Inclusive wayfinding in public transportation in the Indian context. The social model helps unravel the role of societal attitudes, experiences, and behaviour in the

wayfinding process of people with and without vision impairments. The ICF model helps to delve deeper into how the information, service, and built environmental design of Mumbai Suburban Railways impact the wayfinding process.

2.5.1 Disability as Stigma

Across the world, stereotypes, prejudice, and stigma contribute to the discrimination and exclusion experienced by people with disabilities and their families in all aspects of their lives. Disability scholars have examined the relevance of the impaired body in the construction of identity, as disability is experienced in, on and through the body. In all societies, the experience of disability is mediated by sociocultural constructions that give meaning to impairments and influence the experiences and interactions of disabled people in different socio-historical contexts (Ghosh, 2016).

Rohwerder's report (2018) looks at available evidence on the drivers of disability stigma in developing countries. Key findings about the drivers of disability stigma include: 1) Lack of awareness about disability causes and characteristics contributes to stigma. 2) Misconceptions, often rooted in cultural or religious beliefs, blame disabilities on various factors. 3) This leads to dehumanization and shame towards people with disabilities, affecting how they are treated. 4) False beliefs about their abilities, financial contribution, relationships, and contagiousness contribute to stigma. 5) Discriminatory laws and segregation perpetuate negative stereotypes. 6) Attitudes towards disability vary within countries, communities, and families. 7) Different impairments and their severity levels face varying degrees of stigma. People with intellectual disabilities, severe mental health conditions, albinism, and sensory disabilities are often more stigmatized than people with physical disabilities. 8) Women with disabilities face double discrimination due to gender and disability stigma. 9) Socio-economic status influences attitudes towards disability. Rural areas may have more harmful practices towards people with disabilities compared to urban areas.

Stigmatization can exacerbate challenges faced by people with disabilities to negotiate "self" in social interactions. Stigma can be defined as socially undesired differences that can separate and discredit individuals in the larger society. Consequently, individuals facing

stigmatization may perceive themselves as inferior or a failure and experience lower self-esteem (Goffman, 2009).

India is an important context to examine self, disability, and associated stigmatization, because the impact of intersectional issues, such as social class, caste (Kamaya et al. 2019) and gender (Das, 2008), on the experiences of individuals with disabilities is more apparent, relative to Western countries (Rao & Kalyanpur, 2015). Thus, individuals' experiences of their disabilities and self in India have to be examined by considering these intersectional issues that can exacerbate or alleviate stigmatization associated with disability, and hence diversify their experiences. The examination of such variations in the experiences of disability, self, and stigmatization in India can provide scholars and professionals around the world with insights into expanding theories of disability and self and developing stigma- and culturally sensitive approaches to supporting people with disabilities.

Disability complicates hierarchical social structures, affecting families across all social classes and castes. While individuals with disabilities can face marginalization regardless of their social status, those from lower castes or tribes are particularly vulnerable due to the combined effects of social status and disability (Antony, 2013; Buckingham, 2011). In lower-income families, survival often takes precedence, leading parents to prioritize work over health care, and in some cases, send children to work instead of school. This reluctance is especially pronounced for children with disabilities, as they are perceived as less likely to meet societal expectations of contributing members (Staples, 2012; Addlakha, 2007). Hence, children with disability in lower social income groups receive poor education. In hierarchical social relationships, individuals with higher status have greater freedom to express themselves, while those of lower status must adjust their behaviour to accommodate their superiors. As social status increases, individuals are more likely to express their personal, internal selves.

People with disabilities face numerous challenges in their fight for inclusion and equality, with women facing even more significant disadvantages due to the intersection of disability and gender. Further, In India, poverty is seen both as a cause and a consequence of disability. Although both men and women with disabilities experience discrimination, women are particularly vulnerable to "triple discrimination" — both as women and as individuals with disabilities and belonging to lower socio-economic groups. This triple marginalization makes them more susceptible to sexual and verbal abuse, physical violence, economic barriers, and fewer opportunities in education, healthcare, and employment compared to men with

disabilities and non-disabled women (World Bank, 2007). For women with visible disabilities, their encounter with social challenges is common, while women with invisible disabilities are likely to go to great lengths to pass as “non-disabled” to avoid disclosing their disability status and falling prey to this stereotyping (Davis, 2005).

Beyond economic challenges, disabled women also endure social exclusion, stigmatization, and an inability to participate fully in public life. They often face sexual harassment, including inappropriate touching and "gazing," both within their families and in public spaces. This mirrors the broader experience of many women in India, who face humiliation and discomfort in various aspects of their lives (Chahal, 2021; Basu, 2010).

Kayama et al. (2019) advocate that there is a need to holistically assess individuals’ experiences in multiple social contexts to understand their experiences, such as public places fully. Individual interviews with participants with disabilities provided rich information about the real-life experiences of disability and self, which allows us to examine individuals’ experiences in the context of their everyday interactions with others. However, studies on disability identity examining narratives obtained from individuals with disabilities are relatively limited.

The above literature highlights the Indian socio-economic context of disability. It highlights the importance of social and environmental factors while conducting wayfinding research and design.

2.6 Understanding the user

Arthur and Passini (1992) wrote: *‘There is nothing homogeneous or uniform about the users of the built environment—particularly in their abilities to assimilate and process environmental information. It is, therefore, time that we stopped designing for some vague (and imaginary) able-bodied “user” and started to concern ourselves with a much broader but more realistically focused view of user groups that are the ultimate consumers of everything that we design, build, fabricate, and install’*.

In large-scale public buildings, most architectural elements and wayfinding systems have been designed for users of "average" cognitive and physical abilities who possess basic wayfinding skills (Wilkoff, 1994). However, many users cannot fully use the existing designs and services in public buildings because they do not fit the profile of "average" users, like those

with impairments or temporary health conditions (limping while walking due to injury in the leg) or situational conditions (parent facing difficulty climbing the staircase with a toddler in hand) (Microsoft, 2016). Having vision (Passini & Prolux, 1988; Finkel, 1999; McIntyre, 2011; Folska, 2012; Morag et al., 2016) is established as the most critical variable that contributes to the ease of wayfinding.

Wayfinding in large-scale, urban-built public buildings can present significant challenges for impaired individuals. Vision is the primary sensory modality for wayfinding, with other modalities coming into play when vision is unavailable. For individuals with visual impairments, mobility is essential for achieving social and professional independence. International studies like that of Golledge (1999) emphasized that the inability to travel independently and engage with the world can be one of the most significant obstacles those with visual impairments face. Wayfinding is further affected by the types of visual impairments, their severity level and the time of impairment, i.e. by birth or later age.

For individuals with visual impairments, 'inaccessibility' is primarily attributed to difficulties accessing information and spatial knowledge rather than physical barriers within a space (Martson, 2002). This participatory relationship with visually biased public spaces is considered one of the most challenging interactions between humans and environments (Leven, 2003; Clarke et al., 2011). A more significant part of wayfinding support is taken away from individuals due to the primary format of information being print media. Their inability to locate information about where they are or where to go in public places like malls, hospitals, public transportation, colleges and universities, and airports makes it difficult for them to navigate their way around and discourages them from leaving the house. The study shows 80–90% of visually impaired individuals live indoors (Li et al., 2010). Navigating inside buildings presents unique challenges for visually impaired individuals, as they struggle to detect and use environmental cues like light, smell, and noise, which are crucial for orientation (Cattaneo & Vecchi et al., 2011). This difficulty is exacerbated when moving through unfamiliar, crowded, and wide-open spaces, compounded by randomly placed obstacles. Consequently, it often takes them to become accustomed to new spaces and develop a mental map.

While indoor travel might eliminate some outdoor hazards, risks such as head-level and trip accidents or encounters with movable objects persist (Ganz et al., 2012). Learning to navigate environments like hospitals, malls, or large buildings can be particularly challenging due to the lack of accessible information and environmental cues, making it difficult to

determine the best route to reach a destination in such complex, crowded settings (Williams et al., 2014).

Learning to navigate in familiar or unfamiliar places safely and effectively requires substantial practice for people with vision impairments (Fortin, 2008). Learning to navigate in public spaces often begins with assistance from family, friends, or peers with vision impairments during the initial stages of travel (Balata et al., 2014; Afrooz et al., 2012). This guided experience builds their confidence and familiarity with the environment, eventually empowering them to navigate independently (Passini, 1988).

The following section reviews the unique aspects of visual impairment in India, further explaining how they affect the wayfinding ability of people with vision impairments.

2.6.1 Visual Impairment in the Indian Context

Visual impairment describes the total group of persons whose vision is affected by impairments in seeing, irrespective of the nature or extent, and that cannot be fully corrected using glasses or contact lenses (National Blindness and Visual Impairment Survey Report 2015-2019, 2020). Visual impairment is categorized into blind and low vision (Kapur, 2017). Vision impairment is understood in terms of visual acuity (VA). Visual acuity is a measure of the ability of the eye to distinguish shapes and the details of objects at a given distance. 20/20 vision is a term used to express normal visual acuity (the clarity or sharpness of vision) measured at a distance of 20 feet. If you have 20/20 vision, you can see clearly at 20 feet what should usually be seen at that distance. The severity of the vision impairments correlates to the sharpness or clarity of vision at a specific test distance.

Vision impairment is classified under two groups based on distance and severity: distance and near-presenting vision impairment:

Distance vision impairment:

Mild – presenting visual acuity worse than 6/12-6/18 (ratio 1:2)
Moderate – presenting visual acuity worse than 6/18-6/60 (ratio 1:3)
Severe – presenting visual acuity worse than 6/60-3/60 (ratio 1:10)

Blindness – presenting visual acuity worse than 3/60 (ratio 1:20)

Near vision impairment: Presenting near visual acuity worse than 20/40 with existing correction (He et al., 2012)

These definitions of vision impairment are used in the National Blindness and VI Survey (Vashist et al., 2022). Functional Low vision is defined as 'A person with impairment of visual functioning even after treatment and/or standard refractive correction, and a visual acuity of less than 6/18 to light perception, or a visual field of less than 10 degrees from the point of fixation, but who uses, or is potentially able to use, vision for planning and/or execution of a task' (National Blindness and Visual Impairment Survey Report 2015-2019, 2020). The points emphasized are that there is significantly reduced vision, and visual performance is affected, but vision still can be used. For the persons who do not fall in the category of blindness as defined in the Act and whose visual acuity falls between 6/ 12 and 6/60 in the better eye after the best possible correction, the term "low vision" should be used. It is important to note that visual acuity (VA) alone does not determine the overall quality of vision required for optimal functioning. The functional assessment of the vision comprises the visual field, colour vision, stereopsis, extraocular motility, contrast sensitivity, glare sensitivity and night vision, besides VA (Kv & Vijayalakshmi, 2020). Visual impairment can manifest either from birth (congenital) or later in life (acquired) due to various factors. Congenital causes include conditions such as retinopathy, glaucoma, cortical visual impairment, and optic nerve hypoplasia. Acquired visual impairments may arise from cataracts, trauma, accidents, or insufficient nutrition (Kapur, 2017).

2.5.1.1 Prevalence

Globally, at least 2.2 billion people have a near or distant vision impairment (WHO, 2023). 237 million people are thought to have moderate or severe distance vision impairment in 2020. 39 million people are believed to be blind globally in 2020. This is set to increase to 115 million people in 2050. The 20 countries estimated to have low-income countries dominate the highest prevalence of visual impairment (89%). 45% of visual impairment occurs in India and China (Figure 2.2) (LESH, 2023). India is the second most populous country in the world, home to over 20 percent of the world's blind population (Sharma, 2020). Nearly 40- 60 million

people in India have some form of vision impairment (Garewal, 2020). The estimated prevalence of blindness is 0.36% of the population (4.95 million) and 2.55% of mild to severe levels of visual impairment (2.55%) (National Blindness and Visual Impairment Survey Report 2015-2019, 2020).

Population growth and aging are expected to increase the risk of more people acquiring vision impairment (WHO, 2023; Laser Eye Surgery Hub, 2023). Additionally, blindness was more prevalent in rural areas than urban areas, with rates of 2.14% and 1.80%, respectively, in India (National Blindness and Visual Impairment Survey Report 2015-2019, 2020).

2.5.1.2 Economic barriers

Blindness disproportionately affects those in poverty, with the lowest socioeconomic bracket experiencing a blindness rate nine times higher than the highest bracket, as shown in the Andhra Pradesh Eye Disease Study conducted in India (Dandona & Dandona, 2001). Limited access to healthcare due to cost and accessibility exacerbates this disparity. Blindness often leads to a lack of education and unemployment, perpetuating the cycle of poverty and resulting in decreased income and living standards for the visually impaired, ultimately leading to early mortality (Yuki, 2020). Besides the links to poverty, poor vision can have negative psychosocial consequences and disrupt people's daily lives. According to the WHO, adults with vision impairment often have lower rates of workforce participation and productivity and higher rates of depression and anxiety than the general population. This is significantly higher than the prevalence of depressive and anxiety disorders in the general population without vision (Kurian & Ayyangar, 2023).

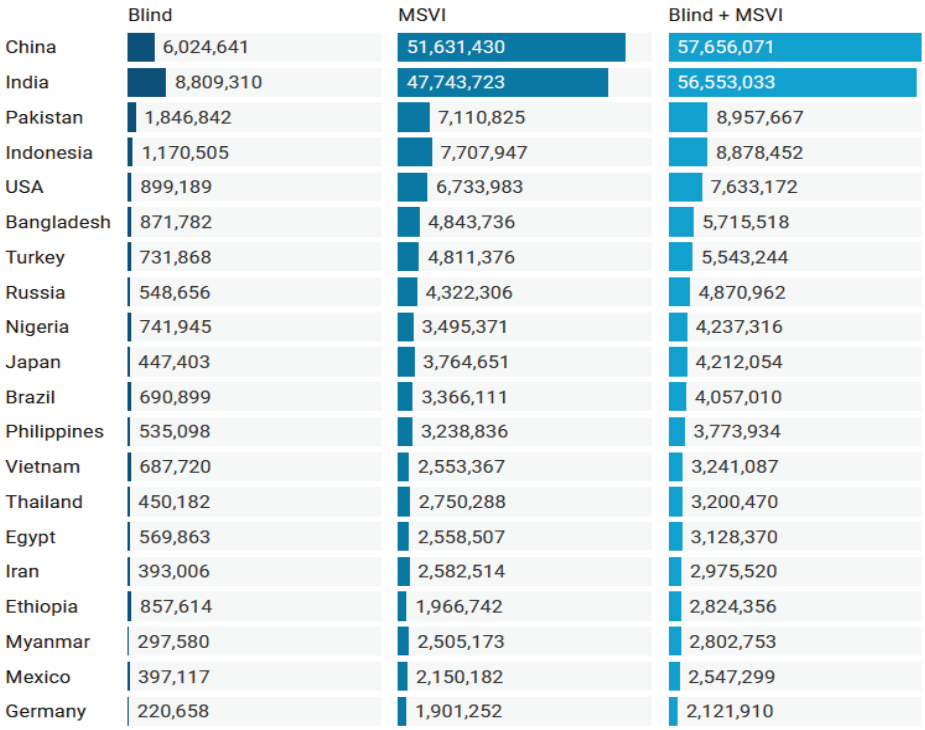


Figure 2.2 The top 20 countries have the highest numbers of people with blindness and moderate to severe visual impairments (LESH, data by IAPD Vision Atlas, 2023).

2.5.1.3 Literacy

Notably, blindness is more prevalent among illiterate individuals (3.23%) compared to those who are literate (0.43%) in India (National Blindness and Visual Impairment Survey Report 2015-2019, 2020). Although braille education is crucial for increasing literacy, independence, and employability among visually impaired individuals (Asian College of Teachers, 2024), braille literacy rates are low worldwide. India hosts 20% of the world's visually impaired population but has been able to achieve only 1% braille literacy rate. In the more developed United Kingdom, this rate is slightly higher at 4% (Yuki, 2020). The challenge lies in the outdated teaching methods and shortage of qualified teachers, making braille literacy difficult, particularly in developing countries. Without braille education, visually impaired individuals face significant barriers to communication and employment, often requiring interpreters for written tasks (Yuki, 2020).

The term "information literacy" has evolved into "digital literacies" with the transition from the information age to the digital age, driven by digitization. Digital literacy encompasses skills needed to navigate information and communication technologies effectively. This shift impacts PVIs, who face challenges accessing and using digital technology. Many websites remain inaccessible to visually impaired individuals due to issues like text colour and layout and web pages lacking text labels for screen reading software used by the blind. Higher education levels, household incomes, and motivation for internet use are linked to more favorable outcomes for PVIs (Venkatesan, 2023).

In conclusion, vision impairment poses significant challenges globally, with India being particularly affected by its large population. People with vision impairments in low- and middle-income countries like India face more significant economic challenges, including poverty, unemployment, and limited access to financial resources, exacerbating social exclusion and dependency on family members for support. Illiteracy is closely linked to higher rates of blindness, highlighting the importance of education, particularly in braille literacy, for visually impaired individuals. Limited access to inclusive education and literacy programs hinders the educational and socio-economic opportunities for individuals with vision impairments, leading to lower literacy rates and reduced access to employment opportunities, perpetuating cycles of poverty. Moreover, the transition to digital literacy presents new obstacles for visually impaired individuals, as many digital platforms remain inaccessible. Overall, while the specific social barriers faced by people with vision impairments may vary between high-income and low and middle-income countries, the common themes of stigma, discrimination, limited access to resources, and social exclusion persist across different contexts. Addressing these barriers requires comprehensive strategies that prioritize accessibility, inclusivity, and empowerment to ensure the full participation and inclusion of individuals with vision impairments in society. People with disabilities face challenges primarily due to societal barriers, which transcend into physical environmental barriers (as the public places are built by the able-bodied world) rather than their visual condition (Envision, 2023). Having vision impairment in low-middle-income countries like India presents a unique set of challenges and opportunities for designing wayfinding approaches in public environments that may not be the same as the ones used by UMIC and HIC countries.

The following section reviews the wayfinding research done in public environments for people with vision impairments.

2.6.2 Wayfinding with Vision Impairment in Indian Context

Effective navigation and orientation skills are essential for sighted and blind individuals of all ages to navigate their surroundings and communities efficiently. However, when there is a partial or complete loss of vision, the task of navigation and wayfinding becomes significantly more challenging. This section reviews the existing research on wayfinding in India and other countries to understand how vision loss affects wayfinding ability. Vision loss can significantly impact wayfinding in countries like India, posing unique challenges due to distinct personal factors associated with vision impairment, social factors and physical characteristics of public environments. Vision loss presents several challenges for people with vision impairments when it comes to wayfinding:

(i) Limited Accessibility: India still faces challenges in providing fully accessible environments for individuals with disabilities, including those with vision loss. Uneven terrain, lack of tactile pathways, and inadequate signage can make navigation difficult for people with vision impairments. Vision loss can make identifying pathways and obstacles in the environment challenging, increasing the risk of collisions or getting lost. Individuals may find it hard to detect barriers, uneven surfaces, or objects in their path without visual cues (Raheja & Tyagi, 2016). Inadequate accessibility exacerbates the complexity and challenges of wayfinding.

(ii) Digital Divide: While digital technology can aid wayfinding through smartphone apps, GPS navigation, and other tools, individuals with vision loss may face barriers to accessing and using these technologies in India. Limited internet connectivity, affordability issues, and digital literacy gaps can hinder their ability to leverage digital navigation aids (Venkatesan, 2023).

(iii) Social Factors: Social norms and practices in India can also influence how individuals with vision loss navigate their surroundings (Ghai, 2001; Das, 2011). Social attitudes, stigma, and perceptions about disability may impact their confidence and independence in wayfinding.

(iv) Overcrowded environments: India is the second most populous country in the world, with almost all outdoor and indoor public places being overcrowded. Overcrowded environments

can significantly impact the wayfinding abilities of people with vision impairments. In such environments, there may be increased auditory and tactile distractions, making it harder for individuals to rely on their remaining senses for navigation. Additionally, crowded spaces can create obstacles and barriers, impeding the ability of people with vision impairments to navigate safely and independently. The lack of clear pathways and unpredictable movements from other individuals can exacerbate the challenges those with vision impairments face in crowded environments, potentially leading to increased stress and difficulty reaching their intended destinations (Nagraj et al., 2021).

(v) Challenges in unfamiliar and changing environments: Navigating unfamiliar or changing environments can be particularly challenging for individuals with vision loss. Difficulty in wayfinding due to vision loss can lead to feelings of anxiety, stress, or disorientation, particularly in unfamiliar or crowded environments (Small et al., 2012). This can affect confidence and independence in making wayfinding decisions. Anxiety correlates with veering, or slight deviations from the path, in blind navigation. PVIs may struggle to gather and interpret spatial information without visual references, leading to increased reliance on assistance from others or alternative navigation aids. Vision loss may necessitate a greater reliance on memory and familiarity with the environment for navigation (Passini, 1996; Small et al., 2012). No Indian study has researched how people with vision impairments live in unfamiliar and changing environments in Indian conditions.

(vi) Reliance on alternative senses: People with vision impairments often rely on senses like touch, hearing, and smell to gather information about their surroundings. A sensory cue is a signal extracted from a perceiver's sensory input. The cue indicates the state of some world property the perceiver is interested in perceiving. Sensory cues are also referred to as landmarks (McIntyre, 2011). The sensory information gathered from different senses serves as an identity sign for place and object or path recognition. Single or multiple senses are employed to gather the same information. Sometimes, a single sensory cue is used differently to get different spatial information. However, these senses may not always provide sufficient or accurate spatial information for effective wayfinding, especially in complex or unfamiliar environments (Folska, 2012).

Tactile information offers direct sensory feedback, allowing individuals to perceive surfaces, textures, and structures through touch. It helps establish spatial orientation and identify critical points in the environment, aiding navigation and hazard avoidance. However, it's limited to nearby objects. The smell can also serve as landmarks, aiding navigation by associating specific scents with locations. Unpleasant or hazardous smells can serve as warning signs, alerting blind individuals to potential environmental dangers. Olfactory cues can be influenced by environmental factors such as air currents, temperature, and humidity, which can affect the intensity and direction of smells. Sound provides crucial environmental cues, aiding location and orientation from a distance. The direction of sounds can guide individuals along their intended path. Verbal instructions or guidance from fellow commuters, station staff, or automated systems (e.g., audio announcements) can provide real-time assistance in navigating complex environments. Excessive ambient noise in crowded or busy environments can make it challenging to distinguish relevant auditory cues, leading to confusion or sensory overload. Effective wayfinding for individuals who are blind typically requires the integration of multiple sensory modalities, including auditory cues, tactile information, and spatial memory, alongside olfactory cues. Depending solely on olfaction, valuable information provided by other senses may be overlooked.

(vii) Limited personal aids and accessible environmental aids: People with vision impairments often require adaptive tools and techniques to support wayfinding, such as white canes, guide dogs, or assistive navigation devices. However, access to these tools may vary, and individuals may face barriers in using them effectively. *Shoreline*, using a white cane along linear paths, is a common technique for blind wayfinding (Passini, 1988). The strategy is used on paths that have an edge to avoid veering. The strategy fails if the sidewalk or road is poorly maintained or has no edges, especially in outdoor road conditions in countries like India (Nagraj et al., 2021). Personal assistive aids designed for people with vision impairments for mobility purposes aimed to improve the functional capabilities of individuals with disabilities (Senjam, 2019). The selling price of personal aids is one of the most critical factors determining the penetration of designed aid for people with disabilities in India (Rao, 2009). The white cane is the most common and popular mechanical and passive personal assistive aid for mobility in India by PVIs (Nagraj et al., 2021). It is a simple mechanical device that is traditionally used for detecting and identifying obstacles within a 3-foot range, finding steps or drop-offs in the

path of travel, or as a symbolic indicator to others that a person is blind, tends to warn other pedestrians to get out of the way (National Research Council, 1986). This assistive aid is popularly used both in indoor and outdoor navigation. It is available at affordable prices ranging from Rs 900 to 2400 depending upon the quality, materials features and technology (National Innovation Foundation, India, 2020). However, mechanical cane has several limitations. In public environments of LMICs like India, the white cane is indispensable due to the intricate environmental factors and elevated levels of ambient noise. (Nagraj et al. 2021). The cane can only detect obstacles up to knee level and only detect obstacles less than 1m, giving users very little time to take any preventive actions. Additionally, obstacles like moving vehicles can only be detected when dangerously close to the person (Singh et al., 2010).

Guide dogs are widely utilized in HIC countries like the United States to aid in safe navigation for individuals who are blind or visually impaired. These specially trained dogs provide independence and mobility by guiding handlers through various environments, navigating obstacles, and locating specific destinations. Additionally, guide dogs contribute to overall well-being, offering emotional support, alleviating isolation and anxiety, and promoting safety and inclusion (Lippa et al., 2016; Havik et al., 2015; McIntyre, 2011; Blades et al., 2002; Carreon, 2000). However, in contrast, guide dogs are rarely used for wayfinding in India (Nagraj et al., 2021), as there is limited social acceptance and restrictions on their use in public spaces. In addition, the affordance and maintenance of a guide dog is an added expenditure that a person with visual impairment in an Indian context will avoid considering the low economic background. Overall, Assistive technology in India is costly, and attempting to make it more affordable for everyone is still a distant dream (Nagraj et al., 2021).

(viii) Access to mobility training: Many sighted individuals take for granted their ability to navigate obstacles, walk in a straight line, and recognize landmarks without conscious effort or specific training. However, mobility training is pivotal for individuals with vision impairments who aim to become competent and independent travellers. This training equips them with essential skills and techniques to safely and independently navigate their surroundings. Through mobility training, individuals learn to use mobility aids like canes or guide dogs effectively, interpret environmental cues and landmarks, plan routes, negotiate obstacles, and utilize transportation systems. Moreover, it fosters the development of spatial awareness, orientation, and mobility skills, bolstering confidence and proficiency in navigating diverse environments

(Giudice, 2018). Accessing mobility training in India poses numerous challenges for people with vision impairments. Sparse availability, particularly in rural areas, limited awareness among individuals and families, financial constraints, inadequate physical accessibility to facilities, shortage of qualified instructors, and social stigma all hinder access to crucial training. Overcoming these obstacles is vital to ensure that individuals with vision impairments can access the training they need for greater independence in navigating their surroundings.

(ix) Reliance on human assistance: Individuals with vision loss often rely heavily on human assistance for wayfinding, particularly in crowded and unfamiliar environments in India, unlike developed nations where wayfinding design interventions have made them more independent. Human interactions (Patil, 2008; Ahmed, 2015; Nagraj et al., 2021) play a crucial role in wayfinding, and this reliance on assistance becomes even more pronounced. A similar finding was stated in a study conducted by Afrooz et al. (2012) on pedestrian wayfinding in Iran (LMIC) by low vision and no vision also reported that total blindness often leads to greater reliance on human assistance, while low-vision individuals use visual cues as landmarks.

The section highlights the distinctive hurdles related to vision impairment in India and their impact on the navigation abilities of individuals with visual impairments (PVIs). Globally, vision impairment presents significant obstacles. However, in countries like India, the challenges are particularly pronounced due to the large population size, limited financial resources, and the high cost of personal wayfinding aids. The strong link between illiteracy and increased blindness rates emphasizes the crucial role of education, especially in braille literacy, which is hindered by limited access to braille signage. The shift toward digital literacy also introduces new barriers, with many digital wayfinding platforms remaining inaccessible to visually impaired individuals. Stereotypes, prejudice, and stigma further compound the challenges, leading to discrimination and exclusion for people with disabilities and their families, exacerbating social isolation and reliance on familial support networks for outdoor mobility. Moreover, overcrowded environments and difficulties in navigating unfamiliar or changing surroundings add to the complexities individuals with vision impairments face. **Notably, the unique challenges faced by individuals with vision impairments in India highlight the need for tailored approaches to wayfinding design in public environments.** The following section reviews the empirical research to study wayfinding behaviour and challenges in large-scale public environments in India and other countries.

2.7 Public Environments

Wayfinding complexity is determined by 1) the purpose of the public environment 2) the architectural design of the built environment (Weisman, 1981; Vision Australia, 2006; Zheng, 2007) 3) wayfinding Information aids such as multi-sensory signage and digital tools and 4) the social aspects of the public environment such as crowd density (Bins Ely et al., 2013; Ahmed, 2015) and human assistance (Dalton et al., 2019).

Architectural Design aspects include Structured hierarchy in spatial layouts, such as grouping similar uses and incorporating symmetry, which aids in sequential decision-making and enhances memorability (Arthur & Passini, 1992). Visual accessibility plays a critical role, with complete visual accessibility simplifying orientation, especially in emergencies (Bins Ely et al., 2013; Peponis et al., 1990; Garling et al., 1983). Internal layouts having a right-angled circulation design system are preferred over diagonal or curved design (Nagraj et al., 2021; Vision Australia, 2006), with textured markings and architectural differentiation all facilitating navigation, particularly for individuals with vision impairments. Architectural differentiation helps prevent confusion between spaces with different functions, while distinct landmarks serve as reference points for memorizing routes (Li & Klippel, 2012; Vision Australia, 2006; Arthur & Passini, 1992). Lighting conditions, both natural and artificial, are essential for providing orientation cues and ensuring safety, particularly for individuals with vision impairments (Vision Australia, 2006). Architectural landmarks, encompassing sensory features, further aid in wayfinding by providing recognizable reference points (Arthur & Passini, 1992). Overall, the multifaceted aspects of the built environment significantly impact the complexity and effectiveness of wayfinding strategies.

Social aspects include human assistance and crowd density. The concept of 'social wayfinding' highlights how the presence and activities of others can influence navigation, even if they are not directly involved in providing guidance (Zacharias, 2001). Human reasoning and problem-solving are inherently social and cultural processes influenced by group communication and past practices (Hutchins, 1995).

"The process of communicating route knowledge is referred to as a cognitive transaction, an individual who needs information seeks it from a knowledgeable source" (Allen, 1997).

The verbal transaction is fruitful if the individual seeking information states his or her inquiry precisely, the source of information comprehends the request rightfully, has the specific information needed, and the necessary information is conveyed (Allen, 1997).

Three steps form the central part of a discourse between the giver and seeker of route directions. 1) The first step is activating the spatial knowledge of the environment stored in a non-linguistic format. The second step requires the choice of a specific route through the environment. The third step is translating the chosen route into verbal instructions. Furthermore, some studies examine the quality of verbal route directions by characterising them in terms of the number of elements (such as landmarks, segments or turns) and subjective ratings of their goodness (Lovelace et al., 1999).

Dalton et al. (2019) proposed four types of social wayfinding: 1) Strong Synchronous Social Wayfinding involves active wayfinding decisions made with intentional input from others. This can occur through direct accompaniment or verbal/gestural instructions from a small group or individuals. 2) Strong Asynchronous Social Wayfinding occurs when communication about wayfinding decisions occurs before travel, such as instructions given by another person or navigation system. 3) Weak Synchronous Social Wayfinding involves indirect and unintentional influence from others on wayfinding decisions. This can occur through "person-place cues", where the presence of people suggests the popularity of a specific location, or "person-space cues", where more people indicate better-connected and centrally located areas. 4) Weak Asynchronous Social Wayfinding involves interpreting physical traces others leave in the environment, such as social trails or desire lines created by repeated footfall. These traces provide indirect cues about efficient routes based on the activity patterns of past pedestrians.

Other people can play various roles in wayfinding, including co-deciders, route instructors, or environmental cues. Integrating social factors into our understanding of wayfinding decision-making is essential for designing wayfinding approaches. **The contribution of other people (sighted) to the wayfinding decision-making by people, particularly those with vision impairment, has been distinctly under-researched until now** (Allen et al., 2017; Dalton et al., 2019) **as the research and design are inclined towards advocating independent wayfinding in UMICs and HICs. This highlights a notable need to study the real-world social interactions related to wayfinding and the effect of crowds**

on wayfinding ability and decision-making, particularly of VI in LMIC, like India, which thrives on this culture of giving and receiving help.

Most empirical research on wayfinding by PVIs has been executed in quieter and controlled settings of HICs and UMICs with low population density, such as shopping malls (Dogu & Erkip, 2000), educational buildings (McIntyre, 2011; Blades et al., 2002; Passini et al., 1998), hospitals (Paul, 2013), libraries (Li & Klippel, 2012), supermarkets (Veeramachaneni, 2014), museums (Chan & Siu, 2013; Hirai et al., 2013).

Compared to controlled indoor public places, work on the wayfinding challenges of people with vision impairments in real-life open and uncontrolled environments is less. There are studies done for PVIs on pedestrians (Afrooz et al., 2012; Carreon, 2000), streets (Havik et al., 2015; Folska, 2012;), airports (Farr et al., 2014; Bins Ely et al., 2013; Cave et al., 2013), metro (Sánchez & Sánez, 2010) and train terminals (Whitfield, 2013; Padzi & Ibrahim, 2012; Martson & Church, 2005).

Outdoor mobility in densely populated urban open or built infrastructure presents a much more complex scenario in low and middle-income countries (LMIC) like India than in high-income countries (Mashiri et al., 2005; Maunder et al., 2004; Venter et al., 2003). **The higher level of wayfinding complexity is due to uncontrolled factors such as high pedestrian and vehicular traffic volume, weather diversity, crowds, noise, etc.** (Nagraj et al., 2021). **Despite this, the existing body of research on the wayfinding of PVI in uncontrolled is predominantly significantly less from LMIC.**

Enhancing mobility is pivotal for reducing poverty in developing nations, enabling individuals with disabilities to participate actively in economic and social spheres **(**Mashiri et al., 2005; Maunder et al., 2004; Venter et al., 2003). **Economically developed countries have made considerable strides in enhancing transport accessibility for individuals with disabilities, mainly adhering to standardized guidelines with some local adaptations. However, developing nations' wayfinding landscape varies significantly** (Maunder et al., 2004).

Rail commuting and metro systems are highly complex wayfinding environments due to their highly dynamic characteristics. They are aided by fast-moving crowds, especially in countries relying on such systems for daily commuting, and present complex wayfinding design challenges to architects and designers. Their design and construction are usually the

responsibility of a public transportation authority, which must frequently overcome severe budgetary constraints and may not focus on seemingly peripheral design considerations, including wayfinding. Rail commuting environments that include trains and metros and terminals/ railway stations present a very complex high-stress wayfinding scenario for PVIs as they involve performing a sequence of activities within a time constraint and in the presence of a large crowd (Nagraj et al., 2021). The commuting systems cater to diverse passenger demographics, including tourists and working professionals. Architectural layout differentiation among train stations, the number of decision points and floor level changes (Fewings, 2001), and the need to change the terminals (Bins Ely et al., 2013), increase in service lines (Nen, 2015) can add to the high wayfinding complexity of the station building for all types of users and can severely impact PVIs.

2.7.1 Wayfinding Studies on Rail and Metro Commuting Systems

Empirical studies are more effective than simulated ones in wayfinding research because they involve real-world observations and interactions that provide authentic and reliable data, unlike simulated studies, which often rely on hypothetical scenarios or controlled environments (Hao & Ching, 2008; Rousek & Hallbeck, 2010; Martson & Church, 2005), empirical studies allow researchers to observe actual wayfinding behaviours, challenges, and strategies in real-life settings. This provides a more accurate understanding of how individuals navigate and interact with their environment, considering various factors such as environmental conditions, social dynamics, and individual differences. Additionally, empirical studies offer the opportunity to gather feedback and insights directly from participants, enhancing the validity and relevance of the findings. Overall, such studies provide a more comprehensive and realistic exploration of wayfinding processes, leading to more insightful conclusions and practical applications for design and intervention, as also advocated by Jenkins (2015). Hence, this section provides an overview of empirical research focusing on wayfinding within rail or metro commuting systems, examining the experiences of individuals with blindness, low vision, and sighted individuals across various income country categories, including low-middle-income countries (LMICs), upper-middle-income countries (UMICs), and high-income countries (UHICs).

Padzi and Ibrahim (2012) studied the accessibility of PVIs in train terminals in Klang Valley, Malaysia (UMIC) using onsite observations and interviews. The authors highlighted infrastructure-related challenges in train terminals, such as tactile ground surface indicators, a braille sign system, colour contrast in the flooring and lack of provision for special ticketing counters for people with vision impairments, creating dependence on human assistance to purchase tickets. Inconsistency in the station layout and location of facilities further created problems in predicting their locations.

Three Indian studies have examined the difficulties faced by people with visual impairments (PVIs) in India's non-suburban rail and metro commuting systems. Additionally, this discussion includes an examination of an accessibility audit conducted on Mumbai Suburban Railways.

Raheja and Tyagi (2016) studied the New Delhi railway station in India, focusing on understanding the mobility experiences of individuals with vision impairments using trace study, access audit and focus group interactions with PVIs. The study was part of the Access Audit at the New Delhi Railway Station (Non suburban Train station), conducted by IIT Roorkee, under the Accessible Indian Campaign. The audit targeted both external and internal zones, excluding train coach design. The audit was done based on a visual survey by the expert, referring to the Indian access standards. The on-site proposal sketches and recommendations were made concerning each issue. The issues were later given priority rating through access indicators with specific criteria. The cumulative result lists priority issues that need immediate attention compared to other issues.

The recommendations from the audit were based on the three-tier model of access to infrastructure, services, and information. (Raheja, 2016) (Figure 2.3, 2.4).

The access audit aims to assess how well a site performs in terms of access and ease of use by a wide range of potential users, including people with disabilities. The research findings highlighted issues in the external and internal environment of the railway station. **The authors stated that the challenges faced by people with vision impairments overlapped with those encountered by other diverse population groups.** The authors proposed adopting universal design principles as a guiding philosophy to address these issues, particularly in addressing wayfinding concerns that affect various population groups. The authors proposed several recommendations to improve accessibility at train terminals, including: 1) Installing 'you are here' maps at critical footbridge junctions 2) Equipping all platforms with tactile paths

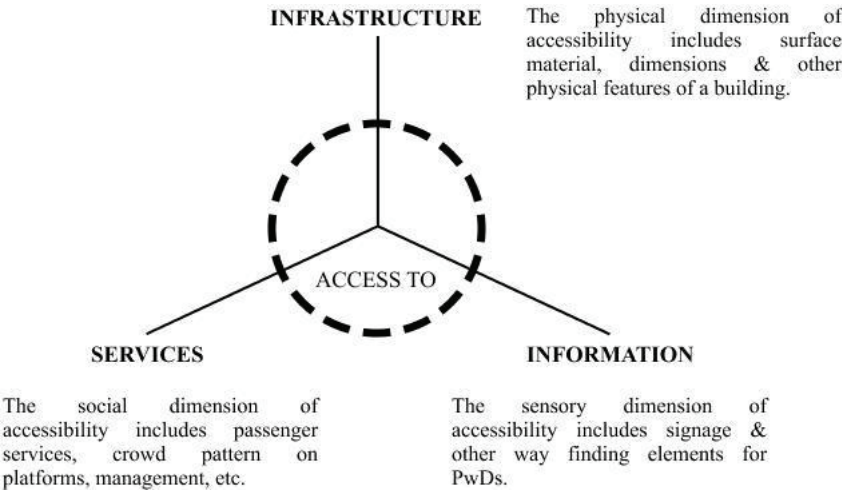


Figure 2.3 The three-tier model on which the recommendations were proposed (Raheja, 2016)

for toilets and furniture 3) Increasing visibility of drinking water facilities with reflective paints 4) Introducing a paid golf cart service at New Delhi Railway Station 5) Implementing accessible parking 6) Ramps with handrails, and braille stickers 6) Providing prior announcements about coach locations for persons with disabilities 7) Conducting sensitization workshops for railway staff 8) Ensuring adequate colour contrast in the built environment 8) Integrating wayfinding signage with the visual aesthetics of the station 9) Offering multilingual options in signage 10) Providing priority seating for elderly and disabled passengers.

The audit did not document the actual needs, challenges, requirements, psychological and social impact of the current station design on user experience. While the audits identify physical barriers and suggest improvements, the proposed recommendations do not adequately address the wayfinding needs of visually impaired and sighted individuals in the travel chain.

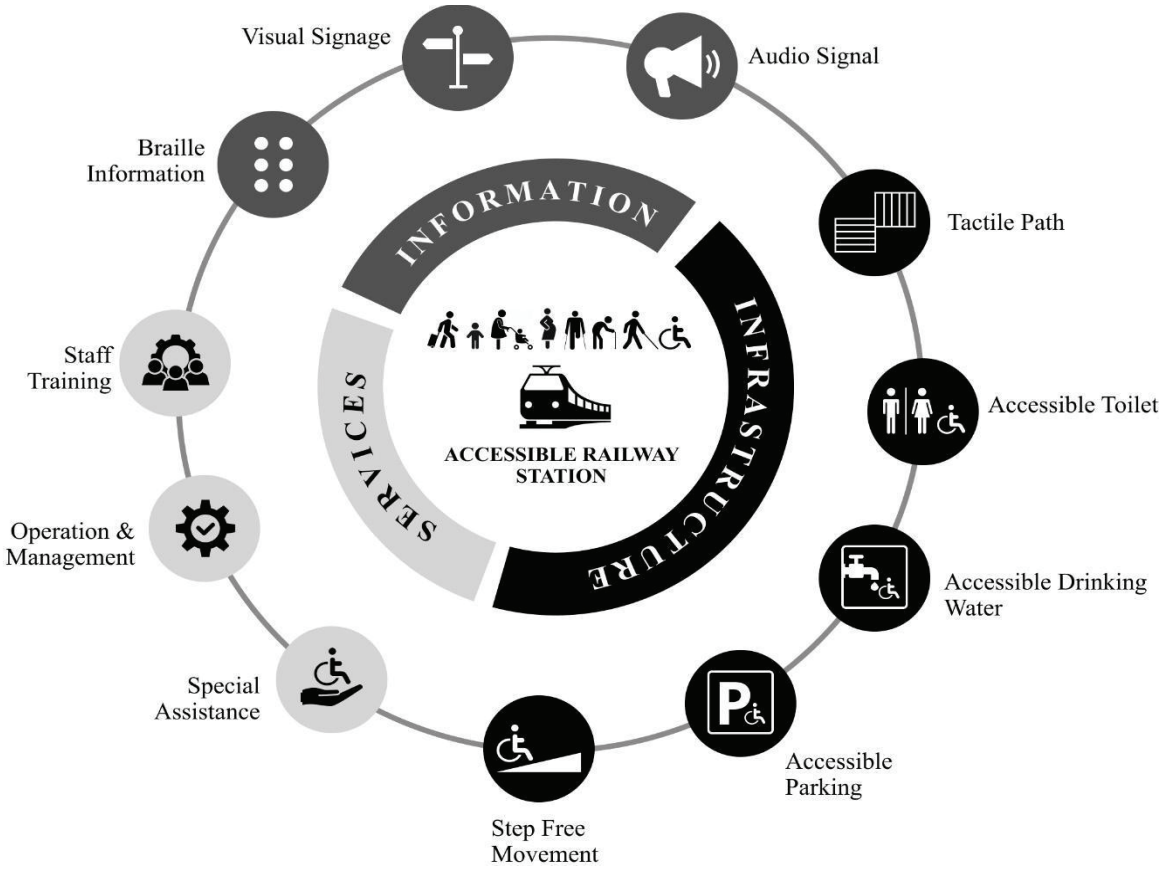


Figure 2.4 Wayfinding aids and through which recommendations will be implemented (Raheja, 2016).

Raheja and Sinha (2018) studied navigation and wayfinding challenges for PVIs in Delhi Metro, India, using mixed methods, combining field observations, interviews, surveys, and audits. The study identified barriers such as a lack of multi-modal information, inconsistent tactile indicators, and difficulties at security checkpoints and lift access points. Facilitators included multiple vertical circulation options, seamless platform-coach access, and audio announcements. Like Raheja and Tyagi (2016), the authors emphasize the importance of interpreting Universal Design (UD) to enhance accessibility in Metro stations and advocate for future research on improving mobility interfaces for diverse disabilities in-built infrastructure.

Nagraj et al. (2021) conducted semi-structured interviews with visually impaired individuals in Bangalore Metropolitan, India, focusing on the social factors influencing navigation experiences. They found that accessibility varies based on the age of infrastructure, with newer facilities like Metro stations being more accessible than older ones like railway

stations. Architectural barriers such as narrow entryways and lack of elevators pose challenges in railway stations, where participants spend considerable time familiarizing themselves due to limited signage. Unlike the earlier two Indian studies by Raheja & Tyagi (2016) and Raheja & Sinha (2018), this study presented findings that considered the social factors of the public environment from the perspective of PVIs. Some notable findings are -that crowded stations hinder navigation and environmental noise masks audio cues from navigation apps. Participants sought assistance when faced with poor accessibility or unfamiliar environments but felt disempowered by unresponsive passersby or worried about offending others. Trust was generally placed in the directions received, although challenges arose from unclear terminology. Technology's role in navigation support was limited by challenges such as device affordability and incomplete app mapping, highlighting the need for tailored interventions considering environmental and social factors. Future technology design should prioritize user interactions and needs, enhance navigation in public transit systems, and provide customized orientation and mobility training modules for India to address unique challenges.

An accessibility audit of 122 Mumbai Suburban Railway stations was conducted by the Collective For Spatial Alternatives and Indian Center for Human Rights Law (2017) to identify all the obstacles and barriers faced by people with disabilities and senior citizens. The survey methodology was designed based on commuters' usage patterns of railway stations and their various services, considering spaces and features. Spaces represent well-defined areas serving specific functions like approach and entrance, ticket purchase, horizontal and vertical movement, waiting areas, administration sections, etc. Features encompass elements or objects within these spaces facilitating transitions, such as counters, booths, stairs, paths, signage, surfaces, etc. These spaces and features were evaluated for their presence, absence, and accessibility using 104 queries, with responses graded accordingly. The audit findings were then assessed for compliance (percentage) with guidelines from the Ministry of Urban Development and Railway Board, with comparisons across the Western, Central, and Harbor lines (including Trans-Harbour).

The audit revealed a notably low level of compliance (37.7%) with the established guidelines. Most railway station entrance areas were inaccessible for persons with disabilities, with poor construction quality, uneven surfaces, broken tiles, and inadequate details. Essential features like guiding paths and ramps were lacking, and booking offices, although showing some improvements with specialized counters, lacked trained personnel to assist people with

disabilities. Tactile schedules were absent, and while some platforms had guiding paths and audio signals, their locations could have been more efficient, posing difficulties for commuters. Additionally, most platforms lacked accessible toilets and circulation features like stairs and ramps, which were inconsistently designed, with steep slopes and insufficient edge indicators. Furthermore, where toilets for persons with disabilities were provided, they were often insufficient in number and frequently locked. Despite some efforts by the Railways to enhance accessibility, the audit findings emphasize the need for significant improvements to develop a universally accessible, comfortable, and safe Suburban Railway network in Mumbai. The audit findings are limited to identifying architectural barriers to physical accessibility to the railway stations.There are few international studies conducted in high-income countries where the wayfinding process has been studied for sighted passengers in train terminals.

Chen (2006) made signage wayfinding recommendations for Taipei's Subway System in Taiwan (HIC), which serves both international and local trains. A visual inventory of photo examples was created with a set of assessment criteria, complemented by a user survey with 100 participants. The study examined the relative importance of color coding, typography, dual language use, information hierarchy, and consistency of approach. Recommendations for improved wayfinding were based on these criteria. Wayfinding encompasses a variety of disciplines, including semiotics, which may be influenced by gender, social group, and cultural differences. Since wayfinding design relies heavily on signs, symbols, and pictograms, a wayfinding designer must have a solid understanding of semiotics to create an effective wayfinding system. Further, it is crucial to thoroughly familiarize oneself with the entire site during the planning phase. Testing prototype signage at potential locations for two to three weeks before permanent installation can help assess its effectiveness in assisting users.

Zheng et al. (2007) studied wayfinding behavior in Tokyo, Japan (HIC), focusing on an above-ground station serving long- and short-distance trains. The aim was to understand how information signs correspond to users' navigation behaviors. The study revealed diverse behaviors among subjects, even without time constraints. For long-distance routes, subjects preferred maps or signs detailing route particulars, demonstrating a relaxed attitude and a strong emphasis on effective self-orientation. In contrast, directional signs were sought for short-distance routes, yet few were available between stations. Subjects encountered decision points, particularly at intersections, indicating the need for more signs in the information system. These

findings highlight the importance of considering user needs, as observed through their wayfinding behaviors when designing information sign systems.

Here are the key findings from the experiments: Wayfinding should ideally be enjoyable, with signs confirming the right direction. Decision-making at intersections is crucial, and directional signs integrated with orientation signs are most effective. People exhibit diverse wayfinding behaviours, so information sign systems should accommodate various user needs. Orientation signs like maps are suitable for long-distance wayfinding, but their effectiveness depends on users' sense of relative location. Temporary signs installed by commercial stores make wayfinding enjoyable, and famous or pleasant spots serve as good orientation clues. Users require information to confirm their direction, especially at intersections. The distance between signs should consider users' memory capacity. Directional information should correspond with landmarks for better wayfinding experiences. Directional signs are more helpful than orientation signs, mainly when stations are nearby. Providing various sign choices can suit different situations. Whether hanging or standing, integrated signs should cater to various users' needs and situations. Additional support, such as station staff assistance, can supplement sign systems effectively.

Whitfield (2013) aimed to investigate the user-friendliness and safety of transit connection points, particularly in complex environments for new transit users, using the “multi-method” technique of Post Occupancy Evaluation, which includes a review of related planning documents and background information, recording of the physical environment, observations of transit users, transit user interviews, interviews with public officials. The research in Washington, U.S.A (HIC) emphasized the need for a signage system designed with ‘Progressive disclosure’, avoiding overwhelming users with too many signs in one area. Safety concerns, especially in underground transit areas, were highlighted, and the presence of security guards was suggested as a solution. The author recommended integrating above ground and underground transit systems, which are crucial for seamless connections and improved wayfinding.

In a study of Singaporean train terminals (HIC), Nen (2015) found that an increase in service lines, the absence of signs at crucial locations, information overload in display areas, and lack of integration between old and new signs contributed to wayfinding difficulties. To address dynamic user needs, channels for feedback to service operators and authorities are necessary and monitored regularly for timely improvements. Interactive screens or mobile apps

could facilitate this feedback process. However, adding more signs to aid commuters can complicate the wayfinding system, requiring re-evaluation before installation. Nen suggests analyzing each station independently to evaluate or develop effective wayfinding systems, as no single scheme fits all layouts. A user-friendly platform, like an interactive screen panel or mobile app, should be implemented so that commuters can quickly provide feedback on their wayfinding experiences. This platform should allow instant capture and storage of feedback, facilitating timely improvements. Regular monitoring of feedback will ensure the wayfinding system remains effective and responsive to user needs, saving time and resources.

Ferri and Popp (2022) introduced the *'wayfeeling'* concept, highlighting user behaviour's emotional and sensorial dimensions in public transit. *Wayfeeling* involves maintaining positive emotional well-being while navigating, which is often overlooked in wayfinding research. In a study conducted in Munich's public transit system (in Germany, HIC), passengers' emotional reactions, such as confusion, annoyance, and frustration, particularly in transfer areas, were observed due to poor layout and lack of visible wayfinding devices. Participants' emotional well-being influenced their navigational decisions, with negative experiences leading to avoidance behaviours. Prolonged exposure to transfer areas intensified negative emotional responses. For some participants, even one significant negative experience overshadowed the entire transit journey. Adverse events during transit journeys significantly impacted overall perception, emphasizing the need to address negative experiences through well-communicated design within complex environments. This understanding aligns with previous research on the importance of affordances and readable spaces, fostering a sense of understanding and comfort for users. Limitations of the study include demographic focus and the need for broader inclusion in future research and exploring emotional connections to navigational tools like smartphones in public transit. Understanding the relationship between navigational activities and users' emotional well-being in public transit spaces is crucial for informing design and transit policies.

The discussed studies highlighted challenges and facilitators in wayfinding within train and metro commuting systems for individuals with and without vision impairments. Key findings suggest that Nagraj et al. (2021) shed light on the unique social factors affecting wayfinding, particularly regarding crowd influence and human assistance. Ferri & Popp's study (2022) highlights how wayfinding activities impact users' emotional well-being in public transit spaces, offering valuable insights for design and transit policies. The accessibility audit of

Mumbai Suburban Railways highlights the existing challenges faced by persons with disabilities due to limitations in station infrastructure. However, the audit did not delve into wayfinding's social and informational aspects affecting wayfinding. International studies by Chen (2006), Zheng et al. (2007), Whitfield (2013), and Nen (2015) primarily focused on evaluating signage and graphic communication, mainly from the perspective of sighted users.

One of the notable findings for us is how the age of infrastructure significantly influences wayfinding complexity (Nagraj et al., 2021). Metro systems, introduced in the 1980s, offer better accessibility and wayfinding systems than the older rail systems inaugurated in 1853. Rail stations tend to have larger layouts, multiple platforms, and complex configurations, posing navigation difficulties, especially without escalators or elevators. Additionally, crowded and noisy rail platforms in countries like India further complicate orientation and navigation for individuals with vision impairments. Limited signage in rail systems often prompts reliance on social wayfinding.

In India, rail commuting comprises two central systems: suburban and non-suburban. Suburban trains, known as 'local trains' or 'locals', primarily serve densely populated urban areas and suburbs, offering high-frequency services for short to medium distances. Non-suburban or long-distance trains connect major cities and regions, serving inter-city and intra-city travel needs across varying landscapes. Suburban systems feature numerous closely spaced stations, catering to frequent stops and high commuter volumes, especially during peak hours. In contrast, non-suburban systems have fewer stations, longer distances between them, and lower frequencies. Suburban rail experiences significant rush hour congestion, while non-suburban routes may see more evenly spread demand throughout the day. Suburban trains are used for daily commuting within the city and suburbs primarily for work purposes, unlike non-suburban trains, whose use is occasional. The suburban rail commuting system presents a highly complex scenario for wayfinding, particularly for individuals with vision impairments due to crowded conditions, frequent stops, and high dependency on daily commuting with the system.

India has ten suburban rail commuting systems in big cities like Mumbai, Kolkata, Bengaluru, Hyderabad, Lucknow, Kanpur, Delhi, Pune and Goa. The suburban rail systems of Chennai and Mumbai have dedicated tracks and tracks shared with non-suburban trains (Shah, 2023), adding to the wayfinding complexity, while others have dedicated tracks for suburban trains only. The Mumbai Suburban Railway stands out as one of the most intricate commuting

systems for wayfinding due to its blend of high population density, expansive network coverage, frequent train service, and status as one of the oldest railway systems.

2.7.2 Wayfinding in Mumbai Suburban Railway

The Mumbai Suburban Railway (also referred to as Mumbai Local Train Commuting System (MLTCS) in this thesis), serving 7.4 million commuters daily in India's financial hub, boasts the world's highest passenger density among urban railway systems (Gardas et al., 2013). This vital mode of public transportation encompasses a sprawling network spanning 465 kilometers, with 130 stations and 2,342 daily services across four lines: Central, Western, Harbour, and Trans-Harbour, established in 1925 during British rule. Despite its age and overcrowding, it remains Mumbai's most dependable and cost-efficient transportation mode amid the city's burgeoning population growth (Kadam, 2015). However, escalating overcrowding has raised significant safety concerns, with approximately 3,500 fatalities annually, translating to an alarming average of 10 deaths per day (Mehta, 2012). Moreover, while not widely acknowledged, the current wayfinding design poses usability and safety risks, affecting all commuters to varying degrees, as highlighted in the Preliminary Research discussed in Appendix A1 and A2. Addressing these challenges necessitates a holistic approach prioritizing safety, usability, and equitable access to public transportation.

2.8 Research Gaps

Following are the research gaps identified from the literature review:

(i) Rail commuting presents more significant wayfinding obstacles for individuals with vision impairments than metro commuting due to its larger, more complex, potentially chaotic nature. The review of the existing studies shows that minimal empirical studies have been conducted on wayfinding behaviour and challenges in rail commuting and metro commuting systems, particularly for PVIs in the world. It is important to note that when India is the second most populous country in the world, home to over 20 percent of the world’s blind population, yet

there is hardly any research done on wayfinding from the perspective of people with vision impairments in public environments except few studies such as that on Metro commuting system by Nagraj et al. (2021) & Raheja & Sinha (2018) on Non-suburban Railway stations by Raheja & Tyagi (2016).

(ii) Most literature on wayfinding in public environments takes an exclusive approach to studying sighted users and non-sighted users. This may lead to distinctive solutions for both user groups. No study has examined how the wayfinding experience differs for people with no vision, low vision, and sighted people, thereby missing the opportunity to identify common problems and solutions.

(iii) Much is written on the role of architectural and graphical communication and technology in the wayfinding of people with and without vision impairments. However, hardly any literature explains the social dimension of wayfinding (Dalton et al., 2019), particularly for people with vision impairments. Existing studies had separate and exclusive focus on architectural, signage, and social aspects of wayfinding, missing out on the interrelationship between these factors.

It is understood that grounded field research informs the development of sound guidelines, ultimately leading to contextually relevant design solutions and implementation. To date, we have yet to find wayfinding research studies for any public buildings in India.

2.9 Research Objectives & Questions

This doctoral research recognizes the Mumbai Suburban Railway as an ideal setting for studying wayfinding challenges due to its complexity stemming from factors like high population density, extensive network coverage, frequent service, historical significance and dependency on daily commuting by people with and without visual impairments.

The research examines how a change in the level of vision affects commuters' wayfinding behaviour and experiences. Three levels of vision are part of the scope of the study: No vision with or without light perception, Low vision with moderate and severe vision impairments and with sight.

The emergence of empirical research and evidence-based design has led to the importance of incorporating human factors into building performance considerations. However, wayfinding research in India must be addressed, and current guidelines may not fully address the needs of people with and without impairments. An exclusive approach to user groups could result in fragmented design approaches. This is especially concerning given that a study by Raheja and Tyagi (2016) highlighted overlaps in challenges faced by people with vision impairments and other diverse population groups. However, this claim was made without empirical research or evidence-based support. Hence, empirical research is needed to build understanding based on subjective encounters and past experiences of wayfinding, feedback, and assessment to address the research gap. This understanding will help to design contextually relevant, user-centered and inclusive wayfinding guidelines for Mumbai Suburban Railways, thereby exhaustively addressing wayfinding needs emerging from differences in the level of vision of wayfinders.

This study examines the wayfinding scenario of a rail commuting system from the lens of people who represent three different levels of vision: No Vision (NV), Low Vision (LV) and with sight. The overarching theme guiding this enquiry is providing an **'inclusive approach to wayfinding design'.**

The principal objectives of the study are to:

O1. Understand how the current rail commuting system fulfils the wayfinding needs of different levels of vision.

O2. Prioritize wayfinding concerns in station use and train travel based on the severity assessment.

Following are the Research Questions :

RQ1. How does the existing scenario of the commuting system affect the wayfinding *experiences* of people with different levels of vision?

RQ2. How does the existing scenario of the commuting system affect the wayfinding *performance* of people with different levels of vision?

RQ3. What is the *order of priority* of wayfinding problems based on the challenges faced by people with different levels of vision?

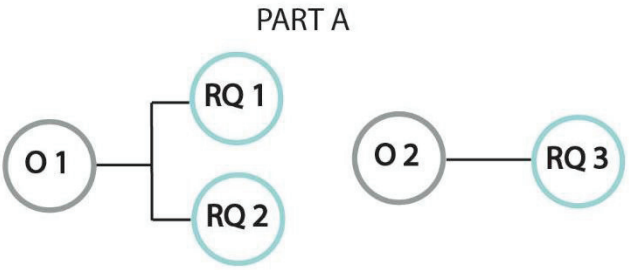


Figure 2.5 Research Objective and Questions

The doctoral research aims to investigate how wayfinding behaviour and experiences of commuters are affected by different levels of vision in the Mumbai Suburban Railway, focusing on no vision, low vision, and with sight. It plans to conduct empirical research to develop contextually relevant, user-centered, and inclusive wayfinding guidelines for the Mumbai Suburban Railway in three phases: understanding how the existing scenario of the commuting system affects the wayfinding *experiences and performance* of people with different levels of vision, prioritizing wayfinding concerns, and developing evidence-based guidelines.

The next chapter presents the first empirical research on understanding the wayfinding experiences of people with different levels of vision.

Chapter 3 Understanding Wayfinding Experiences

3.1 Introduction & Background

The Existing research on wayfinding behavior and challenges in rail and metro commuting systems, particularly for persons with visual impairments (PVIs), is sparse, especially in Indian conditions. Previous studies have predominantly focused on architectural, signage, and social aspects of wayfinding separately, overlooking their interconnectedness. While these studies have advocated for implementing universal design principles to improve existing systems and develop new ones, they have yet to examine commuters' diversity based on their vision level, familiarity, gender and literacy. Mumbai Suburban Railway is identified as an ideal setting for studying wayfinding challenges due to its complexity stemming from factors like high population density, extensive network coverage, frequent service, historical significance and dependency on daily commuting by people with and without visual impairments. This qualitative study examined **RQ1: How the existing scenario of the commuting system affects the wayfinding *experiences* of people with different levels of vision.**

As part of this thesis, we took an approach to conducting a comparative in-depth wayfinding study on people with no vision, low vision and sighted people. As wayfinding is always influenced by past and present experiences (Lynch, 1960), the methodology employed

in the field study presented in this chapter was designed to interact with the participants on their way-finding experience. The research methodology evolved into three sequential studies, as discussed in Chapter No. 1.

The study examines the wayfinding of information needs, challenges, behaviour, strategies, individual abilities, and subjective experiences through participant interactions using semi-structured interviews. This evaluation approach aligns with basic user-centered design principles as Kuliga (2016) also advocates. The first study was done to understand the wayfinding experience of the participants in the Mumbai Local Train Commuting System. An interview guide was made to drive the conversations with the participants. Probes (Robinson, 2023) were used to elicit responses from the participants. This chapter reports the purpose, methodology and findings of the study. The interview findings were consolidated to wayfinding challenges, strategies and design preferences.

This study attempts to gain a comprehensive and adequate understanding of the subject, which requires a critical appraisal of previous knowledge and the possible need for complementary empirical knowledge. The critical appraisal of previous knowledge was carried out by doing a literature review focused on the purpose of the study, as reported in Chapter 2. The literature review offered an essential basis for mapping previous knowledge. In addition, preliminary empirical field research (as reported in Appendix A1 & A2) was conducted using observational and open-ended interviewing methods to develop an adequate understanding of the subject and design a comprehensive semi-structured interview. This knowledge was used to create a predetermined framework for the interview. The preliminary research helped to identify that vision is a dominant variable that affects wayfinding in Mumbai Suburban Railways—past wayfinding research conducted by other researchers, as discussed in Chapter 2, also stated that it is the most important human factor that plays a significant role in influencing the wayfinding behaviour of people.

3.2 Purpose of the Study

This study explores the experiences of individuals with and without vision impairments (ranging from no vision to low vision), drawing upon their recollections of wayfinding in the Mumbai local train commuting system (MLTCS). Previous research by

Golledge (1999), Down and Stea (1997), and Arthur & Passini (1992) has highlighted the challenge researchers face in eliciting wayfinding experiences, which tend to be deeply internalized and thus difficult to extract. To address this, we adopted a user-centered approach, utilizing semi-structured interviews to delve into participants' memories to investigate how changes in visual capability influence commuters' wayfinding behaviour and overall experiences. Through these interviews, we sought to gain insights into various aspects of participants' wayfinding experiences, including their specific needs, the challenges they encounter during navigation and decision-making, available social support, available information for the different wayfinding tasks that need to be executed, as well as the personal strategies employed to execute them. This study aims to contribute to a deeper understanding of how individuals perceive and are psychologically impacted by existing commuting system design.

3.3 Assessment of the method

Semi-structured interviews proved suitable for addressing complex social and behavioural research questions, as they allow for a deeper understanding of users' perspectives and identification of areas for improvement (Adeoye-Olatunde & Olenik, 2021). The method was deemed appropriate for studying past experiences, perceptions, opinions, and emotions surrounding wayfinding in a large-scale computing system (Barriball & White, 1994; Astedt-Kurki & Heikkinen, 1994). Encouraging participants to narrate their previous wayfinding experiences freely facilitated the exploration of subjective knowledge, lacking in Indian literature on wayfinding. Following recommendations by Adams (2015), semi-structured interviews were chosen to accommodate the uniqueness of each participant's experiences and to delve into unforeseen issues, making it a valuable complementary study within a mixed-method methodology.

Moreover, semi-structured interviews were deemed suitable for participants with low awareness of the subject or difficulty discussing specific issues, such as values and intentions (Astedt-Kurki & Heikkinen, 1994). Given the lack of prior background knowledge on wayfinding research in India, this method allowed for a focus on meaningful topics for participants, fostering diverse perceptions. Additionally, it facilitated the recruitment of participants with limited literacy and vision impairments, enabling verbal expression.

The flexibility of semi-structured interviews also enabled interviewers to improvise based on participants' responses, allowing follow-up questions and accommodating individual verbal expressions (Rubin & Rubin, 2005). Building rapport through informal conversations with participants further enhanced their willingness to participate in subsequent studies. McIntosh and Morse (2015) stated the typology of semi-structured interviews. Their typology was based on the purpose of the interview and the research outcome. Amongst four different types of semi-structured interviews, two of them align with the purpose of this study. The first, *Descriptive or interpretive* type of interview, aims to discover the experiential world of the respondent within relevant dimensions of the research. This type of interview is relevant in cases when the knowledge of the researcher and what is reported in the literature is acknowledged to be limited. The subjective knowledge of the participants is critical to knowledge expansion. Sometimes, the knowledge published is refuted by participants' perspectives and gives rise to new categories, themes, and hypotheses with which to understand the experience. The second *descriptive/divergent* type of interview *aims to* apply the same interview guide to different groups of participants to identify different/ contrasting/ similar perspectives and experiences. "The elucidation of divergent perspectives, attitudes, and experiences regarding phenomena enables deeper insight into various ways people negotiate the personal and social contexts that shape human choices and experiences".

3.4 Sampling

3.4.1 Sampling Strategy

Non-probability random sampling (Polit & Beck, 2017) was used to conduct semi-structured interviews. Multiple sampling strategies were used to recruit participants, such as criterion, convenience, and snowball. Using criterion sampling (Cordray & Patton, 2001), participants were recruited based on predetermined criteria of importance. Three levels of vision: No vision, low vision and sight were considered the primary criteria for participant recruitment. However, while recruiting the samples, it was ensured that there was a representation of other human factors such as familiarity, age and gender. All participants with vision impairment were identified and recruited through referrals by previously selected

participants in the pilot study or through people with access to potential participants. This sampling strategy was suitable for recruiting participants with characteristics not commonly found in the general population. All sighted participants were recruited based on convenience sampling.

3.4.2 Sample Size

Sample size in qualitative research tends to be small to support the in-depth analysis fundamental to this mode of semi-structured interviews (Sandelowski, 1995). Ritchie et al. (2003) outline seven factors that affected the potential size of a sample in this research, such as the heterogeneity of the population, the number of selection criteria, the extent to which 'nesting' of criteria is needed, types of data collection methods used; and the budget and resources available. Lee et al. (2002) suggests that studies that use more than one method require fewer participants, as do studies that use multiple (very in-depth) interviews with the same participant (e.g. longitudinal or panel studies). Further, as Charmaz (2006) suggests, a small study with "modest claims" might achieve saturation quicker than those with a high sample size; if the level of structure of the questions in semi-structured interviews has open-ended questions, they tend to produce richer data. Creswell (1997) further adds that semi-structured, in-depth interviews require a minimum sample size of between 5 and 25.

This study recruited thirty participants, and an interview guide was prepared with fairly open-ended questions to gather rich data. In this study, twelve participants with no vision, seven with low vision and eleven participants with sight participated.

3.4.3 Participant's Background Information

This section presents background information about the participants gathered through section 1 of the interview guide. Participants were chosen based on their level of vision: no vision, low vision, and sight. Additionally, data was collected and analyzed for various factors that could impact the study's findings:

Secondary variables like familiarity with the station building and train route may impact the wayfinding strategy. Education and literacy (digital and braille) may influence reliance on wayfinding information in different print and digital formats. Data on exposure to computer and smartphone use was collected to understand digital literacy. Gender could affect social communication and interaction. Additional variables like income might influence spending capacity on personal wayfinding aids and preferences for commuting by local train and coach preference based on the ticket fare. The type of personal mobility aid used for wayfinding could impact wayfinding skills. The specific type of vision impairment could affect participants' ability to access spatial information.

Table 3.1 The age range of participant subgroups

Age Range	**No vision**	**Low Vision**	**Sighted**
19-29	4	5	8
30-39	2	-	3
40-49	3	1	-
50-59	2	-	-
60-69	1	1	-
Mean Age	39	32.57	27.45

Table 3.2 Gender Distribution of the Participant Subgroups

Gender	**No vision**	**Low Vision**	**Sighted**	**Total**
Male	8	3	6	17
Female	4	4	5	13

Table 3.3 Education level of participant subgroups

Level of Education	**No vision**	**Low Vision**	**Sighted**
Primary	2	0	0

Matriculate	6	3	0
Intermediate	2	1	0
Undergraduate	2	1	3
Postgraduate	0	2	8

Table 3.4 A sampling of participants based on familiarity with MLTCS

Level of familiarity	**Level of Vision**		
	No vision	**Low Vision**	**Sighted**
Frequent	9	3	2
Occasional (less than or equal to 3 times in a month)	2	3	3
Hardly /Novice (once in a month or less than that in a year)	0	1	6

(i)Language Literacy: All thirty participants could speak Hindi. All participants with sight and one with low vision could speak English and Hindi.

(ii)Smartphone use: All participants with sight and two with low vision used smartphones. All participants with no vision used basic phones without the features of smartphones.

(iii)Computer Literacy: Out of thirty participants, three participants with low vision, two with no vision and all with vision had computer literacy.

(iv)Braille literacy: Out of twelve participants with no vision, six of them had braille literacy, and out of seven participants with low vision, five participants had braille literacy.

(v)Use of Mobility Aid: All participants with vision impairment are mechanical white cane users. They do not use any other mobility aids.

(vi)Occupation and Income: All participants with sight were students and project staff from the Indian Institute of Technology, Bombay. The participants with vision impairment were recruited from two NGOs in Mumbai- the National Association for Blind (NAB) and the National Association for Disability Enterprise (NADE). One participant with low vision was

from the National Association of Handicaps. The participants recruited from these organizations are either studying or are currently working there. The average earning of each participant with vision impairment was Rs 5000 monthly. The average earning of participants with sight was Rs 20,000 monthly.

(vi)Onset of Blindness: There were three participants with no vision and five with low vision who had vision impairment since birth—nine participants with no vision and two with low vision acquired vision impairment later in their lives.

(vii)Vision Impairment Details: Out of seven participants with low vision, four participants had myopia, and three had hyperopia. A myopic person has clear vision when looking at objects close to them, but distant objects will appear blurred. This is because the light is focused in front of the retina, and being too far forward in the eye, things in the distance look blurred. Hyperopia is the term used to define being long-sighted. The image of a nearby object is formed behind the retina. This means that light is focused too far back on the eye, causing things that are close to appear blurred. Table 3.5 explains the quality of vision of participants with vision impairments.

Table 3.5 Quality of Vision of the participants with vision impairments

Quality of Vision	No vision	Low Vision
1. Light Sensitivity (Sensing the minimum amount of light and light difference)	2	3
2. Color Vision (Seeing functions of differentiating and matching colours)	0	1
3. Contrast Sensitivity (Separating figure and ground)	0	1
4. Visual picture quality (Seeing functions involving the quality of the picture)	0	2

3.5 Data collection

3.5.1 Formulating the semi-structured interview guide

An interview guide (Cordray & Patton, 2001) was created to build the interaction with the study participants, as Appendix B shows. It has a list of questions that direct the conversation towards the research topic during the interview (Cridland et al., 2015; Astedt-Kurki & Heikkinen, 1994). The interview guide design was informed both by the preliminary research and the review of the literature. It had main and follow-up probing questions, which were asked based on the response to the main question. The guide had common and unique questions based on the level of vision. However, based on other human factors such as gender, age, and familiarity with the commuting system, specific questions were selected from the interview guide or emerged from the conversation with the participants during the interview. The interview guide was transcribed and conducted in Hindi for participants who do not have proficiency in understanding English.

Kallio et al. (2016) stated the importance of field testing the interview guide once prepared with the potential participants of the study. Field Testing helps to make the questions more relevant and understandable and determines whether they truly elicited the participant's varied perceptions and experiences. Following the procedure of the method, the interview guide was tested on five participants with vision impairments in the pilot study. The questions were developed, tested, and refined after every fresh interview conducted during the pilot study. The iteration process continued until all the essential and relevant aspects of the study were covered in the interview guide.

The interview guide was divided into five sections 1) Personal Background Information 2) Public Transport Use 3) Mumbai Local Train Commuting System use (MLTCS) 4) Wayfinding in MLTCS 5) Past knowledge of Kurla Station (model Station). The details of each section of the interview guide are below:

(i) Participant's Background Information includes questions on name, age, gender, marital status, family composition, education level, birthplace, period of stay in Mumbai, occupation, monthly income, language proficiency, type of phone used for communication, and commuter literacy. Questions specific to participants with vision impairment include visual acuity function and its measure, quality of vision, age at which vision impairment occurred or started, reasons for loss of sight, the impact of vision impairment on various aspects of the life such as self-image, independent function, education, family life, career, exposure to mobility training and braille.

(ii) Public Transport use includes questions on preferred modes of public transport for commuting based on the purpose of travel.

(iii) MLTCS use includes generic questions on the purpose of local train use for outdoor travel, no. of days/ months/ years of experience of local train travel, most experienced train lines and railway stations, train coach preference, need for personal assistance, and knowledge of station facilities.

(iv) Wayfinding in MLTCS is the most detailed section of the interview guide. It has questions centered around topics like the experience of use of different spatial zones and services, perception of safety associated with wayfinding, the strategy used to overcome limitations and challenges, use of information sign system provided by the Railways, psychological impact based on wayfinding experiences.

(v) Past experience/ knowledge of Kurla Station (model Station) has a set of questions, especially for Kurla Station, as this station was selected as a model station for the station walkthrough for the following study reported in Chapter 5. Hence, it was essential to know the level of familiarity of the participant with the station building and its infrastructure for their recruitment for the next phase. The questions in this section were based on participants' frequency of use, familiarity, and knowledge of station infrastructure.

Kraus et al. (2009) recommend that the order of the questions in the interview guide should be progressive and logical. The interview should start with lighter sections that act as a warm-up to break the ice and create a familiarity with the context of inquiry (Whiting, 2008; Krauss et al., 2009; Rabionet, 2016 and Cridland et al., 2015), followed by in-depth investigation and then it should end on the lighter theme again (Cridland et al., 2015; Baumbusch, 2010; Whiting, 2008). Considering this, the sections in the interview guide were consciously placed to encourage the flow of the interview from general to specific areas of inquiry. Sections 1, 2, and 3 were used to get the introduction of the study participants and their preferences for public transport for different purposes. This was followed by generic questions on their background knowledge of the MLTCS. The three sections were followed by section 4 on wayfinding experiences in the Mumbai Local Train commuting system, which is this study's focused area of investigation. This section has more detailed and in-depth questions. Section 5, the last section of the study, is about familiarity with Kurla station. It has very few questions about this specific station as it will be used as a site for the next study reported in Chapter 5.

All interviews were conducted in the same order of sections as stated above. However, the order of questions within each section of the interview guide changed depending on the flow of the conversations.

The questions in the interview guide were formulated to achieve the richest possible data (Turner, 2010). This meant the answers reflected the interviewees' personal feelings and stories (Rabionet 201,1; Whiting 2008). Caution was taken to not form the questions in the interview guide so that they would lead the participants to elucidate certain response types (Turner 2010; Astedt-, Kurki & Heikkinen 1994). The interview guide blended closed and open-ended questions (Adeoye-Olatunde & Olenik, 2021). Open-ended questions are often accompanied by follow-up questions such as what, when, why or how questions (Turner, 2010). Sections 1,2,3 and 5 had a blend of both closed- and open-ended questions. Whereas Section 4 on wayfinding had entirely open-ended questions with extensive probing to elicit complete information (Adeoye-Olatunde & Olenik, 2021; Adams, 2015; Turner, 2010; Baumbusch, 2010), explore and clarify inconsistencies within participants' accounts (Hutchinson & Skodal Wilson, 1992), recall information for questions involving memory (Smith, 1992).

3.5.2 Permission & Funding for the Field Study

The participants with vision impairments were recruited from the National Association of Disability Enterprise (NADE) and the National Association of Blind (NAB). Both organizations are NGOs working in Mumbai. NADE works to create employment opportunities for all people with disabilities. Written permissions were taken from the presidents of both organizations to recruit participants for the study. Consent forms signed by all participants in the study ensured them that the information they provided would be used for academic publication only and that their identity would be kept confidential in the published material that will emerge from this study in future. The participants work in the organization itself. They are engaged in the assembling and packing work outsourced by NADE from manufacturing concerns. NAB works for the welfare of people with vision impairments. Remuneration for participation in the study was paid only to participants with visual impairments. IDC School of Design, IIT Bombay, funded the expenses incurred during the field research.

3.5.3 Interview Modality, Recording and Transcription

All interviews were conducted in person with the participants in their workplace or residential environment. According to Shuy (2001), the interviewer's presence gives structure to the interview situation. In the case of this research, face-to-face interviews worked best for establishing rapport with participants as they had to participate in further studies using different methods.

The researcher could travel to the participant's respective locations in the city. As suggested by Barriball and While (1994), semi-structured interviews contained open-ended questions. Hence, it is better to audio record the interviews and later transcript them for analysis. Audio recordings provide a detailed insight into the interaction of the interviewee and the interviewer —the interview lasts 30 minutes to 1 hour (Barriball & While, 1994). One hour is considered a reasonable maximum length for semi-structured interviews to minimize interviewer and respondent fatigue (Dicicco-Bloom et al., 2006). Sony, model number ICD-UX533F, was used to record the interviews.

As suggested by Barriball and While (1994), the researcher was conscious that the self-presentation of the interviewer, in terms of dress, etiquette and manner, aids in putting the respondent at ease (Denzin, 1989). Hence, the research used interactive opportunities to break down the barriers of the interviewed participants, reduce tensions, and maintain rapport (Albuam & Oppenheim, 1993). Based on the interviewee's proficiency in the language, Hindi or English language was chosen to conduct all interviews. All interviews were done in Hindi with participants with vision impairments. The researcher introduced herself to the respondents and the purpose of the study. The researcher also gave the participants an overview of the different sections of the interview guide so that they were mentally prepared for the flow of the conversation.

All the audio files were transcribed and in written text manually without using any digital application as local vernacular terms, and the Hindi Language was used to conduct the interviews. As McIntosh and Morse (2015) suggest, when an audiotape is transcribed, the tape must be transcribed exactly (word-for-word) from the tape and not paraphrased. All interviews were translated into English language while transcribing in written text.

3.6 Data Analysis

Content analysis was considered an appropriate method for data analysis as it is helpful in descriptive research designs and quantifying qualitative data. Content analysis is a systematic, objective, quantitative analysis of message characteristics useful for examining document trends and patterns (Schutt, 2006). As such, it is a valuable tool for analyzing the content of reviewed documents and interview transcripts with open-ended questions. Delve & Limpaecher (2023) explain content analysis's qualitative and quantitative aspects.

- Quantitative content analysis measures the presence and frequency of specific words, phrases, or themes in a large sample of texts. It uses a numbers-based method to identify patterns that can answer “how much”, “how many” or “how often”.
- Qualitative content analysis answers “why”, “how”, or “what”. Qualitative content analysis often relies on quantifying the frequency of words, phrases, and concepts to provide such answers.

According to them, there are three main goals of qualitative content analysis**:**

- To identify and understand themes, patterns, and relationships within the data.
- To explore how the data can inform theoretical claims made in research studies.
- To quantify qualitative data.

Questionnaire responses were analyzed following a directed content analysis process. It is a more structured approach where key concepts are identified for initial coding categories. As a next step of the analysis, all highlighted passages were coded using the predetermined codes. Any text that could not be categorized with the initial coding scheme was given a new code (Hsieh & Shannon, 2005). This analysis was chosen as it enabled the data to be qualitatively analyzed and, simultaneously, quantitatively discussed; its descriptive approach allows the coding of the data and the interpretation of quantitative counts of the codes (Morgan, 1993; Downe-Wamboldt, 1992).

Participants were divided into three groups based on three levels of vision: no vision, low vision, and with sight. All responses were analyzed using a directed framework of this study. Each participant's responses were categorized depending on whether they related to wayfinding challenges, enablers, strategies, and design preferences to improve the current

system (Jenkins et al., 2015). The responses drove subthemes in each category, and the number of participants reporting each topic was noted.

Sorting: The responses from each interview transcript were sorted into three broad categories:

- Wayfinding challenges
- Wayfinding Strategies
- Design preferences

The interviews were analyzed at three levels: 1) single interview analysis, 2) interviews of participants belonging to a subgroup, and 3) interviews of all participants of all three groups (Galletta & Cross, 2020). A single interview was analyzed to understand the following: What experience does this participant narrate? What other points from the interview stand out in particular? What questions remain as they relate to this interview? How do data from different segments within the interview relate? Are there contradictory data from different interview segments; if so, how might they suggest a more layered representation of the participant's experience? Subgroup interviews were analyzed to understand the typical, different, contradicting experiences, challenges, and strategies of the participants within a subgroup and across all groups. In what way are these data related to data from other interviews: confirmatory, extending, enhancing, or contradictory? The following section introduces the participants to the readers.

3.7 Findings

The analysis revealed participants' wayfinding challenges, strategies, and design preferences. The findings are presented below using verbatim quotes from the interview transcript and the number of participants who reported a particular sub-theme per category. The specific findings for each theme will now be discussed individually.

3.7.1 Wayfinding Challenges

Wayfinding challenges are discussed under six sub-themes. These themes emerged from the rich data collected from the participants. Out of six four sub-themes, the first five were

based on the wayfinding information classification proposed by Apelt et al. (2007) & McIntyre (2011). (i) Limited signs to identify spatial zones, facilities, and trains (ii) Limited direction signs to reach from one place to another (iii) Poor orientation for entire station and train routes (iv) Lack of updated information to enable the use of facilities, station infrastructure & trains (v) Poor sense of Safety and Security (vi) Receiving, comprehending & trusting public help. Both station and train-related concerns are discussed under each sub-theme. The wayfinding problems were coded, and the frequency of participants reporting the problem is mentioned in the tables below for each type of wayfinding challenge.

3.7.1.1. Limited signs to identify spatial zones, facilities and trains.

Identification signs are made to help recognize places with the help of names, numbers, words, alphabets, etc. The identification sign serves as confirmation that one has reached the desired destination. They help communicate better ways of finding information about a specific spatial element and memorizing and distinguishing between identical spatial elements (Apelt et al., 2007). Mumbai's local train stations had several identification signs for station facilities and services, platform numbers and train lines. However, they have limitations, such as poor placement, standardization, and lack of multisensory signs to make them perceptible to all commuters. The study participants reported several limitations of this kind of sign system, as discussed in Table 3.6.

Table 3.6 Wayfinding concerns related to identifying spatial zones, facilities, and trains (No Vision- NV; Low Vision- LV; Sighted (S); (-) means 'Not Reported'.

Spatial Zones	Codes	NV (n=12)	LV (n=7)	S (n=11)
Station entry	There is no signage to identify and differentiate one station entry point from the other	-	-	1
Ticket hall	No signage to identify the ticket hall	-	-	3
Ticket Window	Difficult to differentiate ticket counters	-	-	2

Platform	Difficulty in identifying platform no. to board the desired train.	-	-	3
	Difficulty in identifying platform in the night	-	2	-
	Difficulty identifying the waiting area of the coach	4	2	-
Foot over bridge	Lack of a system of identification; as a result, unfamiliar commuters need help to memorize them.	12	7	11
Trains	Unable to find the boarding point of the coach without human assistance	1	-	-
	Difficulty in picking the right station due to the usage of acronyms on the train indicators	-	-	1

Station-related concerns

Participants with sight reported no signage to identify and differentiate one station entry point from the other. Further, identifying ticket halls and differentiating ticket windows as different types of tickets are sold on each window is impossible without the help of other commuters. Participants with VI also expressed an inability to identify water stalls and toilets. Visual signs for water and toilet stalls are present at the station to identify and differentiate between stalls. The signs are not perceptible by commuters with low vision. Toilets lack nonvisual cues to further distinguish between male and female toilet stalls.

All commuters, independent of their level of vision, unfamiliar with the station building, face difficulty identifying the foot over the bridge, as shown in Table 3.6. All bridges on the station look identical and connect to different station parts. Unlike platforms (identified through a numbering system), the bridges lack an identification system. As a result, all participants across all levels of vision get confused and find it hard to memorize them, especially on large-scale stations. Station platform number signs are displayed only in visual format; hence, they are accessible to commuters with VI. A quote from one of the respondents highlights wayfinding concerns related to the identification of objects, spatial zones and facilities.

A low-vision respondent reported, "*In the night, it is difficult to identify the platform number; this information is crucial; if it is provided in an accessible format, we can quickly*

reach the platform and board the train. I should be informed about the platform number if I am on the bridge. Information about the indicators should also be made visible to people like me".

Train related concerns

Luggage and general coaches (both men and women can board the coach) of Mumbai local trains do have corresponding waiting areas on the platform, marked with an identity sign. The current identity signs painted on train coach interfaces are not noticeable by sighted commuters. Novice commuters reported additional difficulty in understanding the meaning of coach signs. As a result, such commuters travel in inappropriate coaches for e.g. commuters with general tickets board the first-class coach or PVIs are unaware of the facility of a special coach allocated for them, board another coach. Further commuters with no vision find it hard to detect coach entry as the coach entry point lacks nonvisual cues, a wayfinding concern. The train stops left or right at the place where commuters with vision impairments wait for the train on the platform, and there are no non-visual signs associated with it for easy detection. At some stations, a tactile path has been laid that leads commuters to the train coach from the waiting spot on the platform. However, the coach entry point does not match the tactile path. These factors lead to boarding with delay or an undesired coach. There were also safety concerns associated with boarding by commuters with no vision. Participants, both familiar and unfamiliar with the commuting system, reported that they fear falling in the gap between two coaches due to the non-availability of wayfinding information to detect their reserved coach entry. While traveling inside local trains, many old trains still do not have a public announcement system that announces the upcoming station and platform name of the next train stop. As a result, commuters miss the opportunity to get off the train for a desired station stop. This is a problem faced by all unfamiliar commuters of that train route, independent of their level of vision.

The responses of the participants help us understand that the current station and train commuting system lacks a wayfinding independent guidance system that helps commuters with visual impairments recognize, identify, and differentiate between spatial zones and services. Train coach recognition is a problem faced by all new commuters of MLTCS independent of vision. As a result, many services and station zones remain unused. Lack of identification cues also contributes to delays, frustration, and poor safety, especially for people with no vision.

3.7.1.2 Limited direction signs to reach from one place to another.

Directional signs aid in moving from point A to B, e.g., arrowheads. Directional wayfinding aids hold a significant importance in wayfinding system design especially in large scale-built environments with complex, multi-level layouts. The absence of a seamless and continuous system that guides decision-making to move in the right direction generates stronger emotions of anxiety, fear, helplessness, poor confidence, and poor safety among people (Golledge & Stimson, 1998). The ability to find the right path and maintain the right direction to reach the desired destination depends upon factors like distance between two points, no. of floor level changes (Hölscher et al., 2005) in the route taken, no. of decision points (Finkel, 1999). The participants reported the following (Table 3.7) decision making concerns on station and train travel w.r.t to the direction of movement.

Table 3.7 Wayfinding concerns related to direction (No Vision- NV; Low Vision- LV; Sighted (S); (-) means 'Not Reported'.

a	Spatial Zones	Codes	NV (n=12)	LV (n=7)	S (n=11)
	Platform	Difficult to find, walking in the right direction or not	-	1	4
	Bridge	Difficult to find a bridge from the platform.	7	-	1
	Station exit	It is difficult to find directions to the station exit when arriving by train.	5	3	2
	Ticket hall	Difficulty in finding ticket counters from the platform	5	-	2
		Difficulty in locating the ticket hall	1	-	2
b.	**Station Facilities**				
	Toilets	Difficulty in finding toilet independently	6	-	1

(i) Station related concerns

There are no directional Braille signages provided at the stations, except on the handrails of the staircase of foot over the bridge, which indicates platform number. Participants with sight reported that there are hardly any directional signs in visual format. A lack of directional signs leads to wayfinding errors in selecting the right station path, especially among those who are unfamiliar with the station environment. The presence of visual impairment further increases the difficulty level. Findings from the study reveal that all participants with low familiarity with the station across all levels of vision found it hard to locate destinations on a station that was beyond perceptual access.

Tactile tiles are absent to guide participants with no vision to the main railway station entrance. In a similar study, participants reported major difficulty due to the absence of tactile cues in locating destinations like the nearest ticket hall, desired station exits and platforms.

Ticket hall locations are difficult to predict from station to station as they may be placed on side platforms or on any of the foot-over bridges of a railway station. In addition to this, commuters with no vision face additional challenges like reaching ticket windows inside the ticket hall. They further reported an inability to find the nearest toilet and help desk services at the railway station.

The foot-over bridge is a very important architectural element that connects different station zones, such as station entry/exit points and platforms. Installation of tactile ground surface indicators at a few stations was reported helpful to people with VI in locating foot over bridges from station entry points or platforms. Sound travels for a distance; hence, audio signs serve both as identification and direction signs for people with VI.

The installation of audio beepers at the waiting area of the coach for people with disabilities on the platform is the only non-visual aid installed in the entire travel chain for commuters with VI. Participants reported that the audio signage is very helpful in detecting the waiting area on the platform for their coach. At the same time, they also reported challenges associated with the beepers. The auditory beeper has several limitations like they are not installed at all platforms. If installed, they do not work. They were of no use when trains of different coach orders arrived at the same platform; in such situations, the coach's position changed with respect to the audio signage. Extreme sensory backgrounds such as loud, persistent noises mask targeted beep sounds that come from the beepers in the peak hours. The

sound of multiple beepers installed at different locations on the platform and neighboring platforms conflicts with each other. As a result, it is difficult to follow one sound and get directed.

(ii) Train related concerns

While traveling inside the local trains, there is a lack of information to help people anticipate the platform direction of the upcoming station as the coach has two-way entry and exit from both sides. In many new local trains, LED visual indicators are installed that display upcoming station names and platform directions. However, many participants with sight have reported that the display did not match the platform direction. Further, they found difficulty in understanding the display. Commuters with no vision need information on whether the train is standing on signal or the platform. Lack of public announcements about such important information inside the train has led to participants with no vision, unfamiliar with the train route, falling onto the railway tracks instead of getting down on the platform.

Lack of direction signs led to wayfinding errors, resulting in time loss and frustration for all. However, this lack has a much more substantial impact on the wayfinding experience of people with VI. Considering the above points mentioned, finding and maintaining the right direction during station use is a matter of concern for all participants in an unfamiliar station building or a train route.

3.7.1.3 Poor orientation for entire station and train routes

Spatial orientation implies access to the overview of the building and train routes. This overview puts commuters in control of their own visit and allows them to make informed choices rather than wander. The lack of an overview creates difficulty in finding decisions beyond visual access. The large building size and complex spatial layouts do not allow for the building to be perceived from a single vantage point. Participants pointed out several wayfinding concerns that were due to the differences in architectural variability between different railway stations and inconsistent location of station facilities as reported in Table 3.8.

Table 3.8 Wayfinding concerns related to orientation (No Vision- NV; Low Vision- LV; Sight (S) (-) means 'Not Reported'.

a	Spatial Zones	Codes	NV (n=12)	LV (n=7)	S (n=11)
1	Station entrance	Difficulty in detecting station entry and which part of the station it is located	1	-	-
2	Bridge	Too many bridges lead to confusion in locating the desired one	3	2	3
3	Platform	Detecting central and western line platforms	-	-	1
4		Presence of offset platforms	3	2	2
5	Station exit	Difficulty in locating east or west side to exit from stations.	2	-	1

(i)Station spatial zones

Station Entry and Exit: Station Entry and exit to a railway station is from the same point. They are designated through- ticket halls, foot-over bridges, circulation paths and platforms. Commuters new to a railway station with VI, especially those with no vision face difficulty in detecting station entry and which part of the station it is located. As a result, such commuters cannot develop mental maps of the station without the awareness of their current location as they enter the station.

A regular user of MLTCS with no vision reported, "*I face difficulty in finding the right bridge and the staircase connected to the bridge from the entry/exit points of the station and platform."*

Some facilities are quite far and isolated from the reach of commuters. The lack of standardization of ticket halls and washrooms at each station creates difficulty in locating them. Participants reported that they predicted their location at unfamiliar stations based on their previous understanding of past visits to other stations. Ticket halls were predicted to be located near station entry points outside the station building or on the side platform. Washrooms were also predicted to be located on the side platform.

A regular user of MLTCS participant with no vision reported *"Washrooms were located on the side platform. I don't know whether they were located on all platforms."*

Another participant with no vision regular to MLTCS use reported, *"Toilets are located at the extreme end of the platform. I don't know whether they are located on all platforms or not."*

Such predictions were only sometimes accurate for all railway stations. For example, washrooms were mostly located at platform ends, but not all platforms have this facility. In addition to this, either of the two platform ends has a washroom facility. Sometimes they are also located in the center of the platform.

Foot Over Bridge: The complexity of wayfinding increases with the scale of the station as the choices of interior paths and spatial elements increase. On a large-scale station like Dadar, the selection of the right foot over the bridge is a concern for all users across all levels of vision and familiarity. Foot-over bridges connect to different parts of the station. Each foot-over bridge is designed differently in terms of its connectivity to different station parts. They may or may not lead to all platforms or station exits. On some stations, they are only used to change station sides, offer no connectivity to the platform and serve the purpose of shopping from vendors. It is difficult to visualize the connectivity of the bridge from a single vantage point, especially in large-scale stations. Hence, many times, it leads to the wrong bridge selection. This is one of the major concerns of all participants independent of level of vision as given in Table 3.8. Participants across all levels of vision, unfamiliar with the station, are unable to identify the layout of the foot over bridges without assistance. Further, foot over bridge is one such spatial element that has multiple choice points that connect to different platforms, foot over bridges, ticket halls, and station exit points. The lack of nonvisual signs makes wayfinding very difficult for commuters with VI on an unfamiliar bridge. This is a reason why they always prefer to use a bridge where they have gained experience of use by repeated walk. Wrong selection of foot over the bridge or a wrong turn from the bridge both result in frustration and physical loss of energy and time as they are aided by long staircases.

Platforms: The design of the platforms varies from the side platform to the island platform. Many stations have offset platforms i.e. platforms that are not parallel to other platforms. Their position is away from a common set of platforms. People find difficulty in locating such platforms in the absence of wayfinding signs. Unfamiliar commuters with the

station across all levels of vision face challenges in determining the eastern and western sides of the station. They further face difficulty in differentiating between platforms of different train lines.

An unfamiliar participant with sight vision reported, *"...for an outsider, if a person who had not travelled a lot, it can confuse anyone if he doesn't know what the western line is and what is the central line. If you have a ticket to Dadar, you can be on Central or Western, and all the stations look the same; they are not different platforms. But for the outsider, it becomes a little difficult to come across these problems."*

An unfamiliar-sighted participant reported, "Stations are not so complicated; there is the exit from both sides. Normally, you go on the bridge and from there, you take an exit. Dadar, there are certain bridges that are complicated, but yes, there also you can go to another bridge and take the exit."

3.7.1.4 Lack of updated information to enable the use of facilities, station infrastructure & trains

These are challenges related to information about features, functions, and services of the facility, e.g., rules and regulations for station use. Such information is both static and dynamic. Static information is information that gets updated after a prolonged period. For example, train coach typology, commuter eligibility criteria, and related boarding and coach use rules. Dynamic information keeps getting updated in real time. In mass transit systems such as railways, information related to trains is mostly dynamically updated in real time. The participants' concerns under this theme mainly relate to local train travel (Table 3.9).

Table 3.9 Real-time and static Information related concerns (No Vision- NV; Low Vision- LV; Sighted (S), (-) means 'Not Reported'.

Spatial Zones	Codes	NV (n=12)	LV (n=7)	S (n=11)
Platform	Poor Quality of Public Announcements on the platform	7	3	3

	Difficulty in understanding LED display and signage boards	-	-	1
	Incorrect information given by indicators on the platform	-	-	1
Trains	Late public Announcements inside the train about changes in the platform	2	2	2
	Difficulty in understanding the indicators	-	-	2
	Not enough information on which direction the train comes from	1	1	-
	Coach for PwDs does not stop exactly near beepers	6	1	-
	People don't know the whereabouts of braille signage	1	-	-
	People board the wrong coach due to a lack of awareness of coach typology and boarding rules	4	1	-
	Lack of information about train standing or not on the platform	2	-	-

Novice participants across all levels of vision lack awareness about Mumbai local train coach typology and boarding criteria based on user and ticket type. This led to boarding in ineligible or undesired coaches. Similarly, they also faced difficulty in the selection of platform and train since train indicators were difficult to comprehend due to the use of acronyms for station names. All participants across all levels of station familiarity and vision reported dissatisfaction with the delay in dynamic information updates about train arrival time on the platform. Public announcements were the only way to access information on platform numbers and trains for commuters with VI. However, they were ineffective due to a lack of timely updates and low audibility in peak hours. Lack of audio-visual alert of the departure time left for trains parked on the platform leads to hasty decisions for boarding and alighting from trains. Such situations become life-threatening for commuters, especially for commuters with VI. In addition to the above concerns, when trains halt between two stations, there is a lack of audio updates inside the train. As a result, one of the participants with no vision and unfamiliar with

the train route shared that he had fallen on the rail track under the impression that the platform of the desired station had arrived.

3.7.1.5 Poor sense of safety and security

Safety is one of the severe wayfinding challenges faced especially by commuters with vision independent of familiarity with the station building and train route. Poor safety during station navigation and train travel is interlinked with built environmental limitations, crowds, and lack of wayfinding signs. The challenges reported by the participants are given in Table 3.10.

Table 3.10 Wayfinding safety concerns and Negative impact (No Vision: NV; Low Vision: LV, Sighted (S) means 'Not Reported'.

No.	Spatial Zones	Codes	NV (n=12)	LV (n=7)	S (n=11)
1	Platform	Forget directions in the presence of the crowd	1	1	4
2		Feel Anxious	2	-	2
3		It affects the ability to make wayfinding decisions	4	-	3
4		Audibility of PA decreases	4	-	1
5		People collide with objects and other people	7	1	-
7		Poor lighting conditions lead to feelings of poor safety and insecurity	1	1	-
8		Face the misbehavior of the crowd	2	5	1
9	Bridge	It is challenging to locate a bridge on the platform in a crowd	-	-	1
10	Trains	Boarding and getting down from the train is life-threatening (people slip on the rail tracks) due to the crowd and the	12	7	3

		large gap between the platform and the train footrest.			
		People collide with luggage and personal belongings of people inside trains	1	-	-

(i)Built environmental Challenges: Built environmental challenges such as poor floor conditions, unwarned floor level transitions, presence of physical barriers, and absence of door closing feature in all train coaches lead to falls, injuries and life-threatening situations for people at the time of boarding and getting from trains for train commuters.

a. Poor Floor Conditions: Commuters with no vision generally feel unsafe if the walkways are not quality. Floor erosion in walking surfaces, the presence of potholes, unevenness, inundations, cracks, bumps and stones lead to unsafe navigation, especially in the immediate station exterior area, creating fall risks. Uprooted tiles of the foot staircase over the bridge created a fall among commuters with vision impairments. Poor environmental protection against monsoon rains leads to commuters getting wet inside the station building; further rains reduce the visibility of low-vision commuters and make walking surfaces slippery.

b. Unwarned floor level transitions: Lack of warning signs that help to anticipate a walking surface level change from floor to steps or staircase, drop-offs create a situation of fall among totally blind commuters. The ramp cum staircase was challenging to use for the same reason. Steep ramps were difficult for all commuters to negotiate across all levels of familiarity. Lack of environmental protection to avoid falls in the gap between the train and platform interface and between two coaches while boarding and alighting the train is one of the major safety concerns commuters with vision impairments face.

c. Physical barriers*:* There is a lack of warning signs to alert commuters without vision about the architectural barriers upcoming in their navigation paths, such as overhead walls, girders, free-standing poles, and seating areas. Poles are structural members that hold the roof of the platform. Train indicators, station names and coach identification signage are installed on them. Mizuno et al. (2009) emphasized the critical role of tactile surface indicators (TGSIs) in

facilitating safe navigation for visually impaired individuals. However, the participants of this study revealed a notable absence of TGSIs at most stations. Furthermore, the findings indicated a lack of proper tactile guidance paths in many areas, posing significant challenges, if not outright dangers, for commuters. Without tactile ground surface indicators at the platform edge, island platforms with tracks on both sides were perceived as more dangerous than side platforms because the latter had one side guarded wall. Hence, the chances of falling on railway tracks are high on such platforms. The inability to judge and estimate spatial depth and distance within the context of a space affected PVIs ability to way-find (McIntyre, 2011). Platforms having guiding paths lack standardization both in width and placement. This can lead to an error in finding the correct guidance pathway for blind or visually impaired passengers. Few stations have strong colour contrast on the tactile path for visibility by commuters with low vision.

d. The presence of crowds leads to poor safety: The threat to safety stems from collisions with fellow commuters and their belongings, such as luggage and baskets. This difficulty is compounded by the reduced levels of vision and heightened mobility of the crowd, increasing the risk of injury from inadvertent collisions, especially during rush hours (7 am to 10 am and 5 pm to 10 pm). High-risk areas for collision include the platform-train interface and foot overbridges. PVIs struggle to remain visible amidst the congestion despite using white canes and black glasses as identifying markers. Jampacked station and train environments present significant obstacles to wayfinding and cane navigation for commuters with vision impairments. Further, tactile surface indicators remain undetectable by foot.

Consequently, navigating the densely packed environment of stations and trains has fostered negative perceptions among commuters, regardless of the level of vision of the participants, especially those unfamiliar with the station or the commuting system itself. It heightens their sense of vulnerability and poor confidence, as exemplified by instances where individuals with VI encounter derogatory remarks and discriminatory behaviour from fellow commuters.

A participant with vision impairment shared his experience, *"When we walk, people do not see us, they push us, and many times they break our cane. I cannot say anything to them. People do not see that a blind person is coming."*

Similarly, collision happens when a commuter with no vision cannot gauge the presence of other commuters in his/her path during navigation. In such situations, the intolerant and insensitive behaviour of commuters with vision was reported by participants.

For example, a participant with no vision shared his station experience, *"I collided with a woman sitting on the bench, she called me mad, and then I gave an answer that I am not mad, I am a handicap."*

The presence of crowds also leads to unsafe conditions such as falls on railway tracks by the push of the public and difficulty in detecting floor transitions both on the bridge and while boarding and alighting the train (this is a significant concern for participants with no vision as shown in Table 3.10.). Two participants with no vision reported falling on railway tracks in peak hours as the fast-moving crowd pushed them. For commuters with sight, navigating the crowded platforms and trains during peak hours presents challenges, including missed stations and difficulty boarding late trains.

A sighted participant familiar with local train travel shared his experience of train travel in peak hours, *"Once I missed the platform because of the crowd, I did not know which side it would come, could not get down, had to go to the next station and then come back".*

Another commuter with sight, unfamiliar with local train commuting, reported a station visit in peak hour as an *"overwhelming experience"*. He said, *"Due to the crowd, I could not identify which coach to get in, so I got into the luggage coach; I think looking around for information would be possible in a quieter setting."*

Overcrowding disrupts directional navigation and aggravates the challenges faced by those with low or no vision. The influx of people inhibits the ability to seek out wayfinding information and increases the likelihood of errors, affecting users across different levels of vision and familiarity with the system. A novice-sighted commuter of the local train shared that the crowd disturbed his mental state.

A participant with low vision shared her experience of a station visit in peak hour, *"I have great difficulty in walking. I get carried forward in the flow of the crowd".* Another participant with no vision reported, *"When there are many crowds, then it is difficult to maintain direction, detect the staircase of the bridge. We took the wrong bridge".*

In addition to the built environmental factors, the absence of adequate wayfinding information compounds safety concerns for commuters, as decisions must often be made quickly amidst the chaos, as discussed in points (i) to (iv) of section 3.7.1. It is also linked with a collision with the public while navigating a crowded environment inside the train and at the railway station, as discussed in section 3.7.1 (v). From the above findings, we can conclude that the overcrowded environment significantly impacted people's wayfinding experiences. People with VI feel more vulnerable and unsafe and have less control over their wayfinding than commuters with sight.

3.7.1.6 Difficulty in Receiving, Comprehending & and trusting public help

In Mumbai's local train commuting system, asking for help from the public has formed a culture of finding a way to the station and train travel. This is because there are very few wayfinding signs in general in public environments of the country and hardly any multi-sensory signage for PVIs. There are many ways in which there can be a mismatch in information communicated and comprehended, especially when the information is given by a person with sight, and the seeker has a vision impairment. The challenges with public help are given in Table 3.11.

Table 3.11 Wayfinding concerns related to Receiving, comprehending, and trusting public help (No Vision- NV; Low Vision- LV; Sighted (S) means 'Not Reported'.

No.	Codes	NV (n=12)	LV (n=7)	S (n=11)
1	People provide incorrect information	5	2	-
2	Difficulty in comprehending given directions	8	-	-
3	People misbehave	-	-	2
4	Request for help left unheard, unanswered	12	-	-

Due to a lack of eye contact, all participants with no vision reported that they were unheard or unanswered.

A commuting system familiar participant of MLTCS with no vision shared his experience, *"After saying aloud ten times, 11th time some commuter will respond, what do you want? This is the biggest difficulty. Nothing is as difficult as this."*

Moreover, individuals with sight often offer verbal directions such as "go straight ahead," "turn left," or "turn right" to assist commuters. However, for those with vision impairments, relying solely on verbal guidance poses challenges in comprehension and decision-making. Participants with vision impairments struggle to discern the spatial context in which these commands are given, making it difficult to orient themselves and make informed decisions.

Poor information comprehension leads to misguidance. Misguidance leads to unsafe navigation and wayfinding errors. Unlike platforms, bridges have no identification signs and path guidance systems, as section 3.7.1 (i) states. As a result, people with vision impairments face difficulty explaining to commuters with vision which bridge they desire to take as there are multiple bridges on a railway station and not all bridges lead to all platforms and desired station entry/exit points. Hence, they are sometimes escorted to the undesired bridge where they find it hard to make their way as platform nos., as indicators and other sign boards are only in visual format. There were incidents reported when commuters with no vision were escorted or directed to undesired train coaches by commuters with sight. A blind commuter reported being escorted to a 1st class coach instead of a reserved coach for PwDs. Such incidents occur due to the need for more awareness among the public about the provision of such reserved coaches on local trains, also stated in (iv) 3.7.1.

The upcoming section discusses how participants adapt to different wayfinding strategies to overcome some of the challenges reported in the above section.

3.7.2 Wayfinding Strategies

Wayfinding strategies encompass commuters' techniques to overcome navigation challenges within the Mumbai Local Train Commuting System (MLTCS), tailored to their levels of vision. Through interviews, participants in this study revealed four primary strategies utilized for wayfinding and navigation:

(i) Traveling with an escort: Participants often rely on the assistance of family, friends, or colleagues, especially when they are new to the MLTCS and require guidance in wayfinding.

(ii) Cane usage: Another common strategy involves using a cane, particularly during the initial stages of learning to navigate and wayfinding in the MLTCS independently.

(iii) Utilizing sensory cues: Over time, commuters develop sensory cues through repeated exposure to the system. These cues aid navigation and become increasingly relied upon as familiarity with the MLTCS grows.

(iv) Seeking public assistance: When individuals are still acclimating to travelling independently, they may turn to fellow commuters or the general public for guidance and assistance.

Out of these four strategies, sighted commuters rely on sensory cues and public assistance. These strategies evolve in tandem with commuters' progress in becoming more adept at navigating the MLTCS. While reliance on personal escorts and public assistance may diminish with increased familiarity, sensory cues become more pronounced, reflecting a shift towards greater independence in wayfinding.

There were six different reasons for which participants used social support and sensory cues.

a. Identification of spatial zones, facilities and services
b. Finding direction
c. Walking without deviation
d. Safe Navigation
e. Information about station architecture, facilities, train arrival and departure
f. Orientation

In the section below, each wayfinding strategy is discussed in detail.

3.7.2.1 Travel with an escort

Learning to navigate in familiar or unfamiliar places safely and effectively requires substantial practice for people with vision impairments. People with vision impairments at the early stages of commuting learn to become travel active on local trains with the help of personal escorts. These escorts are their friends, family and peers. They may have vision or vision

impairment or any other disability. Three out of seven participants with low vision and six out of twelve with blindness travel with escorts on unfamiliar train routes and station buildings.

Table 3.12 Reasons for having a personal escort while using MLTCS. (-) means 'Not Reported'.

No.	Codes	NV	LV
1	Sense of companionship in a familiar station	4	1
2	Companionship to familiarize with a new station	1	1
3	Act as an escort to other people with vision impairment	-	2

Participants, particularly those with vision impairments, expressed apprehension about entering new station buildings without accompaniment. Their lack of confidence in visiting unfamiliar stations was evident, as they heavily relied on personal escorts, typically family members, for guidance. Learning to navigate the local train system often begins with assistance from family, friends, or peers with vision impairments during the initial stages of travel. This guided experience builds their confidence and familiarity with the environment, eventually empowering them to navigate independently. Along the way, they develop sensory cues to aid in memorizing routes for future independent travel. Individuals with disabilities often support each other's needs, forming a mutual assistance network. For instance, a person with low vision may assist someone without vision, facilitating their navigation through local trains. This collaborative approach allows individuals to compensate for each other's limitations and navigate public transportation challenges more effectively. A quote from the interview of a participant in our study substantiated the same.

A low-vision participant stated, *"When we guide blind people, we tell them that the staircase is about to come. Tell them about food stalls and right/left directions."*

Relying on personal escorts for outdoor mobility imposes financial strain on the families of individuals with vision impairments. The escorts, who could otherwise be engaged in income-generating activities, are compelled to dedicate their time to ensuring the safety of their visually impaired family members due to the lack of a safe commuting environment.

3.7.2.2 Use of cane

The use of a cane is reported to be much higher and more diverse among participants with no vision than among those with low vision. Table 3.13 shows that the cane is primarily used for two purposes: 1) Identification of spatial zones, facilities and services and 2) Safe navigation. Using a cane helps gather spatial cues, followed by object and social cues.

Table 3.13 Use of cane as an audio-tactile cue by No vision (NV) & Low Vision (LV) for different uses: a. identification of spatial zones, facilities, and services b. Safe Navigation. (-) means 'Not Reported'.

Type of cue	**Reason of use**	**Use Code**	**NV**	**LV**
Spatial	Helps to detect seating furniture	Identification	7	-
	To detect platform edge, especially on island platforms	Safe navigation	6	-
	To detect staircase	Safe navigation	5	1
	To judge depressions and elevations on the floor	Safe navigation	6	-
	To cross the road in a crowded setting	Safe navigation	-	1
	Uses cane in unfamiliar places, especially after sunset	Safe navigation	-	1
Object	To detect luggage (obstacle) of other people	Safe navigation	6	-
	To detect help desk	Identification	-	1
Social	To let people know that one has low vision so that they can provide help	Identification	-	6
	To detect people sitting on furniture	Identification	5	-
Object	It helps detect pole location at coach entry. If the pole is located at the extreme ends of the coach entry. It implies that it is a handicap coach.	Identification	6	-

	To detect whether the train is standing on the platform or not	Identification, Safe navigation	3	-
	To detect a gap between two train coaches	Safe navigation	1	1
	To detect vehicles parked at the immediate station exterior	Safe navigation	2	-

***(i) Identification of spatial zones, facilities and services*:** At railway stations, individuals with vision impairments rely on their canes to navigate furniture, locate help desks and discern the reserved coach for Persons with Disabilities (PwDs) from other coaches. In the reserved coach, a distinctive pole positioned at the extreme end of both ends or one of the ends of the platform facilitates wheelchair access, whereas, in other coaches, the pole is typically situated at the center of the entry. People with no vision utilize their canes to sense the pole's presence and identify their designated coach. However, while essential, this method could be more time-efficient, especially considering the limited window of opportunity for making boarding decisions as trains halt for only 15 to 30 seconds. Without a proper perceptible non-visual signage system, boarding the train poses significant risks for commuters with no vision.

Most participants with low vision indicated minimal use of the cane, primarily employing it for identification and safe navigation. Interestingly, they noted a significant increase in its utilization to signal their visual impairment to sighted individuals, particularly in densely crowded environments where assistance may be needed. Below are the quotes from the participants' interactions that explain how to use a cane in wayfinding and navigation.

A participant with low vision who was unfamiliar with local train travel reported, "*If we have to take help, we open the stick to take help; otherwise, people do not help."*

Another participant with low vision, unfamiliar with local train travel, shared her experience, *"Prefer using a cane, as with my eyes people do not understand that I have low vision, but with a cane, they know I am handicap, and I can ask questions like which train is there, which coach is it here, where is ticket counter, can travel in a handicap coach, else people will not understand why I am asking these questions. Cane helps people take notice and prevent collisions."*

***(ii) Safe Navigation**:* Participants with vision impairments utilized canes as a proactive tool to navigate their surroundings, identifying and circumventing obstacles and potential hazards

along their path within the Mumbai Local Train Commuting System (MLTCS). The cane served multiple functions, including:

- Obstacle avoidance: Participants relied on their canes to detect and avoid obstacles such as seating furniture, help desks, vehicles, and luggage, enhancing their ability to navigate safely.

- Occupancy Detection: The cane aided in discerning whether seating furniture was occupied by individuals, enabling participants to make informed decisions about seating availability.

- Floor Surface Assessment: By sweeping their canes along the ground, participants could anticipate changes in walking surfaces, including plains, slopes, small steps, and staircases, minimizing the risk of tripping or stumbling.

- Detection of Floor Irregularities: Canes helped participants navigate floors with uneven surfaces, such as depressions and elevations, reducing the likelihood of encountering potential hazards.

Additionally, participants with no vision utilized their canes to sweep along the platform edge, enabling them to ascertain whether a train was present and to detect gaps between train coaches, ensuring safe boarding. However, these navigation techniques carried inherent risks due to the need for more information regarding train status and safety signage, indicating gaps between coaches. Consequently, participants often had to approach the platform edge closely to gauge the train's position, potentially exposing themselves to danger.

3.7.2.3 Sensory cues

Sensory cues are categorized into social, spatial and object-based cues. Social cues are the ones that are derived from the social environment of the system. Spatial cues are characteristics of architectural elements that are immovable. Object cues are characteristics of the objects in the space that are movable. The use of each sensory cue is discussed in detail below.

i. Auditory Cues

Participants with no vision predominantly reported the use of auditory cues. Auditory cues are primarily used to identify spatial zones, facilities, services and safe navigation (Table 3.14).

Table 3.14 Participants use auditory cues to gather various kinds of spatial information (category of use: identification of spatial zones, facilities and services and safe navigation by No Vision (NV), Low Vision (LV), (-) means 'Not Reported'.

Type of cue	**Cue**	**Reason of use**	**Code**	**NV**	**LV**
Social	The noise level of the public	To understand whether the train is standing on the signal or platform. More noise means the train is standing on the platform	Identification, Safe Navigation	3	-
		To find the ticket window	Direction	1	
	The body language of people	To detect whether the train is standing on the platform or not	Identification, Safe Navigation	1	-
	Vendors' loud voice while selling their goods	Helps to detect vendors and canteen	Identification	7	-
Object	Sound of utensils	Indicate canteen is close by	Direction	3	-
	Sound of fan	Indicate the position of the coach for disabled commuters	Identification	1	-
		To detect ticket hall interiors	Identification	2	-
	The sound of ticket machines and money	To detect ticket hall interiors	Identification	2	-

	The sound of shoe cleaning brush	To detect cobblers nearby	Identification	2	-
	The sound of the train	To detect that the train is standing on the platform	Identification, Safe Navigation	6	1

While commuting via local train, the ambient noise level of the public on the platform serves as a critical indicator for sensing whether the train is stationary at the signal or the platform. A bustling noise typically signifies the train is stationary on the platform, while silence suggests it is halted at a signal. Similarly, the sounds of a fast-moving crowd on the platform signal that the train is present, awaiting passengers for boarding and disembarking. Moreover, loud calls from vendors assist individuals with no vision in identifying their presence. Furthermore, sounds emitted by objects and facilities installed on railway stations aid in identifying spatial zones and services. For instance, the clattering of utensils signals the proximity of a canteen. At the same time, the whirring of a fan mounted on the ceiling indicates the location of the waiting area for coaches for people with disabilities, particularly in the absence of auditory beepers. Additionally, the distinct sounds of ticket machines and currency transactions help locate the ticket hall, while the scraping of a shoe-cleaning brush alerts commuters to the presence of cobblers.

(ii) Tactile Cues

Both participants with no vision and those with low vision reported the utilization of tactile cues. However, a more significant proportion of participants with no vision mentioned their reliance on tactile cues compared to those with low vision. Primarily, tactile cues are employed to identify nearby spatial elements, features, and objects. Their usage is confined to the immediate body field of the individual, as spatial information can be discerned through tactile sensations in the hands and feet, supplemented to some extent using a cane, as elaborated in section 3.7.2 (ii). (Table 3.15).

Table 3.15 Use of tactile cues (category of use: a= identification of spatial zones, facilities and services, finding direction, c= Walking without deviation, d=avoiding obstacles and possible hazards) No vision (NV), Low Vision (LV); (-) means 'Not Reported'.

Type of cue	Environmental Cue	Reason of use	Challenge Code	NV	LV
Spatial	Slippery/rugged floor surface finishes	To identify bridge and platform	Identification	3	3
	Raised/depressed floor surface detail on the platform	To identify the entry of coaches for people with disabilities	Identification	3	1
		To identify the central and western line station zone	Identification	-	1
	Walls	To walk straight	Walking without deviation	1	-
		To walk away from the platform edge	Safe Navigation	3	-
		Helps to detect canteen or bookshop	Identification	2	-
Object	Seating furniture	To detect waiting areas for coaches for disabled commuters on the platform	Identification	3	1
	Pole	To identify coaches for people with disabilities	Identification	6	1
	Window	To detect the ticket window	Identification	3	-

During interviews, participants with visual impairments (VI) shared five types of tactile cues they rely on to discern spatial zones, facilities, and services at railway stations. In the absence of tactile ground surface indicators, individuals with VI employ self-developed

floor markers to navigate architectural spaces. They memorize variations in floor finishes, such as slippery or rugged surfaces, to identify specific bridges and platforms. Details of raised or depressed floor surfaces are memorized through touch to locate platforms for different train lines and the entry point for the reserved coach for people with disabilities. Moreover, poles installed at the entry of the reserved coach for people with disabilities, both inside the train and on the platform, serve as tactile identifiers to distinguish them from other coaches, as outlined in section 3.7.2 (ii) of the study. Participants memorize the location of seating furniture on the platform to pinpoint the waiting area for this coach. Similarly, the tactile sensation of window frames aids in identifying ticket windows. Spatial zones with defined edges, such as foot overbridges and platforms with railing or walls, assist individuals with VI in maintaining a straight path, avoiding obstacles, and minimizing hazards. These tactile cues are crucial in enhancing navigation and wayfinding, ensuring safety for commuters with VI in railway station environments.

ii. Olfactory cues

Table 3.16 shows that participants with no vision use olfactory cues more than those with low vision. Such cues help identify spatial zones, facilities and services but do not lead a way-finder to the exact location. Olfactory information helps to detect only those spatial elements and objects that emit smell. There are a few spatial elements in railway stations that emit a smell, such as canteens and toilets located on the platform and immediate platform exterior. Twelve participants with vision impairments reported three distinct olfactory cues that were helpful in wayfinding on the station. Familiar participants with VI reach the station entry point by mapping the smells from shops located at the immediate station exterior arterial road. Similarly, the smell of boot polish from the cobblers seated on the platforms helped them detect their self-location on the platform or other parts of the station.

Table 3.16 Use olfactory cues for a) identification of spatial zones, facilities and services. No vision (NV), Low Vision (LV); (-) means ‘Not Reported’.

Type of cue	Environmental Cue	Reason of use	Challenge Code	NV	LV

		Indicate canteen is close by	Identification	5	1
	Food smell	To identify station entry	Identification	5	1
Spatial	Foul smell	Indicate toilet is close by	Identification	2	-
	Boot polish smell	To detect cobblers nearby	Identification	1	-
Object	smell of books	to detect book stalls	Identification	2	-

iii. Visual Cues

As stated in Table 3.17, the use of visual cues on the station is reported in a limited way by very few participants across levels of vision, including the ones with sight. These visual cues were mainly spatial based, followed by social and object cues.

Table 3.17 Use of visual cues by No Vision (NV), Low Vision (LV), and Sight (S) for different uses: a. identification of spatial zones, facilities and services b. finding direction c. Walking without deviation, d. Avoiding obstacles and possible hazards, e. Information about station architecture, facilities, train arrival and departure f. Orientation (-) means 'Not Reported'.

No.	**Types of cues**	**Cue**	**Reasons for use**	**Category of use**	**NV**	**LV**	**S**
1	Social	Public queue	Indicate ticket window	Identification	-	1	-
2		Group of ladies on the platform	To detect ladies' coach location on the platform	Identification	-	-	1
3		Crowd movement	Follow it to get out of the station	Direction	-	1	3
4			To understand which direction platform of the upcoming station is about to come	Direction	-	-	2

5	Spatial	Size of the bridge	Helps to memorize it	Identification	-	-	1
6		Bridge location in respect to the train	Helps to memorize it	Orientation	-	-	1
7		Bridge location in respect to the ticket hall	Helps to memorize it	Orientation	-	-	1
8		Food stalls	Helps to detect path to station entry	Direction	-	2	-
9		Change in environmental light	Helps to detect the transition from the foot over bridge to the platform	Identification	-	1	-
10		Shadow of the canteen wall	To detect canteen	Identification	1	-	-
11		Shadow of the roof of the platform	To maintain safe walk on the platform	Safe Navigation, Walking without deviation	1	1	-
12	Object	Shadow of train	To detect whether the train is standing on the platform or not	Identification, Safe Navigation	3	-	-

Social cues play a significant role for participants with low and sight, particularly those less experienced with local train travel. For instance, observing people standing in queues helps locate ticket windows, while groups of women on the platform indicate the waiting area for the ladies' coach. However, navigating large station buildings with multiple exit points poses challenges for commuters, especially those unfamiliar with the Mumbai Local Train Commuting System (MLTCS). In such cases, individuals with sight and low vision rely on the

movement of departing crowds to find their way to the station exit, considering it a 'universal rule' for navigation, particularly in India.

Moreover, spatial cues, such as foot overbridges, serve as guiding landmarks. Sighted participants memorize bridge locations based on their size or relative positions to other spatial features. Additionally, the presence of food stalls helps individuals with low vision discern the path to the station entry. For those capable of perceiving light transitions, spatial information is interpreted through changes in shadows, aiding in navigation and spatial awareness.

Light intensity varies across different spatial elements within the station environment, influenced by natural and artificial lighting, the presence of roofs, and the time of day. These changes in light conditions facilitate the identification of spatial transitions and zones. Participants with no vision, possessing light perception or low vision, utilize light and shadow cues to identify spatial zones, avoid obstacles, and maintain a straight path while walking.

3.7.2.4 Assistance from other commuters

Social wayfinding involves verbal and gestural communication between individuals to seek and receive assistance with navigation. On railway stations, assistance from fellow commuters plays a crucial role in wayfinding, regardless of the individual's level of vision or familiarity with a specific route or station building. Participants across the study reported a consistent need for social assistance for various purposes, as outlined in Table 3.18.

Table 3.18 Participants ask for public help for six reasons: a. identification of spatial zones, facilities, and services; b. finding direction, c. safe navigation, d. Information about station architecture, facilities, train arrival and departure, e. Orientation); No vision: NV | Low Vision: LV | Sighted: S, , (-) means ‘Not Reported’.

Spatial Zones	Reasons for help	Code	NV	LV	S	Total
Ticketing	To find the ticket hall	Direction	4	1	2	4
	To select the ticket window	Information	-	-	1	1
	To find bridge	Direction	7	1	2	8

Foot over Bridge	To select bridge	Orientation	7	-	-	4
	To find the staircase of the bridge	Orientation	2	1	-	4
	To find a way to the desired platform	Direction	8	3	4	13
Platform	To find platform no. for the desired train	Information	7	3	4	12
	To identify the platform number	Identification	5	-	1	6
	To identify the platform of different train lines	Identification	7	1	1	5
	To find the direction of the upcoming train on the platform	Direction	4	1	-	4
	To identify whether the train is standing on the signal or platform from inside the train	Information	2	-	-	2
	To find whether the train is standing on the platform or not while being on the platform	Information	1	1	-	4
	To find out whether the upcoming train will go to the desired station	Information	1	1	1	3
	To detect the entry of coach for differently abled	Identification	7	2	-	6
Station exit	To get out of the station	Direction	9	3	1	10
Toilet	To locate toilet	Direction	7	1	-	6
Train	Help is provided to pick if fallen on rail tracks or save from falling	Safe Navigation	4	-	-	4
	poor lighting condition	Orientation	2	-	1	3

	providing help boarding the coach	Safe Navigation	2	-	-	2
	providing help in getting off the train	Safe Navigation	1	2	1	4
	To find out upcoming station names during the train journey	Information	3	2	8	13
	To find the timings of express trains	Information	-	-	4	4
	To find the time left for the upcoming station stop inside the train	Information	-	-	4	4
	To find the platform direction of upcoming station stop during the train journey	Direction	5	1	6	12
Non-Stage Specific	**Reasons for help**	**Code**	**NV**	**LV**	**NM**	**Total**
	To find a way on the new station	Direction	12	1	-	8
	To find east/west side of the station	Orientation	7	1	-	6

The table above highlights information that is currently unavailable to commuters in an accessible format, or if accessible, remains underutilized due to various reasons. While participants across all levels of vision seek assistance from others for wayfinding, those with no vision exhibit a particularly high dependency on human help. The need for assistance primarily revolves around finding directions on stations and inside trains, reflecting a notable absence of mechanisms enabling independent navigation within station environments. This absence of directional aids emerges as a significant wayfinding challenge, as outlined in section 3.7.1 (ii).

Participant responses reveal that individuals with visual impairments (VI) often receive social support, even when not explicitly requested, particularly in situations posing life risks or potential injury, as indicated in Table 4.5. This highlights the inadequacy of current

physical infrastructure for safe navigation by individuals with VI, as highlighted in section 3.7.1 (vii). Most social support is sought for platform and train usage, highlighting the critical need for assistance in these areas, as evidenced by Table 4.5.

Participants with VI who came from different cities found the Mumbai public beneficial compared to the ones in other cities. Quotes from two participants with no vision illustrate the positive perception and gratitude towards commuters of Mumbai for providing voluntary help to them.

A participant with no vision reported, *"We depend on public help for station mobility. If I do not have information, we rely on public help. Without public help, I cannot travel by train."*

One of the participants with no vision reported, "*In Mumbai, people voluntarily help, especially commuters with no vision. They give verbal directions and information, but in special cases, like commuters with no vision, they even escort them from one point to another inside the station and help them board the train. People voluntarily provide help when they find any commuter with VI about to collide with a physical barrier, or about to fall due to floor transitions or save them from getting hurt by luggage or rushing crowd"*.

For sighted participants, public help from people is a substitute for the weak signage system of the local train commuting system. Wayfinding signs display wrong information due to technical faults and other reasons. One can get extra information by asking people, which is not possible with wayfinding signs as they are designed only for specific information.

Wayfinding signs were limited and installed at specific locations and may only sometimes be available where the information is desired. In such cases, people were the only alternate source for instant information. The following quote from one of the participants from the study substantiated the same.

A sighted participant who was unfamiliar with MLTCS use reported, *"People guide you at every step. I ask people and follow rather than look around."*

Further, the presence of large crowds at the station and environmental noise restricts the ability to access information displayed on signboards. Asking for help from the public was preferred over signage by sighted participants for this additional reason. The following quote from the participants reflects the same.

As one of the sighted participants stated, *"I think looking around for information would be possible in a quieter setting."*

Sighted commuters used verbal help from people to validate the information provided through signage and vice versa. Furthermore, help provided by one individual is also confirmed by asking multiple individuals for accuracy. Some participants reported that they had more trust in the help given by people than wayfinding signs. Help given by daily commuters was perceived to be reliable as they were understood as the most experienced source of information than the sign system. Infrequent sighted commuters spot daily commuters with visual identity markers like those who carry a small backpack and those who walk confidently. A sighted participant infrequent to local train travel reported that he avoids taking help from those with luggage as it is an identity marker of novice travelers. Sighted participants unfamiliar to MLTCS use, prefer taking help from shopkeepers and railway staff as they had spent more time on stations and know the station in and out. Participants with no vision reported no such preference as they cannot spot people based on occupation and appearance.

In the next section, participant's suggestions to improve the wayfinding situation of MLTCS are reported.

3.7.3 Design Suggestions

All participants across all levels of vision stated several preferences that, according to them, would ease their wayfinding experience at the railway station. The design suggestions are discussed based on user groups in Table 3.19. The design preferences are discussed for different station zones, station facilities, trains and non-wayfinding stage-specific categories.

Table 3.19 Participants' suggestions to improve the wayfinding experience at the station, (-) means 'Not Reported'.

Station Zones	Codes	NV	LV	NM
Ticket Hall	Install machines for checking PNR Status	-	-	1

	Design ways to make novice commuters understand modes and rules of ticket purchase and station rules for novice commuters.	-	-	1
Platform	Provide safety measures to avoid falls on railway tracks	1	-	-
	Information regarding platform numbers should be provided in an accessible format, as it is difficult to see them at night	-	1	-
	Incorporate the timetable of trains on the platform	1	-	1
	Public Announcements should be heard at platform extremes	-	-	1
Foot Over Bridge	There should be multisensory information that helps in selecting and directing on foot over the bridge.	1	-	1
	There should be only ramps, not ramps cum stairs.	-	1	-
Station Exit	Provide wayfinding information in a visual and nonvisual format to support selection and direction to the desired exit.	2	1	1
Station Facilities				
Help Desk	Increase no. of help desks and place them at station entry, platforms, and other junctions where people ask for maximum help.	1	-	1
Medical Facility	Provide medical facilities at every station.	-	-	1
Toilet	Provide direction signs to locate the toilet	-	-	1
Trains				

Public announcements inside all trains should announce the name of upcoming stations, platform no. and the left/right direction of the platform location of upcoming station stop.	2	2	-
Public announcements should inform the train stop location in the middle of the train journey.	3	2	-
Provide audio or tactile cue to locate handicap coach entry	3	1	-
Install dynamic maps inside local trains and station layout maps. Maps inside the train should help commuters visualize the train route, lines, and platform direction.	-	1	2
There should be a security guard in the handicap coach to control the general crowd on board the train.	1	-	-
Handicap coach should be bigger	-	1	-
The position of the reserved coach for people with disabilities should be fixed on the platform for all trains.	1	-	-
Acronyms of station names, train lines, and train types (slow/fast) should be avoided in the signage for novice commuters to easily understand.	-	-	1
Provision of information to all novice commuters about train coach typology and train type.	-	-	1
Non-stage-specific			
There should be continuous audio inputs that help in making wayfinding decisions from station entry to exit.	1	1	1
Use bright colours and pronounced contrast in signboards for better readability, even at night.	-	1	1
Big fonts should be used to identify ticket halls, washrooms, and stations that quickly exit from a distance.	-	-	2

The station environment should be well-lit.	-	1	-
Develop indoor wayfinding app for all railway stations	-	-	1
Provide a telephonic Interactive Voice Response System helpdesk that answers station- and train-related queries.	1	-	-
Information systems should be improved for all people with disabilities, not just those without vision.	2	-	-
Provide better public announcements and train indicators	-	1	1
Install dynamic maps inside local trains and station layout maps. Maps inside the train should help commuters visualize the train route and platform direction. The map of the station should be interactive, and commuters should be informed about the station layout and the location of services and facilities. Further, it should also inform commuters of the station location.	-	1	1
Provide more information through the signage system and increase the number of signs to reach the desired location at the station	-	-	3
Incorporate changes in surface texture as a warning sign to detect platform edge, staircase, and steps.	1	-	-
We should be able to understand the east and west sides of the stations and whether they will come on the left/right side.	1	-	-

3.8 Discussion

This study aimed to understand how the current rail commuting system fulfils the wayfinding needs of different levels of vision. To answer this question, an approach to establish interactions with commuters regarding their wayfinding experiences was adopted. Semi-structured interviews were conducted with thirty participants to understand their experiences. Some of the principal and unique findings from this study are:

(i) Overlapping wayfinding challenges

The study identified shared wayfinding challenges across participants, regardless of their level of vision, familiarity, and gender differences. All unfamiliar participants faced issues with information, direction, and orientation, with more severe obstacles reported by those without vision. Participants across all levels of vision, unfamiliar with the station, cannot identify or orient themselves on foot over bridges without assistance as they vary in connectivity pattern, as also stated in Appendix A3. Similar challenge is also reported in studies conducted by Raheja & Tyagi (2016) & Padzi & Ibrahim (2012).

(ii) Wayfinding challenges explicitly faced by different user groups

Commuters new to a railway station with VI, especially those without vision, face difficulty in detecting station entry and determining which part of the station it is located. A finding is also confirmed by Zheng et al. (2007) in their study on railway stations as reported in Section 2.7.1 of Chapter 2. Some facilities like toilets were reported to be pretty far and isolated from the reach of commuters, as also identified as a concern reported by Padzi & Ibrahim, 2012 in their study reported in section 2.7.1 of Chapter 2.

Poor safety led to falls, injuries and life-threatening situations; a concern echoed by most participants with vision impairments. All participants with vision impairments shared experiences of falling onto rail tracks, highlighting their vulnerability and helplessness on railway platforms as a major safety concern. Island platforms (with tracks on both sides) are riskier for participants with no vision, as Padzi and Ibrahim (2012) reported. Safety concerns of such severity have limitedly been reported in international research, especially from UMICs and HICs, including studies by Afrooz et al. (2012) (Iran), McIntyre (2011) (Scotland), and McKeen (2011) (Albama), Jenkins et al., 2015 (Albama) as well as Indian studies by Raheja & Tyagi (2016), Raheja & Sinha (2018), and Nagraj et al. (2021).

Commuters with no vision generally feel unsafe if the walkways are not of good quality (Jenkins et al., 2015; Afrooz et al., 2012). The findings indicated a lack of proper tactile guidance paths in many areas, posing significant challenges for commuters, if not outright dangers. This deficiency was also highlighted in an audit report on the Mumbai Suburban Railway system by the Collective For Spatial Alternatives and the Indian Center for Human Rights Law (2017).

The threat to safety also stems from collisions with fellow commuters and their belongings, such as luggage and baskets (Raheja & Tyagi, 2016). PVIs struggle to remain visible amidst the congestion despite using white canes and black glasses as identifying markers. Jampacked station and train environments present significant obstacles to wayfinding and cane navigation for commuters with vision impairments, as confirmed in a study on Bangalore Metropolitan by Nagraj et al. (2021).

Surprisingly, sighted individuals reported more identification issues than those with visual impairments. Our findings suggest that in the absence of non-visual wayfinding aids, individuals with visual impairments, especially those with no vision, develop their ability to identify places, zones, and facilities using multi-sensory cues and cane, as reflected in Table 3.12 to Table 3.16, unlike the sighted counterparts. However, using sensory cues could not essentially reduce the safety threats posed by external, uncontrolled built environmental and social factors.

(iii)Inadequate and non-inclusive wayfinding signage

Current wayfinding design aids used in Mumbai Suburban Railways are inadequate for all commuters independent of visual abilities. The ones that exist are primarily provided in visual format. Most of the visual signages are inaccessible to participants with low vision.

(iv)Ineffective help desk

Help desks were reported to be less effective in participant wayfinding, especially for those with no vision, as their locations are difficult to predict at each station, as reported by Raheja & Tyagi (2016) in their study on the New Delhi Railway station. Further, the help desks are not detectable due to a lack of non-visual cues.

(v)Use of sensory cues increases the ability to wayfind, but has limitations

Researchers investigating sensory cues among individuals with varying levels of visual ability found differences in reliance on different sensory modalities for extracting environmental information. However, to some extent, such findings depend on the environmental context under study. Afrooz et al. (2012) noted that individuals with no vision predominantly rely on auditory cues, while those with low vision attempt to use their vision but also incorporate other senses, such as touch, especially in pedestrian environments. At the same time, Folska (2012) reported that for people without sight, the tactile modality is relied on most often during wayfinding in the pedestrian environment. The hearing and tactile senses were

used most compared to the olfactory senses of all the non-visual sensory modalities. Our study found that participants with no vision reported more multisensory non-visual cues in their interviews than participants with low vision.

In our study, participants with no vision use the auditory sense more intensely. As stated by Nagraj et al. (2021) and McIntyre (2011), extreme sensory backgrounds such as loud, persistent noises mask targeted audible signage. Sight is the most dominant sense for information extraction from the environment by sighted people, as this study's participants hardly reported using other sensory cues for wayfinding. A similar finding was reported by Finkel (1999) in her study in an educational setting.

Visual cues were reported to be used by participants with low vision and sight. However, except for the social cues, such as following the crowd's movement to get in and out of the station, distinct, uncommon visual cues were reported by both the participant groups for different purposes in their wayfinding journeys. Surprisingly, except for tactile cues, not much overlap is visible in our study's other sensory cues used by participants with no vision and low vision. There is a slight overlap in the visual cues used by participants with low vision and sight. There was no overlap in the cues reported to be used by participants with no vision and sight, as also reported by Golledge and Stimson (1997) in their study.

Social uses play a significant role in wayfinding in Mumbai Suburban Railways. They are perceived by using auditory and visual senses. Auditory cues are reported to be used by participants with no vision, and visual social cues are reported to be used by all participants independently of visual ability.

Further, like McIntyre's (2011) findings, our study also reported that participants with less visual ability mostly used immediate landmarks, whilst those with more visual ability used distant informal landmarks. McIntyre’s study further noted that the participants with VI used sensory cues for orientation, navigation, and identification of the nature/function of the space. Our study found that all sensory cues, which were auditory, tactile, olfactory, and visual, were mainly used to identify spatial zones, facilities and services. This is probably because countless people around mask all the distant spatial information.

(vi)The presence of a crowd around both acts as a boon and bane

Filingeri et al. (2017) emphasizes the tendency to overlook human factors within crowds when addressing design, planning, and operations. Our study has recognized that the current situation of the Mumbai Local Train commuting system is characterized by overcrowded environments, significantly complicating wayfinding, especially for inexperienced commuters, particularly those with no vision. While user experiences are often disregarded, our study illuminates how the presence of crowds affects the wayfinding abilities, safety, and security of individuals, especially those with vision impairments. While the presence of people can be beneficial for those seeking help, overcrowding contributes to a hostile environment, leading to unsafe navigation both within stations and on trains. The problem of collisions among commuters is a distinct wayfinding challenge reported in our study. Overcrowded environments have a significant detrimental psychological impact on people's wayfinding experiences, particularly those with no vision.

(vi)Social Wayfinding

The findings of this study revealed both positive and negative aspects of the social support received by participants with varying levels of vision. Unlike previous research (McIntyre, 2011; Mckeen, 2011; Afrooz et al., 2012), which highlighted negative aspects such as 'social awkwardness', our study found a high reliance on social wayfinding among individuals regardless of their level of vision, gender, or age, despite instances of misbehaviour reported by participants.

In Balata et al.'s (2014) study conducted in Prague, 51% of visual-impaired participants hesitated to ask strangers for wayfinding instructions due to difficulty finding willing helpers. This mirrors McKeen’s (2011) research on social wayfinding among sighted individuals in Alabama, where only 27% preferred asking strangers for directions, and 40% opted to solve navigation challenges independently. Afrooz et al. (2012) conducted a study in Iran, where the researchers’ observed differences in help-seeking preferences between participants with no vision and low vision, with 83.3% of those with no vision comfortable asking for help compared to 66.7% of low vision participants, who relied more on visual cues like landmarks. In our study, 28 out of 30 participants, regardless of vision level, reported a high dependency on strangers for wayfinding support. Like low-vision participants in Afrooz et al.'s study, two-sighted participants relied on visual cues (Afrooz et al., 2012). This heavy reliance on social wayfinding, particularly among those with no vision, stems from inadequate, unreliable, and

inaccessible wayfinding information provided through signage, digital apps, and human services like help desks. Obtaining information from the public is often faster and more efficient than navigating crowded and noisy station environments to access signage or help desks.

In relying on others for assistance with way-finding journeys there were two contrasting types of experiences found in our study as well as McIntyre's study: Overcompensation (people insisting on helping participants when no help is needed); or avoidance (people ignoring participants when help is needed and is being asked for). In addition to what McIntyre (2011) has reported, our study explains the problem of mismatches in information communicated and comprehended in cases when the information source is a sighted person, and the seeker is the one with vision impairment. Further the impact of poor information comprehension leads to misguidance. Misguidance sometimes further leads to unsafe navigation or wayfinding errors.

In our study on social wayfinding, we discovered a unique aspect: assistance is not limited to verbal directions but also includes physical guidance i.e. Escorting, where individuals with visual impairment are escorted by strangers from one point to another. This support is offered both upon request and voluntarily, particularly in unsafe situations.

In social wayfinding, factors such as physical appearance, gender, occupation, and demeanor play a crucial role in instilling confidence and a sense of safety in the information provided by strangers. Mckeen's (2011) study on sighted individuals revealed that participants felt more at ease seeking directions from strangers who appeared competent and safe, alleviating anxiety. Similarly, Ahmed (2015) discovered that people heavily rely on asking seemingly trusted individuals for directions when unsure. Well-dressed and older individuals are often perceived as more trustworthy, with auto-rickshaw drivers and street vendors also considered reliable sources of information. Women tend to prefer seeking help from other women, potentially influenced by cultural upbringing and feelings of insecurity in unfamiliar areas, as Lawton and Kallai (2002) noted. Our study's findings echoed those of Mckeen's and Ahmed's, revealing that sighted participants have distinct preferences when selecting individuals to ask for help (Ahmed, 2015; Mckeen, 2011). Daily commuters, especially those in professional attire with confident demeanor, were preferred over novice commuters, while cobblers and shopkeepers at book stalls and canteens were trusted sources of wayfinding information, particularly by female participants with low and those with sight. Help provided

by fellow commuters is frequently cross-checked, especially by sighted people, to ensure accuracy and reliability (Ahmed, 2015; Nagraj et al., 2021).

Wayfinding challenges related to safety, direction and orientation in unfamiliar settings are significantly more severe for people with visual impairment than sighted people. None of the strategies involving sensory cues, social support, cane usage, or travelling with a personal escort proved effective in orienting participants, regardless of visual ability, about station and train layouts, organization, and configuration. This highlights the persistence of unresolved challenges in certain aspects of wayfinding despite participants' efforts to develop strategies using social and environmental cues. While individuals have become adept at self-reliance, these strategies offer a limited understanding of the environment, leaving essential information and environmental support necessary for decision-making, especially in situations involving high safety risks, unaddressed by the current wayfinding system design of the Mumbai Suburban Railways.

Low-vision participants served as escorts to those without vision. Most participants with low vision indicated minimal use of the cane, primarily employing it for identification and safe navigation. Interestingly, they noted a significant increase in its utilization to signal their visual impairment to sighted individuals, particularly in densely crowded environments where assistance may be needed.

Familiarity with the station building and train route plays a major role in improving the wayfinding experience. Still, commuters face specific challenges despite familiarity, such as collisions with other commuters, etc.

Braille signage was not reported to be used by any participant with vision impairments; neither did they report use of any mobile application and web-based information for wayfinding as majority of participants with VI were users of basic keypad phones. Except two participants with vision impairments having smartphones expressed use of M-Indicator mobile application for train route. All participants with VI rely solely on a white cane as an outdoor personal mobility aid. All commuters with VI prefer to travel from the reserved coach to them. However, women with vision impairments prefer to travel from the general ladies' coach for better safety. All commuters with vision impairments expressed unaffordability of the first-class ticket.

3.9 Chapter Conclusion

Understanding the complex interactions of real-world factors that influence the use of rail transport systems by people with visual impairments is crucial to ensure their full participation. This study delves into issues identified through participants' past wayfinding experiences, categorizing findings into challenges, facilitators, and suggestions for improvement. The insights emerged from personal semi-structured interviews, providing a firsthand perspective of individuals directly impacted by the Mumbai Local Train commuting system.

Like McIntyre (2011), our study unveils participants' positive and negative wayfinding experiences. Negative experiences extend beyond mere difficulty reaching destinations, encompassing feelings of vulnerability, encountering life-threatening situations on rail tracks, collisions, and a sense of helplessness. However, participants also expressed gratitude for initiatives such as audio beepers and dedicated coaches for special needs passengers, acknowledging these efforts for enabling their travel.

The study sheds light on the strengths and limitations of existing signage systems, human assistance, and architectural communication. It highlights the inadequacy and lack of inclusivity in the current wayfinding system, failing to meet the information needs, safety, and dignity of commuters with poor familiarity, irrespective of their level of vision. Overcrowding and crowd behaviour exacerbate wayfinding difficulties, particularly for those with vision impairments, compromising their safety significantly.

Contrary to past research overlooking emotional and social dimensions in public transit, our study, like Ferri and Popp (2022), emphasizes these aspects. Understanding the relationship between wayfinding activities and emotional well-being in public transit spaces is pivotal for informing design and transit policies.

Moreover, our research uncovers unique social aspects of wayfinding, encompassing human assistance and the impact of crowds. Participants' reliance on social help for wayfinding emphasizes the need for improved social communication systems, as also advocated by Dalton et al. (2019). Sensitization and training of railway staff and security personnel emerge as critical aspects of enhancing accessibility, as Raheja and Tyagi (2016) proposed.

By elucidating the role of sensory cues in the experiences of people with visual impairments, the study advances our understanding of their participation levels in rail transport

systems. Designing public spaces with strategically embedded sensory cues can enhance accessibility without stigmatizing specific user groups.

Furthermore, the study identifies a significant overlap between the wayfinding issues of people with visual impairments and those of other diverse population groups. This study highlights the need for greater information depth in the MLTCS system, particularly for first-time commuters and those with vision impairment. The current signage system primarily serves regular-sighted commuters, suggesting scope for improvement to make it more user-friendly and inclusive for unfamiliar commuters with regular and low vision. Our research supports the need for holistic wayfinding support to strengthen various forms of communication, such as architectural-informational-social communication. It highlights the importance of wayfinding support across physical, sensory, and social dimensions of railway station environments. It highlights the current system's limitations in ensuring safe navigation and wayfinding experience for all commuters, particularly those with vision impairment.

This is the only study that has studied a commuting system wayfinding for railway stations and trains, whereas the other literature findings were limited to station environments.

There is a need for an inclusive design strategy, necessitating the involvement of individuals with disabilities, including those with visual impairments, that consider the diverse user base in the research and design stages.

The next chapter reports another field research on ‘measuring the wayfinding performance of people with different levels of vision’ in a railway station using an evidence-based cognitive walkthrough method to confirm and expand the findings they have reported in this study through live observations.

Chapter 4 Assessing Wayfinding Performance

4.1 Introduction & Background

In the previous chapter, semi-structured interviews were conducted to understand the participant's wayfinding experiences with MLTCS. This includes identifying their wayfinding needs, challenges while performing wayfinding tasks, and the strategies used to perform different wayfinding tasks. The study reported positive and negative wayfinding experiences of people on stations. The study identified that the wayfinding concerns stated by people with VI in many aspects overlap with those of sighted people. However, for individuals with visual impairment, navigating unfamiliar settings presents significantly more severe challenges (wrt. safety, direction, and orientation) than those with sight. Despite the aid, such as sensory cues, social support, cane usage, or travelling with a personal escort, participants struggled to orient themselves in large-scale complex station layouts. While individuals have adapted to rely on these strategies for self-reliance, they provide only a limited understanding of the environment, leaving essential information and environmental support necessary for decision-making—especially in high-risk safety situations—unaddressed by the current wayfinding system design of the Mumbai Suburban Railways.

Another empirical study is warranted to delve further into how individuals with varying levels of vision wayfind the MLTCS and how the current state of the commuting system affects their wayfinding performance. This study aimed to gather and analyze evidence concerning the

wayfinding process, behaviour, and performance at a railway station within the Mumbai Suburban Railways network. The study addresses the **RQ2. How does the existing scenario of the commuting system affect the wayfinding *performance* of people with different levels of vision?**

This study adopts a spatial problem-solving approach to wayfinding, drawing on the conceptualization by Passini & Proulx (1988). Using the walk-through method, each step of the wayfinding process at local train stations is analyzed to assess the effectiveness of the wayfinding systems. This method involves behavioural observations, mapping, tracking of participants' journeys, and self-reported walk-through experiences. By combining quantitative and qualitative data collection and analysis, the technique explores participants' behaviour, cognition, and emotions during interaction with the built environment (Finkel, 1994).

Participants were asked to perform a sequential set of task protocols within a large-scale station building in this phase. The wayfinding performance of the set of tasks was measured against performance measures like time taken to complete each wayfinding task, no. of halts, no. of errors and deviations from a most efficient shortest path, no. of physical barriers faced, no. of times help asked and received, use of sensory cues. Similar to Carreon's study on wayfinding in urban environments by individuals with vision impairment (Carreon, 2000), this field study comprised two phases: Phase 1 involved participants completing wayfinding tasks at the selected railway station, while Phase 2 consisted of interviews to gather insights into their experiences and opinions regarding the route traveled.

The findings from this study helped to expand our understanding of the existing wayfinding scenario through evidence-based research. Further, they shed light on the areas in which design efforts need to be invested to assist in the wayfinding of people with different visual and non-visual abilities inclusively. Studies presented in Chapters 3 and 4 resulted in the identification of several wayfinding problems and participant suggestions that were consolidated in Appendix D1 and D2. The following section discusses the details of the way wayfinding performance study was conducted.

4.2 Walkthrough Method

The walkthrough method consists of walking in “co-present immersion with” the participant (Urry, 2006) while simultaneously conducting observations and field notes. The

walk-through method (Carreon, 2000) sets out to analyze each step in the wayfinding action sequence and evaluate the success of the wayfinding systems at local train stations on whether it helps or hinders the wayfinders from achieving their goals. Observational method was used to understand how each wayfinding task is related to another, how spatial relations affect wayfinding among participants, how the environment supports or interferes with wayfinding behaviour, and how and when people ask and give route directions and how participants react to wayfinding cues of the environment (Carreon, 2000). As Wharton et al. (1994) suggested, for systems of any complexity, the analysis should be limited to a reasonable but representative collection of benchmark tasks; a series of representative tasks was chosen for the participants to perform the wayfinding task.

The post-walk-through interview aimed to determine the participant's cognitive process used to accomplish given wayfinding tasks at the railway station. Furthermore, it provided us with the subject's assessment of the following: their wayfinding task performance (Passini, 1980); their overall experience of wayfinding, signage system, and human services deployed at the station to assist people in wayfinding; quality of help provided by the other commuters on the railway station.

4.2.1 Pilot Test

A pilot test was conducted at Kurla Station over two weeks, involving five participants with VI, with two only completing the first phase and the remaining three completing all three phases of the study. Data collected from each stage was then analyzed to refine the wayfinding scenario.

Developing the wayfinding scenario during the pilot study allowed for critical reflection and adjustments, surfacing several logistical issues and giving the researcher valuable experience working with participants. Primarily, the pilot helped evaluate the suitability of the proposed wayfinding scenario phases, task settings, tasks, and the participatory input of individuals with various visual impairments. This process gave the researcher insights into data capture and coding techniques, including interacting with visually impaired individuals, structuring conversations, capturing wayfinding-related data, organizing and storing information, and refining analysis and coding skills. Additionally, the pilot fostered a

relationship of trust with local NGOs and rapport with visually impaired participants. Regular visits to the NGOs helped participants understand the study's goals and ultimately facilitated consent for outdoor activities with the researcher at the station.

Key lessons from the pilot trials included:

1) Modification of Wayfinding Tasks: The initial pilot setup had participants navigating from their train disembarkation points, which varied for each individual. For the main study, the route was standardized to begin at a fixed station entry point, making comparisons across participants easier and more reliable.
2) Iteration of Questionnaires: Both structured and unstructured questionnaires were refined throughout the pilot to ensure comprehensive data collection in the wayfinding case study.
3) Refinement of Familiarity-Based Sampling: During the pilot, participants were categorized as rare, occasional, or regular commuters w.r.t to the commuting system. In the main walkthrough study, they should also be recruited based on varying levels of familiarity with the station site for the main walkthrough study as stated in Tables 4.4 and 4.5
4) Streamlining of Data Collection: Following the pilot, it became evident that the railway authorities were unwilling to grant extended filming permissions for more than a month. Hence, data collection was streamlined for the main study to ensure that all information could be gathered efficiently before analysis commenced.

The pilot study was instrumental in fine-tuning the methodology and approach, paving the way for a more structured and effective main study. From Section 4.3 onwards, the main walkthrough study is reported.

4.3 Sample Size and Participant Profile

Twenty-two participants from the previous study, reported in Chapter 4, participated. Six had no vision, six had low vision, and ten were sighted people. Table 4.1 explains the age distribution; Table 4.2 explains the gender distribution; Table 4.3 explains the participants' education level; Table 4.4 explains the participant’s familiarity with the commuting system; and Table 4.5 explains the participants' familiarity with Kurla Station.

Table 4.1 The age range of participant subgroups

Age Range	No vision	Low Vision	Sighted
19-29	2	4	8
30-39	1	-	2
40-49	-	1	-
50-59	2	1	-
60-69	1	-	-
Mean Age	41.5	34.6	27

Table 4.2 Gender Distribution of the Participant Subgroups

Gender	No vision	Low Vision	Sighted
Male	6	3	6
Female	0	3	4

Table 4.3 Participant's level of education

Level of Education	No vision	Low Vision	Sighted
Primary	2	0	0
Matriculate	3	2	0
Intermediate	2	1	0
Undergraduate	0	1	3
Postgraduate	0	1	7

Table 4.4 Participants' familiarity with Mumbai Suburban Railways

Level of familiarity	Level of Vision

	No vision	Low Vision	Sighted
Frequent	4	4	3
Occasional (less than or equal to 3 times in a month)	2	2	2
Hardly /Novice (once in a month or less than that in a year)	0	0	5

Table 4.5 Participant's Familiarity with the Site

Level of familiarity	Level of Vision		
	No vision	Low Vision	Sighted
Full Familiar	2	1	2
Partial Familiar	1	1	3
Fully Familiar	3	4	5

i. Onset of Blindness: There were three participants with no vision and five participants with low vision who had vision impairment since birth. Among participants with no vision, three had congenital blindness, and three had acquired blindness, whereas among participants with low vision, two participants had acquired blindness, and four participants had congenital blindness.

ii. Vision Impairment Details: Out of six participants with low vision, three had myopia, and three had hyperopia.

iii. Quality of Vision: Out of twelve participants with vision impairment, all six participants with low vision and three with no vision had light sensitivity. Three participants with low vision had colour sensitivity, and three participants had contrast sensitivity. Two participants with low vision could see the pictures, and one participant could read text from a very close proximity to the eyes. All participants with vision impairment had no additional impairment and sufficient independent mobility in their daily lives. Table 4.6 explains the quality of the vision of all participants.

Table 4.6 Quality of Vision of the participants with vision impairment

Quality of Vision	**No vision**	**Low Vision**
1. Light Sensitivity (Sensing the minimum amount of light and light difference)	3	6
2. Color Vision (Seeing functions of differentiating and matching colors)	0	3
3. Contrast Sensitivity (Separating figure and ground)	0	3
4. Visual picture quality (Seeing functions involving the quality of picture)	0	2
5. Read Text	0	1

iv. Mobility Training: Out of twelve VI participants, two participants with no vision and two with low vision had mobility training provided to them in the NGO or the school.

v. Language Literacy: All twenty-two participants could speak Hindi. All sighted participants and one with low vision could speak English and Hindi.

vi. Smartphone use: All sighted participants and two with low vision used smartphones. All participants with no vision used basic phones without the features of smartphones.

vii. Computer Literacy: Out of twenty-two participants, two had low vision, one participant had no vision, and all participants with vision had computer literacy. Braille literacy: Out of six blind and six low-vision participants, only three participants with no vision and four with low vision have braille literacy.

viii. Use of Mobility Aid: All participants with vision impairment are mechanical white cane users. They do not use any other mobility aids.

ix. Occupation and Income: All sighted participants were students and project staff from the Indian Institute of Technology, Bombay. The participants with vision impairment were recruited from two NGOs in Mumbai- the National Association for Blind (NAB) and the National Association for Disability Enterprise (NADE). One participant with low vision was from the National Association of Handicap. The participants recruited from these organizations are either studying or are currently working there. The average earning of

each participant with vision impairment was Rs 5000 monthly. The average earning of sighted participants was Rs 20,000 monthly.

4.4 Site Selection

A wayfinding performance study was conducted on one of the MLCTS railway stations. The scale was one of the primary criteria for the station site selection (Khameh et al., 2016), as large-scale environments are more challenging to perceive in their entirety from any one location (Dogu & Erkip, 2000). Kurla station was selected as a model station for this reason. The station is located on the central line of Mumbai Suburban Trains (Figure 4.1).

It serves as both an interchange and terminal station for only local trains. Kurla station is built above ground level. It has 9 working and two non-working platforms. In Kurla station out of nine platforms, there is one sided platform, eight middle platforms and two non-functional platforms. The island platform is a single platform serving two tracks passing on either side. The side platform is usually determined by two platforms with double tracks of railway lines (Padzi & Ibrahim, 2012). The station has 3 ticket halls, 3 sets of men's and women's toilets, and 6 station entry/exit points (Figure 4.2).

4.5 Permission from agencies, Ethical Considerations & funding

(i) Railways: Written permission was taken from the Chief Public Relations Officer (CPRO) of Central Railways to conduct photography, videography and interviews with train commuters and railway staff for phase 2. A copy of the permission letter was submitted to various departments of Kurla station, the station master office, the Railway Police office and the Mumbai Police Office for their information and support. The walk-through studies were conducted between 10 am to 4 pm, i.e. non-peak hours, as the Railway authority refused to grant permission to shoot in peak hours due to strict norms. However, a security guard was recruited by the Railway Police Department of Kurla Station for the protection of the participants and the research team, as the station environment is very crowded, and to ensure no interruption during the study.

(ii) NGOs working with disability: Written consent was taken from the Presidents of the National Association of Blind and the National Association of Disability Enterprise to recruit students and employees from their organizations for the field study.
(iii) Participants: A consent form was signed by all participants in the study where they were granted permission to use their responses, videos, and images for research work. Remuneration for participation in the study was paid only to participants with visual impairment.
(iv)Videographers: A written letter of the settlement of remuneration was also made for videographers for their contribution to the study.

The field study was funded by IDC School of Design, IIT- Bombay. Confidentiality was protected by identifying transcripts, data sheets, audio tapes and interview guides by alphanumeric codes rather than by participant's name.

4.6 Wayfinding Protocol

The wayfinding studies involve participants completing a series of tasks along a designated route (Passini, 1984; Carreon, 2000). We utilized a protocol and interview method to assess task difficulties (as in Passini, 1980). In our study, a challenging path was selected at the station site, determined through a personal visit and pilot test with PVIs. (Passini et al., 1988). Seven tasks were identified along this path, starting from a fixed station entry point: 1) Locate ticket hall, 2) Purchase a ticket for Chinckpokli station, 3) Exit ticket hall, 4) Find restroom, 5) Identify relevant platform, 6) Locate waiting area on the platform, and 7) Identify desired coach entry without boarding the train (Figure 4.3). Participants were instructed to complete these tasks sequentially from the fixed entry point to facilitate comparison. The tasks assigned are part of the highlighted journey stages as seen in Fig 4.4.

The study was planned, drawing on the research designs of Passini (1980) (Jacobson et al. 1998) and Kuliga (2016). When selecting the tasks for inclusion in the study, specific criteria were considered to ensure that the walkthrough study best captures the wayfinding complexity.
(i) Considering the exploratory nature of the survey, tasks were chosen to require diverse sign system support related to safety, identification, direction, and orientation.



Figure 4.1 Mumbai Suburban Railway Train Line Map (Rane, 2013).



Figure 4.2 Annotated plan view of Kurla Station.

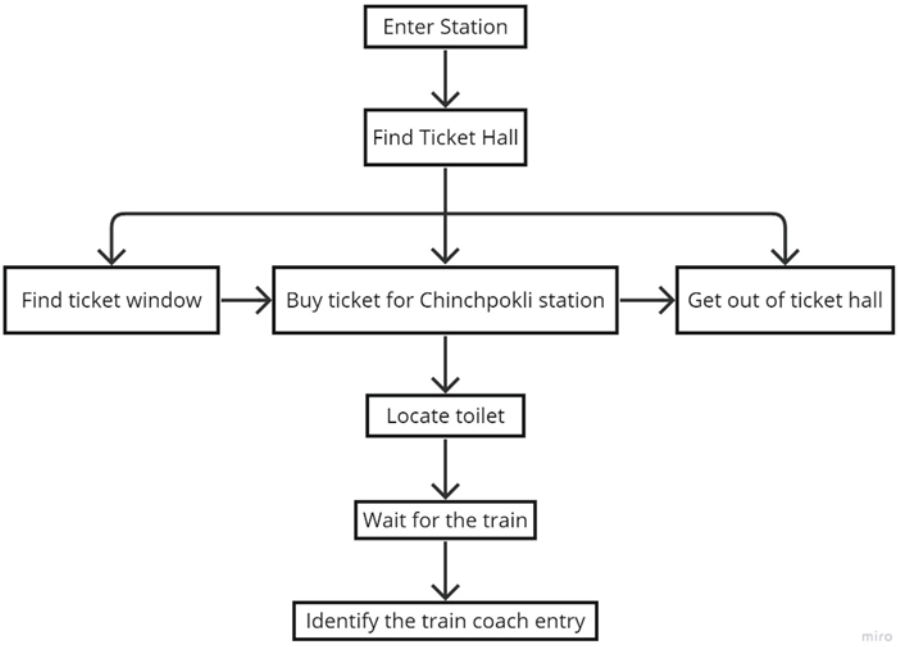


Figure 4.3 Wayfinding Task Flow.

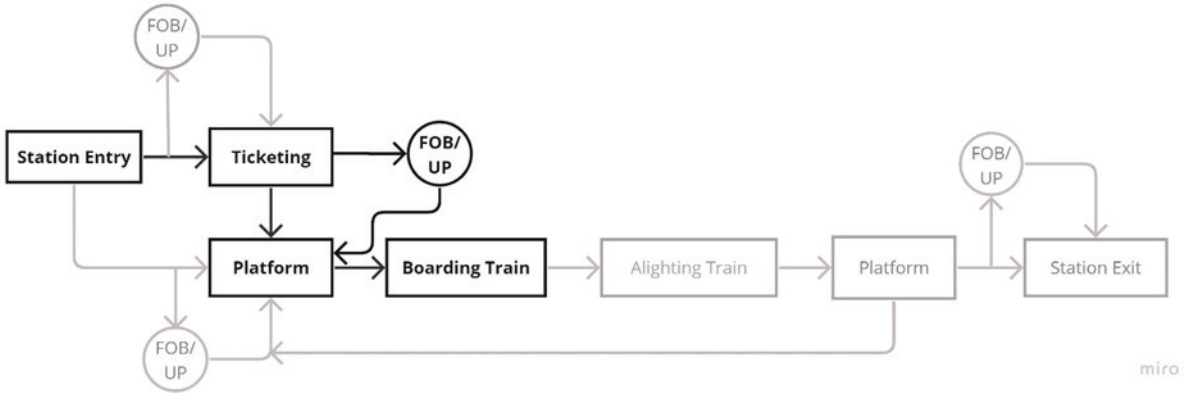


Figure 4.4 Selected journey stages for station walkthrough study.

(ii) Selected tasks required participants to visit crucial and unavoidable station locations with varying wayfinding situations regarding spatial characteristics, usage, activities, population density, and dynamics. For instance, platforms and foot overbridges present dynamic and crowded spatial environments compared to ticket halls, where movement is typically steady.

(iii) All tasks selected for the study were deemed fundamental, significant, unavoidable, and urgent, necessitating wayfinding support.
(iv) Tasks were chosen to provide multiple path possibilities involving several decision points, floor-level changes, and poor visual accessibility.
(v) Identifying the train to Chinchpokli station was consciously selected as part of the protocol as it is a small intermediate station that falls on the central train line. Hence, many unfamiliar participants to the central line train route would not be aware of this station's positioning on the train route.

No guided tours were given to the participants as learning trials, nor were they asked to retrace their paths. They were expected to perform the task independently. However, they can request help from the railway staff or other commuters. Participants were provided no directional guidance or advice by the researcher on reaching the destination from the starting point. No conversation was allowed with the researcher throughout the task performance. However, the researcher always walked away from the participant, observing all the body movements and interactions with the spatial and social environment. Unlike Passini & Prolux's (1988) and Carreon's (2000) study, there was no interference from the observer if the participants took wrong turns with, of course, an exception of safety concerns. All the participants in the study used a white cane (as in Passini et al., 1988) but no other aid like the use of guide dogs as reported in international studies conducted by Carreon (2000); Blades et al. (2002); Havik et al. (2015); McIntyre (2011); Lippa et al. (2016). The field study was conducted regularly in the afternoon between 10 am to 4 pm (non-peak hours). Surveying during peak hours was impossible due to the hefty crowds at stations and inside trains. However, the crowd in the afternoon was reasonably heavy yet manageable to conduct a walk-through study. The duration of the test lasted from 1 hour to 1.5 hours. A refreshment break was offered after the participants had completed the walk-through.

4.7 Formulating the semi-structured interview guide

Semi-structured interviews were used as an interview style as they had both open and close-ended questions using the Likert scale. Probes were used in the open-ended questions (Ericsson & Simon, 1993) to record comments by participants to understand the cognitive

process during their walk-through through retrospective verbalization, use of sensory cues and other strategies used to make sense of the space and direction and the behavioural, psychological, and emotional impact of the task performance on their wayfinding. Retrospective verbalizations were prompted using video as evidence to raise the prompts. Participants' memories of previous way-finding experiences were activated by events and occurrences during the task performance, and they also narrated past incidents. During the verbalization, the participant reflected upon his/her decisions of taking turns or maintaining the direction reasons for halts, confusion, stress, and anxiety faced. The researcher asked participants what elements during their walk-through aided or limited their wayfinding activities and what sensory cues or environmental signages they relied on while performing the wayfinding tasks. Participants were also asked what areas needed to be addressed to make trains and stations more effective for wayfinding (Carreon, 2000). The close-ended questions included participants' assessment of station staff and audio/ visual signages on the station used during the walkthrough (Kuliga, 2016) by them using rating scales. The questionnaire is given in Appendix E.

4.8 Recording Technique & Modality

The field study used qualitative and quantitative methods to accurately record how respondents used the built environment. The station walk-through experience was video recorded with the help of two assistants. They used two handheld video cameras to record participants' wayfinding from short and long distances. The cameramen walked with each participant to capture his/her body movements in the context of the background environment. The videography was ideal as it recorded the journey as evidence of the real-time participants' wayfinding experience. It allowed a detailed analysis of wayfinding's behavioural aspects without losing critical evidence. Before the field study, the participants were briefed on the research objective. Matters concerning safety, confidentiality and procedures of the observational study were also discussed with the participants. The participants with vision impairment were assured that the researcher and the assistants would follow them to maintain their safety. A dictaphone was attached with a microphone to the participant's body to record the concurrent verbalization with self, other commuters, and railway staff during the study. The observer used a stopwatch from the smartphone to record the time each participant took to

complete each task during the wayfinding journey at the station. An interview guide was used at the end of the walk-through session. All interviews were done in the model station, i.e. Kurla, selected for the walk-through study. A voice recorder was used to record the interviews. The average time taken to complete the walk-through by the participants was 30 minutes, and an additional 30 minutes was taken to complete the interview session with each of them.

The presented study differed from the approach reported by Passini (1980) & Passini & Proulx (1988), where participants were required to verbalize continuously what they were doing and why they were doing it, especially when the participants had vision impairment. Continuous verbalization of the cognitive process will distract the participants from concentrating on the environment around them. Hence, an interactive session was conducted right after the walk-through to understand the mental process behind their actions. Interviews at the end of the wayfinding task focused on participants' assessment of the environment regarding their wayfinding process based on their familiarity with the station and the selected path.

4.9 Data Analysis

The data analysis was divided into three parts. The first part of the analysis includes a quantitative assessment of the wayfinding performance measures. In the second part, the conversations recorded in Phase 1 and the interviews conducted in Phase 2 were transcribed and analysed. In the third part of the analysis, location-based behavioral observations of wayfinding activity were recorded on annotated station maps (Zeisel, 2006) from the videos using the method of behavioral mapping (Sommer & Sommer, 2002). Comparisons were made between all subjective and objective data recorded throughout the route. Objective data is explained with the support of subjective data. Findings are reported after consolidating all three parts of the data analysis.

4.9.1 Quantitative Assessment of the Wayfinding Performance Measures

Below is the list of performance measures used to compare the wayfinding performance for each participant group. The similar studies that used each performance measure are marked in the bracket:

- Time taken to complete each task and the total time for the entire journey (Kuliga, 2016; Martson, 2002; Zheng et al., 2007; Baskaya et al., 2004; Blades et al., 2002)
- Errors are explained as wrong wayfinding decisions made in the identification of spatial elements or path selection during walkthrough (Passini et al., 1988; Blades et al., 2002; Baskaya et al., 2004; Kuliga, 2016)
- Deviations are explained as slight veering, though the participant is on the right path (Bradley & Dunlop, 2005; Kuliga, 2016).
- Halts were logged when a participant stopped for a while at different locations on stations. If the reason for the halt was confusion in making a wayfinding decision, then those halts were considered (Jacobson, 1998; Kuliga, 2016).
- Help asked from other commuters for completion of each task (Carreon, 2000; Martson, 2002)
- Help was received by other commuters to complete each task. (This data is specific to the context and not used in any other study)
- Audiovisual signage and help desk service used for each task during wayfinding (Carreon, 2000)
- Sensory cues used for each task (Passini et al., 1988; Carreon, 2000; Kuliga, 2016)
- Obstacles and hazards encountered while performing each task (Carreon, 2000)

A record of the frequency of occurrence of performance measures for each task was taken into account to calculate the mean value for each group, which was then compared with other groups. The total mean for all groups for all tasks was also calculated.

4.9.2 Conversations and Interviews

The interview as part of Phase 2 and the conversations of the participant with self, other commuters and railway staff around during the walkthrough as part of Phase 1 recorded during the walk-through were transcribed on a recording sheet. The transcriptions of both types of audio recordings were done in direct speech. The researcher's observations regarding the participant's walk-through of the entire route were also recorded on the same sheet. They were analyzed for common codes, categories, and themes relevant to the study. A tally of these themes was charted for group comparisons. Data was collected and coded into various

categories, such as which elements of the environment were used most often, the areas that were problematic to wayfinding, and what design considerations should be taken (Carreon, 2000) to improve the rail and station environment. Scaled-rated answers as part of the interviews conducted during phase 2 were calculated for the mean values of each group and compared with other groups.

4.9.3 Behavioral mapping

Behavioural mapping systematically records people's actions (Sommer & Sommer, 2002) in specific locations of research interest. It is an evidence-based method that illustrates where and what behaviours occur, which may contrast with what was planned for the space. Behavioural maps are categorized as place-centered and individual-centered.

Place-centered mapping involves observing people at a specific location, where the observer positions themselves to observe activities at that site. Conversely, individual-centered mapping tracks the movements and activities of individuals over time and across various locations, focusing on understanding their social behaviour and interactions. In this study, individual-centered mapping was done with the consent of the participants, and participants were tracked from a distance. Maps were created later using the video and audio-recorded interview data.

An annotated architectural floor plan drawing of Kurla station was made using Adobe Illustrator software. The drawing was not on an actual scale but had all the built environmental details, services, and facilities offered at the station on various platforms. The ideal shortest path that could be used for performing all the given protocol tasks was traced on the map (Figure 4.5). Decision points were logged on the shortest path. Decision points are all those locations on the station with possibilities of multiple path directions, i.e. left/ right/ forward/ backwards/ upward/ downward. The complexity of the path is measured by the no. of decision points in the path (Passini & Prolux, 1988; Finkel, 1999). There were 10 decision points noted in the shortest path. Observations like the path taken, the point of help given, the point of help asked, hand and cane touch points, deviation, errors and halts, obstacles and hazards encountered during the wayfinding were logged using distinct legends on the path taken. The Participant's movements

in Phase 2 were charted on the annotated floor plan of Kurla Station (Figure 4.6). The annotated map became a record of each Participant's way-finding trace. A log was also made of the helpers' gestures of help given, i.e., touching the shoulder or hand, hand support, hand direction, verbal support, and holding the stick for a later part of the analysis. The important interactions of the participants with the built station environment and people were extracted as still images from the walk-through videos. Distillation was done from the commentary log of key comments that described an important interaction with the built station environment and people.

Similarly, still images from the videos were distilled. Both critical comments and still images overlapped each participant's wayfinding behavioural map. Continuous observations for each participant were carried out for a maximum of half an hour, depending on the time each participant took to complete the wayfinding tasks. Wayfinding behavioural maps of different user groups based on the level of vision, familiarity, age and gender were superimposed to find how the performance is impacted based on individual differences by current wayfinding environmental conditions (Figure 4.7-4.9).

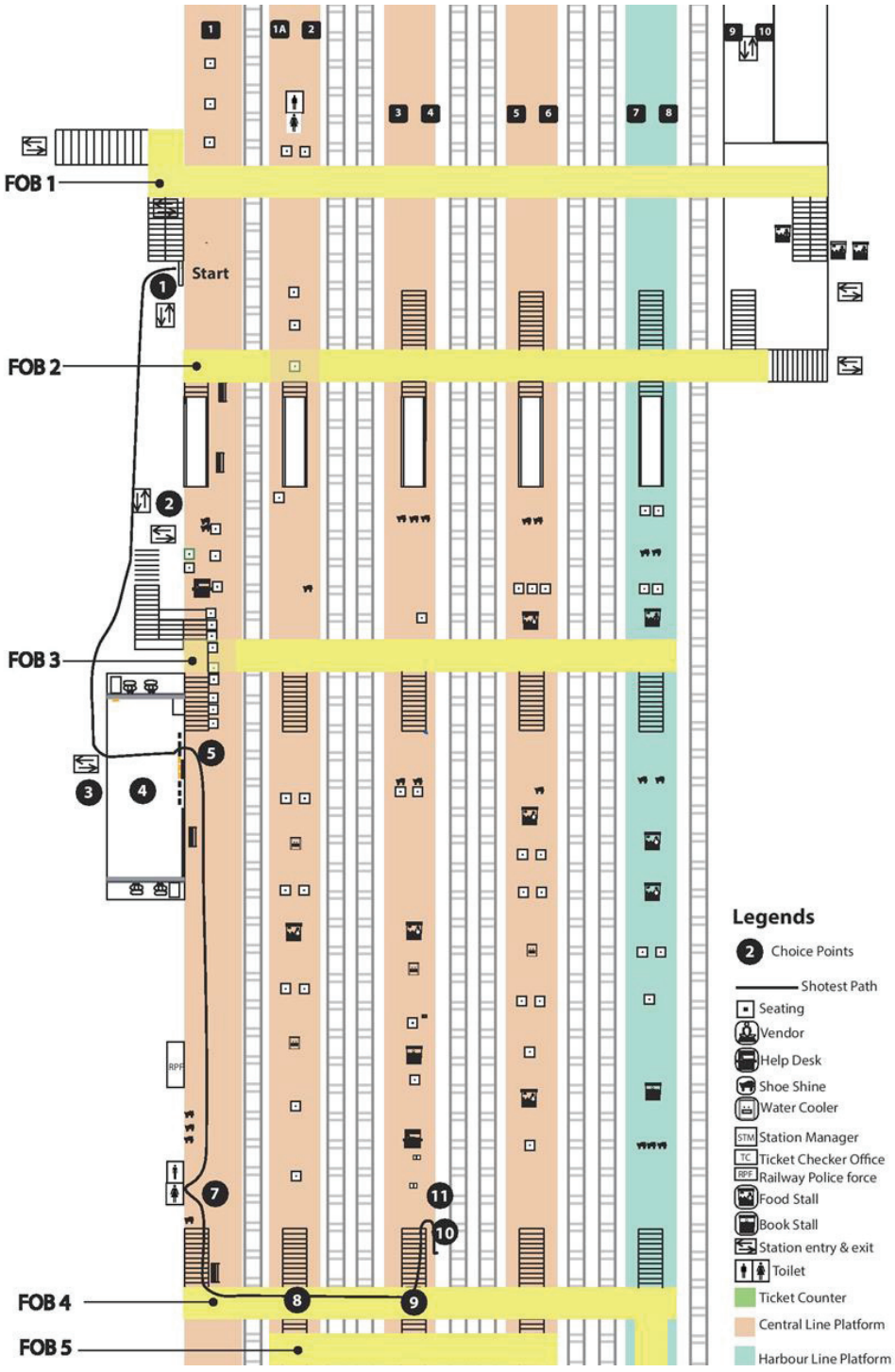


Figure 4.5 Schematic layout of the building and the shortest path to perform wayfinding tasks decided as a protocol for station walkthrough.

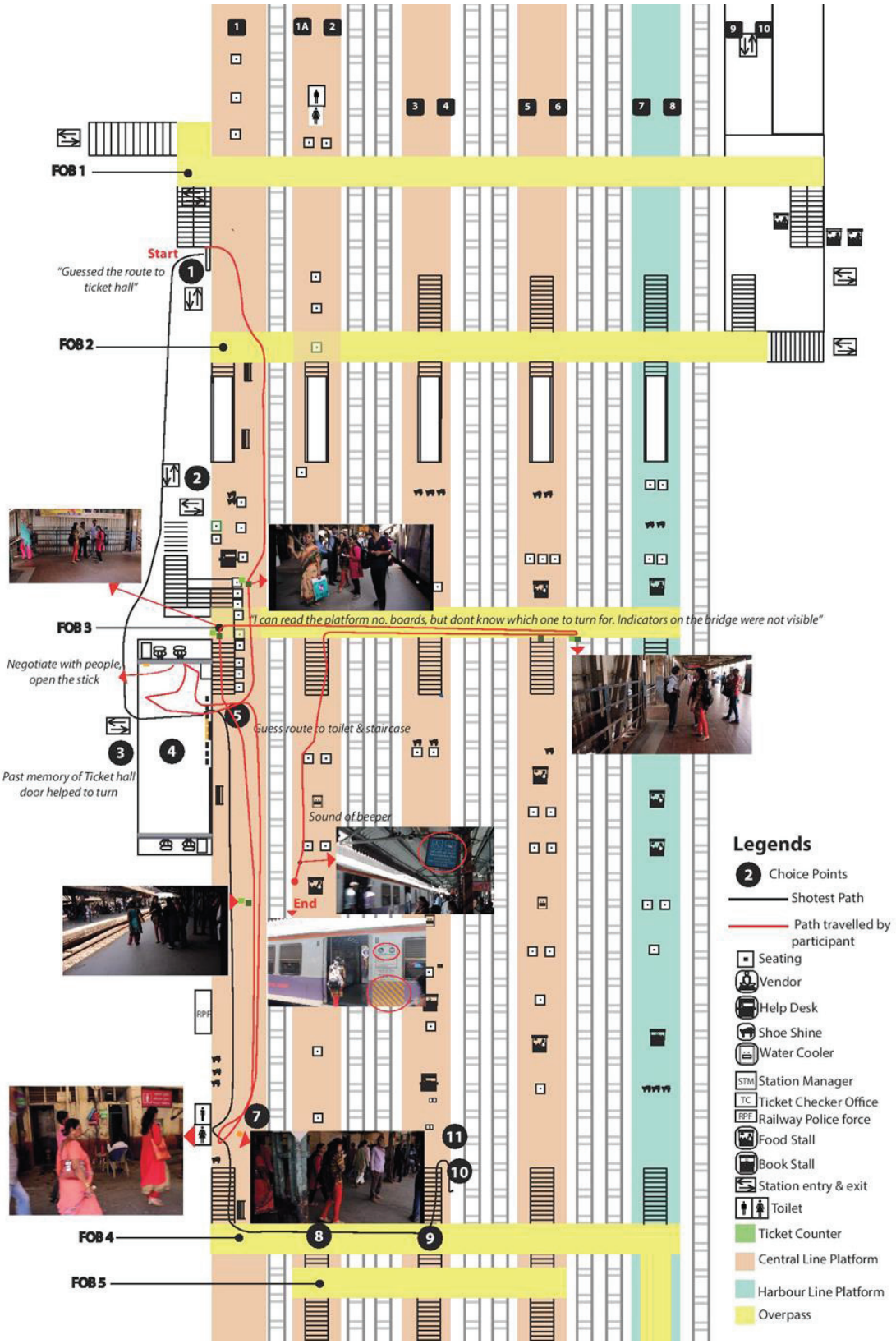


Figure 4.6 Wayfinding behavioural map of a participant involved in the walk-through study.

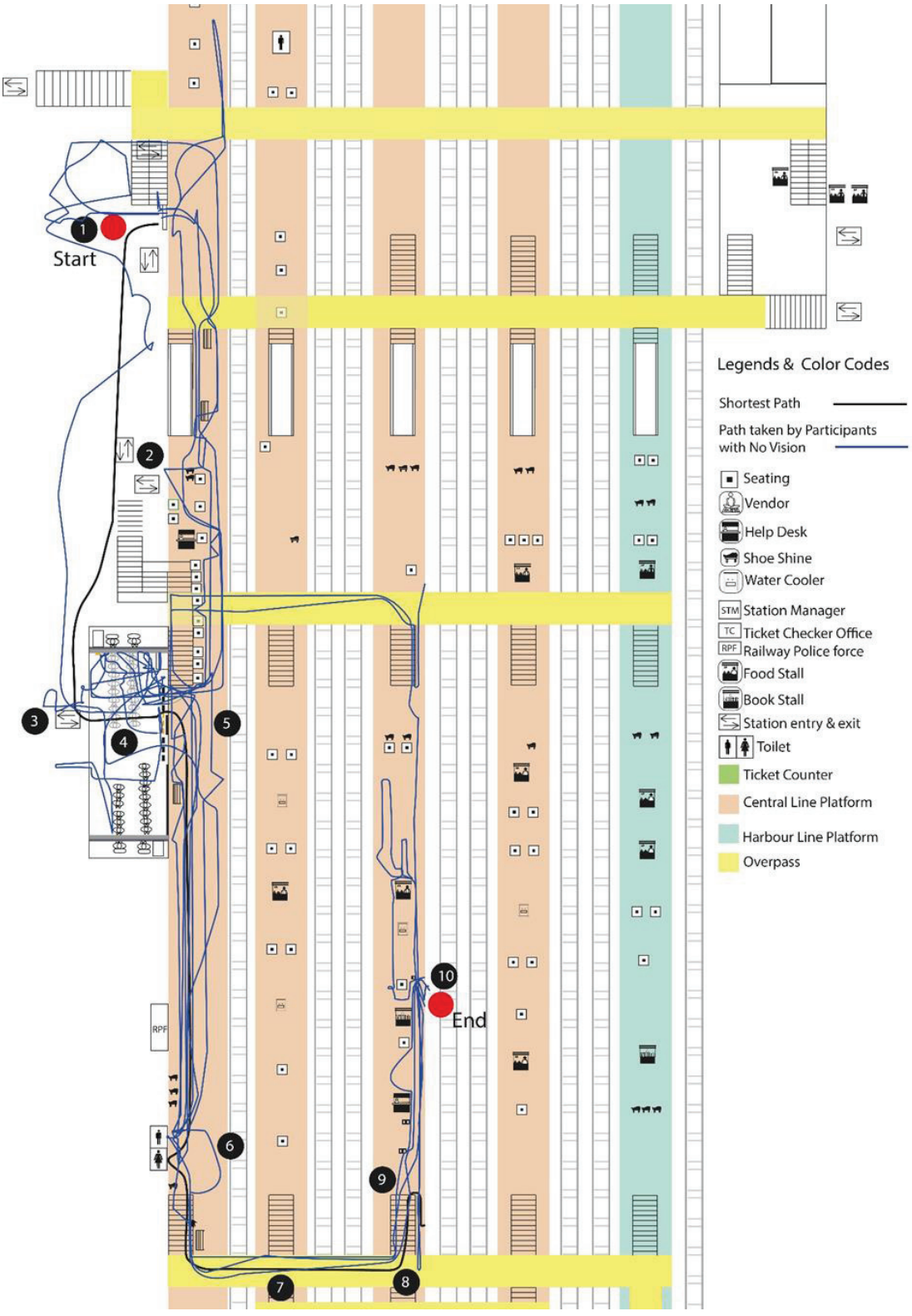


Figure 4.7 Section of station map showing the participants' paths with no vision and the shortest route.

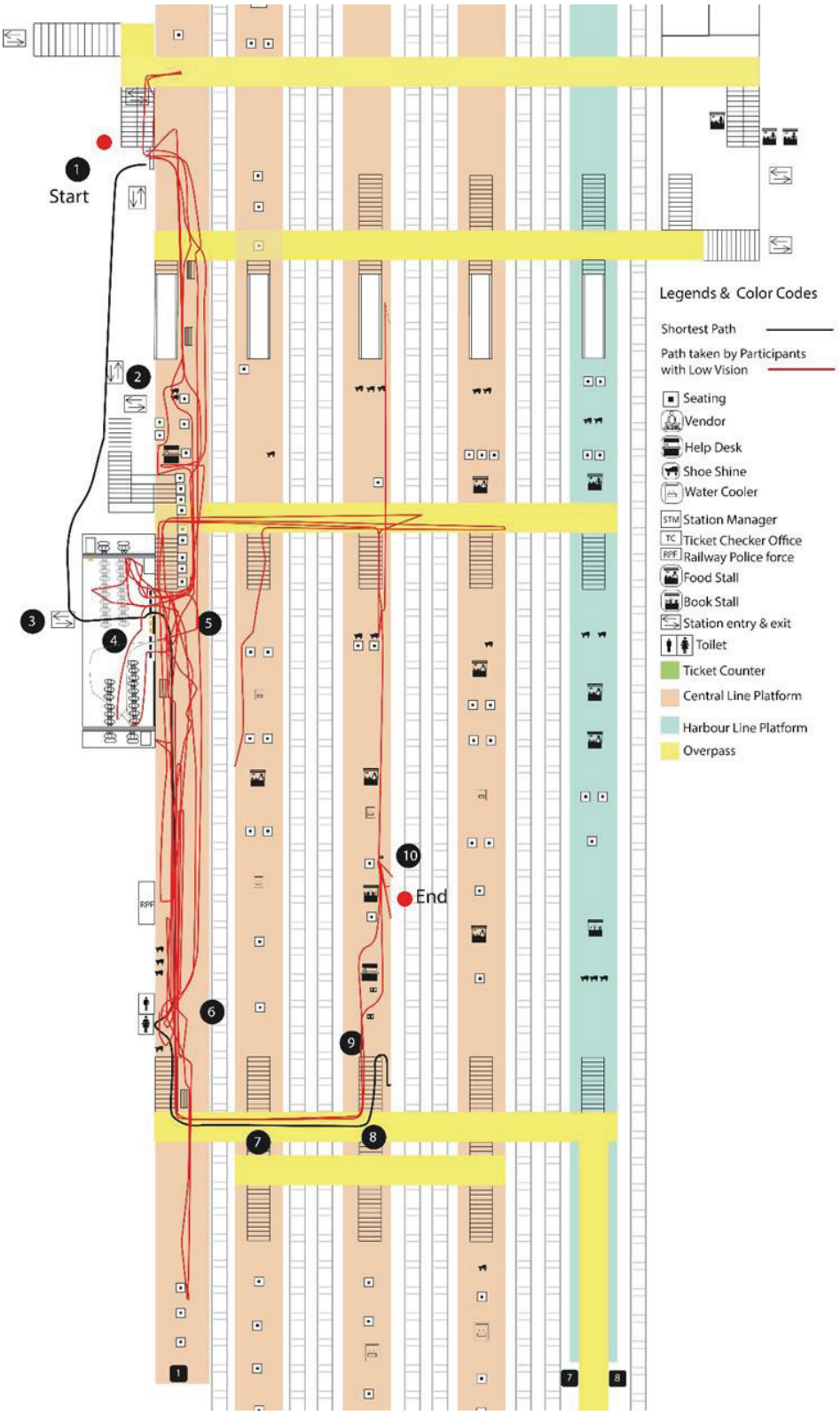


Figure 4.8 Section of station map showing the participants' paths with no vision and the shortest route.

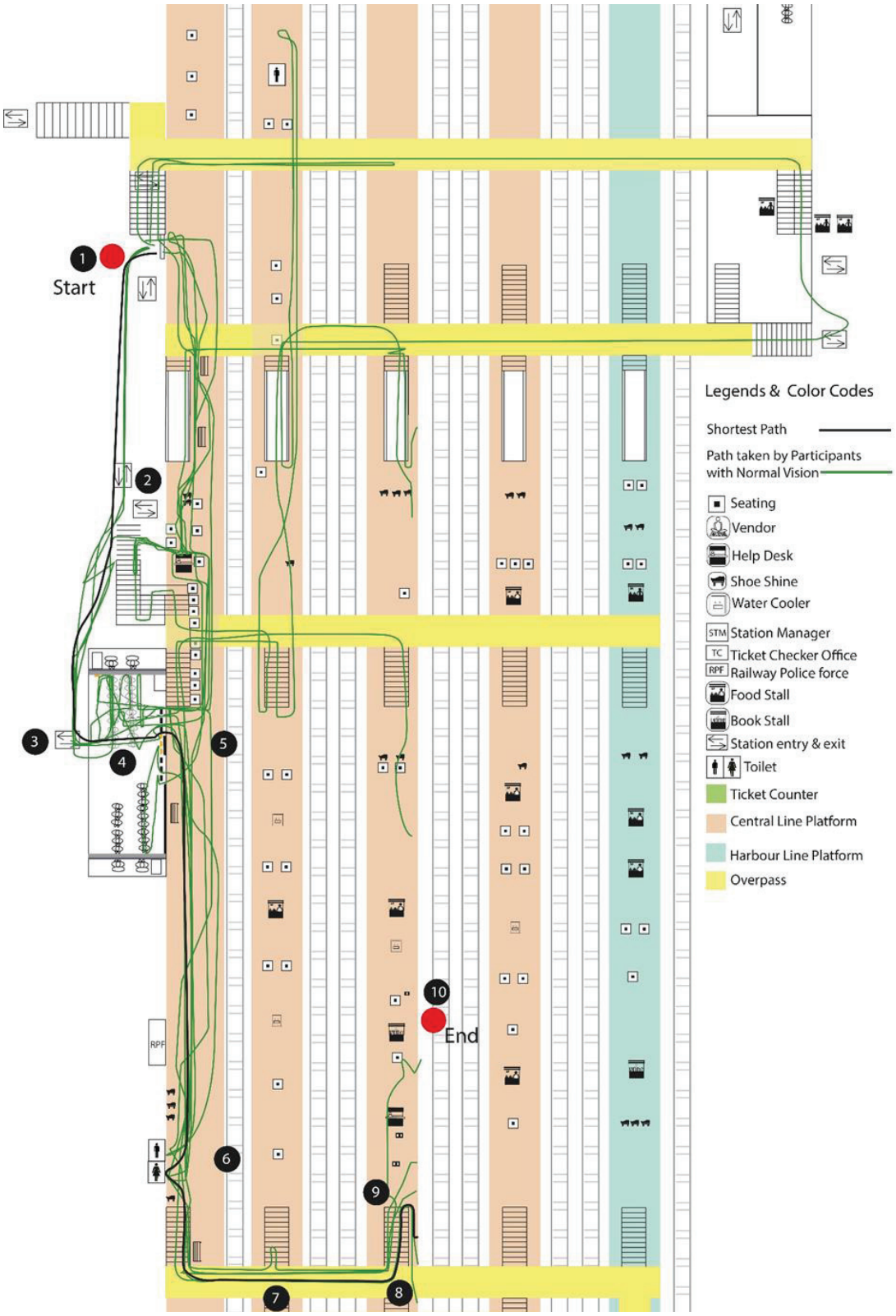


Figure 4.9 The section of the station map shows the paths taken by the sighted participants along with the shortest route.

4.10 Results

In this section, the wayfinding of participants against each performance measure is discussed to understand how the current system fulfils the wayfinding needs of people with different levels of vision.

4.10.1 Error

Errors in wayfinding refer to incorrect decisions made when identifying spatial elements or selecting a path. Accordingly, the errors can be categorized into two types: identification errors and path errors. Identification errors occur when participants fail to recognize spatial elements, facilities, or services, often due to difficulties in perceiving the built environment. Path errors, on the other hand, occur when participants choose an incorrect route to reach their desired destination. The frequency of path errors tends to increase with the number of decision points and the distance between the origin and destination points, especially in environments with poor visual accessibility. Both types of errors were observed among participants during the protocol, highlighting limitations in the current design of wayfinding systems. Table 4.7 illustrates the average errors made by all participants and the average number of errors made by each subgroup. The average error made by each participant subgroup is no-vision (2.0), low vision (2.67), and sighted (1.2). Like having a vision, familiarity with the station reduces wayfinding errors (Unfamiliar- 2.4; partial familiar 2.7 and fully familiar-0.2).

Table 4.7 Average of the no. of errors made by participants for each task (Unexpected results are marked in red)

Error	N	Ticket hall entry	Ticket window	Ticket Hall exit	Toilet	Platform	Waiting area	Coach entry	Total
All	22	0.6	0.1	0.1	0.2	0.4	0.2	0.2	1.8
NV	6	0.7	0.3	0.3	0.0	0.3	0.3	0.0	2.0
LV	6	0.8	0.0	0.0	0.3	0.7	0.3	0.5	2.7
S	10	0.5	0.0	0.0	0.2	0.3	0.1	0.1	1.2

We will now delve into the reasons behind these errors for each task performed by participants in the study.

Find Ticket Hall

The average number of errors was the highest for locating the ticket hall (0.6) as compared to all tasks included in the protocol (Table 4.7). All participants, regardless of their familiarity with the Kurla station and their level of vision, made errors in locating the ticket hall (no-vision (0.7); low-vision (0.8) and sighted (0.5)). Although all Participants made path errors in locating the ticket hall, unexpectedly, participants with low vision made more no. of errors as compared to those with no vision as they were more self-reliant (average time help asked is 1.8, help received is 1.8) than no vision ((average time help asked is 6.5, help received 3.0)) while locating ticket hall. An unfamiliar-sighted participant took the longest route, crossing three foot over bridges, as illustrated in Figure 4.10. Table 4.8 provides insights into his decision-making process during the journey.

Table 4.8 Anecdote of the thought process of an unfamiliar-sighted participant

- *I took the route to the staircase because I thought that it was the easiest way to get inside the station and it was the closest visible route from my current location.*
- *I was looking for a notice board or a sign to help me to move out.*
- *I had seen small hawkers on the bridge.*
- *I was surprised that the bridge had no staircase that led to the platform. I was looking left and right.*
- *When a person visits a station, it is like this only, he /she feels lost. I felt like I had been trapped.*
- *After I climbed down from one bridge, I thought there was no point in tracing the same route backwards. Hence, I took another bridge.*
- *I was looking for a board saying ticket hall and crowd. But then I saw a help desk and asked a man.*
- *In Bhopal, there are small counters where you can get a rail ticket for Rs 1. But I did not find them here. There is a grill on them from where you can identify them. I was looking at each platform while crossing bridge no. 2 to find the ticket counter.*



Figure 4.10 Section of the Map that demonstrates the longest path taken to locate the ticket hall by an unfamiliar-sighted participant

Several factors contributed to the high average error among all participant subgroups in locating the ticket hall: 1) Participants needed to gain awareness of their starting point at the station entrance due to the absence of signage. 2) The route to the ticket hall involved numerous decision points, including changes in floor level. 3) The location of the ticket hall was perceptually distant from the starting point of the protocol for all participants. 4) There needed to be communication regarding the station rule prohibiting entry to the ticket area without a ticket. 5) Directional cues were lacking at each decision point along the shortest route to guide

participants in the right direction. 6) The variability in the placement of ticket halls at different stations makes it challenging to predict their location.

Detect Ticket window, Buy Ticket and Exit from ticket Hall

The average error made to locate the ticket window by all participants was 0.1 as given in Table 4.7. Only participants with no vision were found to commit identification errors when attempting to locate the ticket window (0.3) and path error while exiting the ticket hall (0.3), as given in Table 4.7. The following factors contributed to errors in these tasks for this subgroup: 1) Lack of non-visual cues to detect the ticket window, mainly when there is minimal noise from the public standing in the ticket queue. 2) Difficulty in identifying operational ticket windows due to some of them being non-operational. 3) Absence of non-visual cues to locate the entry and exit points of the ticket hall. 4) The average time help received (1.0) is less than help asked (1.8) for locating the ticket window and for ticket hall exit (help received (0.7); help asked (1.2)).

Figure 4.12 explains the wayfinding experience of a no-vision participant with partial familiarity performing the task of locating the ticket hall. In the figure, he made two identification errors. The first error he made was in reaching out to a closed counter and the second error he made was to sense a ticket vending machine as a ticket counter (Figure 4.11).



Figure 4.11 A participant with no vision and partial familiarity encounters a closed ticket window for buying a train ticket.

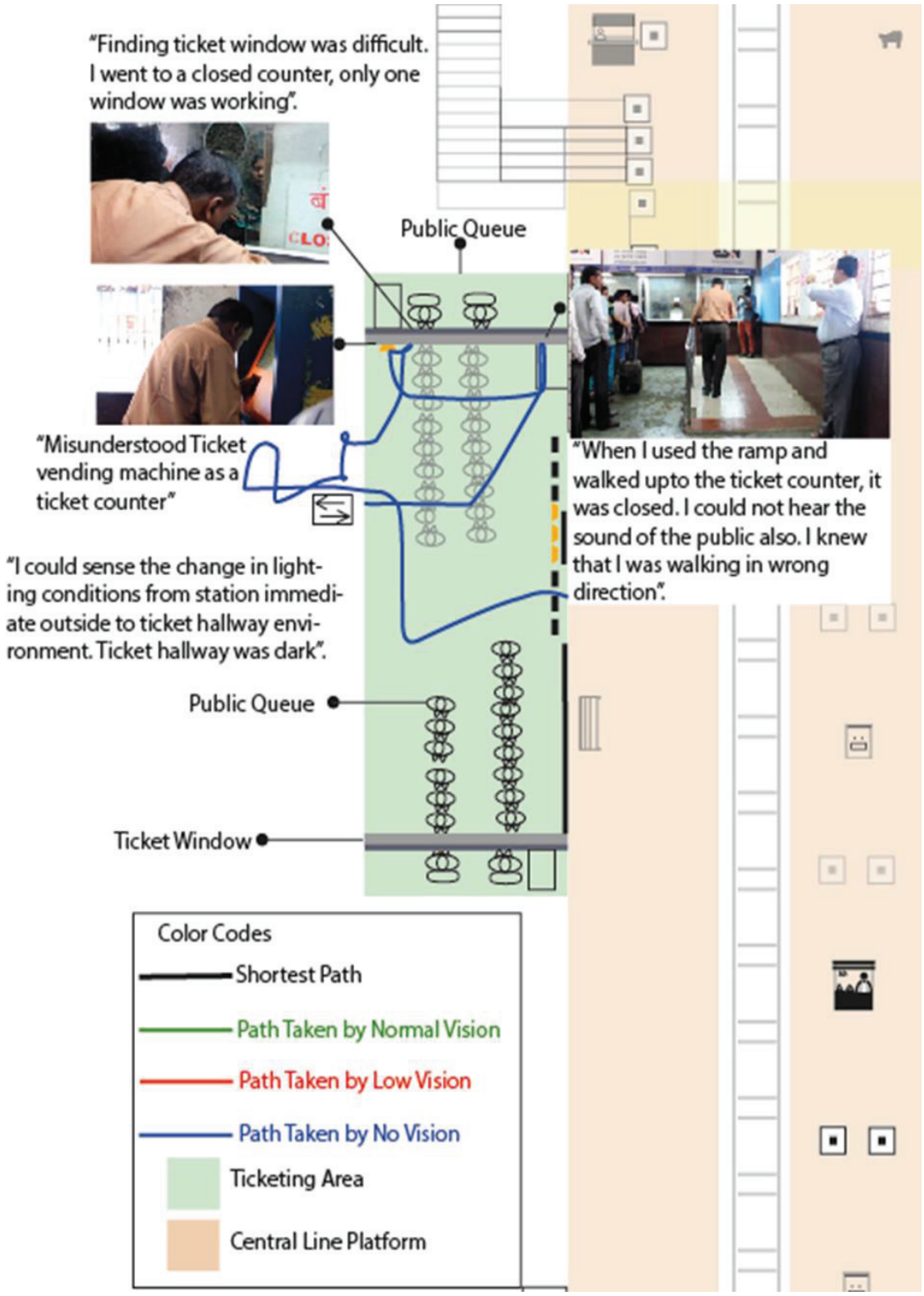


Figure 4.12 Section of a behavioural map of a partially familiar participant with no vision with anecdotes of his experience regarding detecting ticket window and exiting from the ticket hall.

The average error made to locate the ticket window by all participants was 0.2 as given in Table 4.7. Unexpectedly, an error was made only by participants with low- vision (0.3) and those with sight (0.2), as seen in Figure 4.8. No-vision outperformed low-vision participants as they were more reliant on human help compared to low-vision. No-vision participants asked for an average of 2.8 times help and received an average of 3.0 times help; this implies they have received voluntary help from other commuters. Unlike, no-vision, low-vision groups were more self-reliant (help asked 1.8 and help received 1.5). This is because a low-vision group, being a more self-reliant group, as a result, made more no. of errors in asking for help. This shows how important it is to have a good wayfinding system to make PVIs more self-reliant.

Locate Toilet

Locating the toilet was perceived as a daunting task by two participants with low vision and partial unfamiliarity and two sighted participants with unfamiliarity with Kurla Station. The low vision sub-group was reliant on verbal help, whereas the sighted subgroup was highly reliant on their vision and experience of station use. The reasons for making errors in locating toilet stalls were: 1) No directional cue in any format that helps to locate toilets at important decision points on station entry, on the platform and on foot over the bridge. 2) No nonvisual cue to differentiate between the male and female toilets (Figure 4.13). 3) The location of the toilet is difficult to predict on each platform as the deployment is not standardized across all platforms of each station. 4) Misguided by people and poor comprehension of help asked and received.

Both path errors and identification errors were observed highest in the walkthrough of low vision participants as they were reliant on their residual vision, compared to no vision, who were dependent on human assistance. A sighted participant with partial familiarity with Kurla station also made a path error in identifying the nearest toilet as he was totally self-dependent. A low-vision participant, unfamiliar with Kurla station, considered the Railway Police Office (RPF) as a toilet as an identification error. Figure 4.14 explains the walkthrough of one of the female unfamiliar low vision participants who was struggling to find a toilet. She made a path error for the task despite multiple verbal support from the passerby commuters.



Figure 4.13 A participant with no vision seeking help to locate a toilet on the station

Locate Platform for the Chinchpokli Train

Eight participants, all with partial or unfamiliarity with Kurla station, made errors while locating the platform for the Chinchpokli train, with an average error of 0.4 (see Table 4.7). Interestingly, despite prior tasks showing different trends, low-vision participants made more errors on average (0.7) than non-vision participants (0.3). This was unexpected, as low-vision participants tended to rely more on their residual vision (average help asked: 1.8; average help received: 1.3), whereas no-vision participants sought (average help asked: 3.0) and received (average help received: 2.5) assistance from other commuters.

Several factors contributed to these errors: 1) Lack of information about platforms and trains for intermediate station stops in both visual and non-visual formats. 2) Difficulty in understanding current train indicators for novice-sighted commuters and those with low vision. 3. Misguidance from people and difficulty in comprehending assistance received. Reaching the wrong platform can have serious consequences, such as boarding the wrong train or having to retrace one's steps back to the footbridge to locate the correct platform. Figure 4.14 illustrates the wayfinding journey of an unfamiliar low-vision participant on the wrong platform due to inadequate information from the current wayfinding system and human assistance.

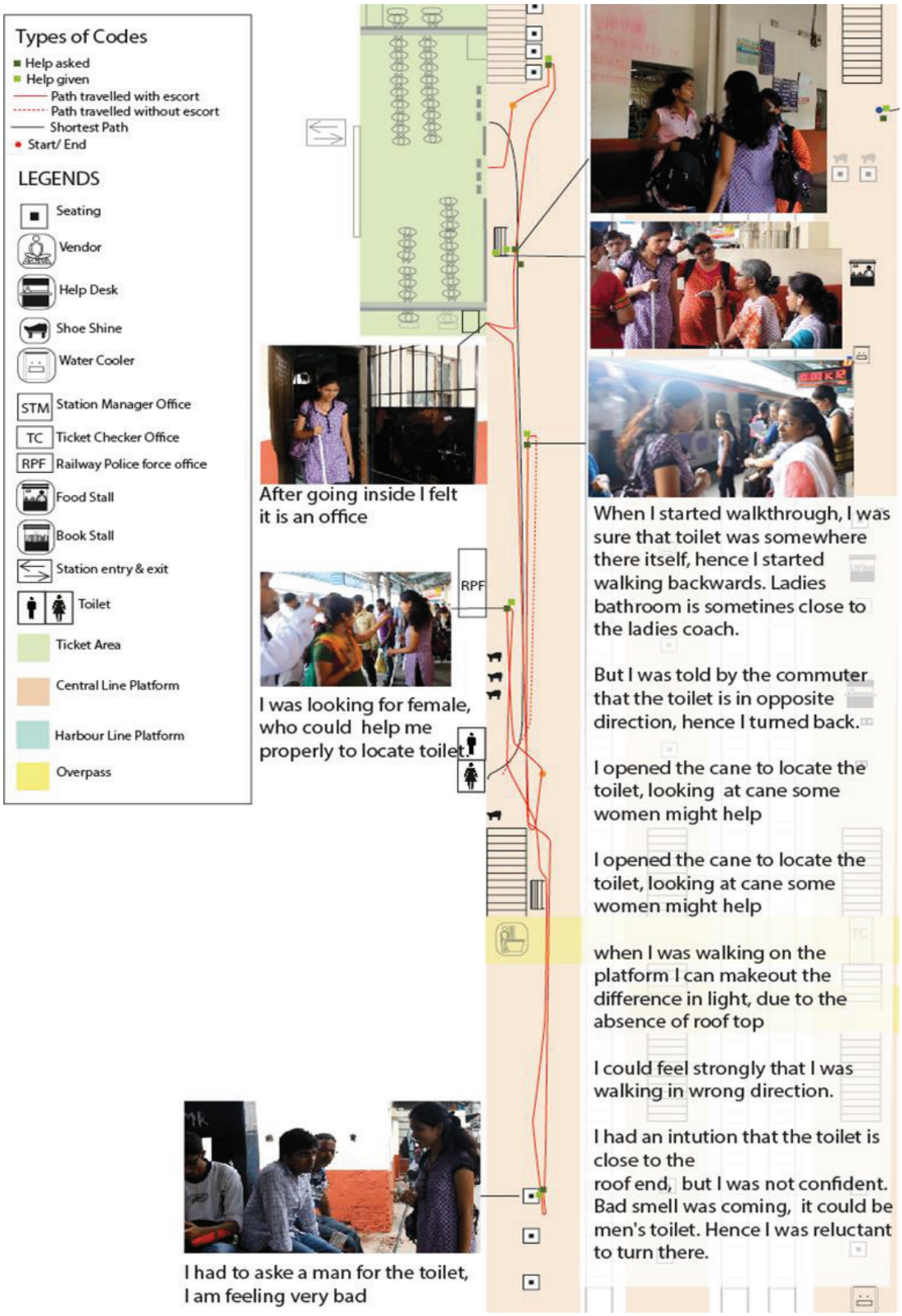


Figure 4.14 Section of a behavioural map of an unfamiliar participant with low vision with anecdotes of her experience while locating the toilet.

Among eleven participants, five unfamiliar individuals (two with no vision, two with low vision, and one with sight) made errors in identifying the waiting area for the desired coach, resulting in an average error rate of 0.2 among all participants. Additionally, four unfamiliar participants, including those with low and sighted, made errors in identifying the correct coach. Participants made no identification errors and had no vision, as they received voluntary assistance to locate the reserved coach entry for disabled commuters (average help asked: 0.7, average help received: 1.0). Both path and identification errors were observed during these wayfinding tasks, with several reasons contributing to these errors:

-The audio beeper indicating the location of the handicap coach was not functioning, leading participants with visual impairments to make path errors. A quote from the interview of a participant with low vision illustrated the same.

Low vision participant (LV3): *"I was confused about which side I should turn for the handicap coach. Either the beeper was not working, or the handicap coach was not nearby".*

-Participants with visual impairments were misguided by others and needed help understanding the assistance provided.

-A participant with low vision ended up on the wrong platform, leading to further errors in identifying the waiting area and the coach of the wrong train, as seen in Fig 4.15.

-An unfamiliar-sighted participant mistook the luggage coach for the general coach, indicating a lack of clear signage. A quote from his interview substantiates the same, "I do not see anything written on the coach".

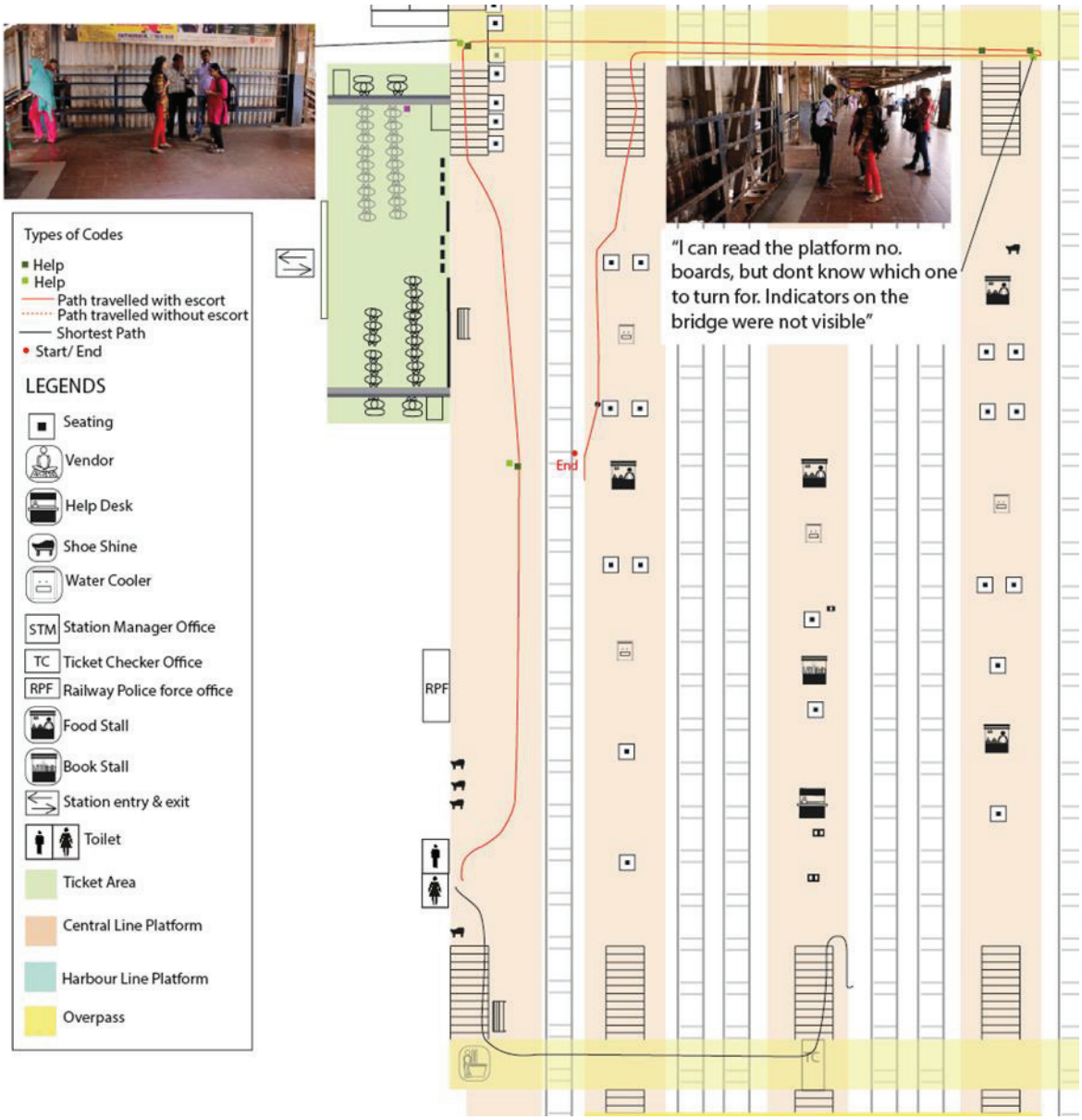


Figure 4.15 Section of a behavioural map of an unfamiliar participant with low vision with anecdotes of her experience while locating the platform.

Locate the Waiting Area of the Coach and identify coach entry for people with disabilities.

-Participants with low vision and some familiarity with local train commuting had a basic understanding of the location of the handicap coach relative to the platform and coach order, which helped them to some extent in locating it, as stated in the comments below:

No vision participant (NV3): *"Sometimes the ladies coach is next to the handicap coach; if we find the ladies coach, it is easier to locate the coach entry of handicap coach"* (Figure 4.16)

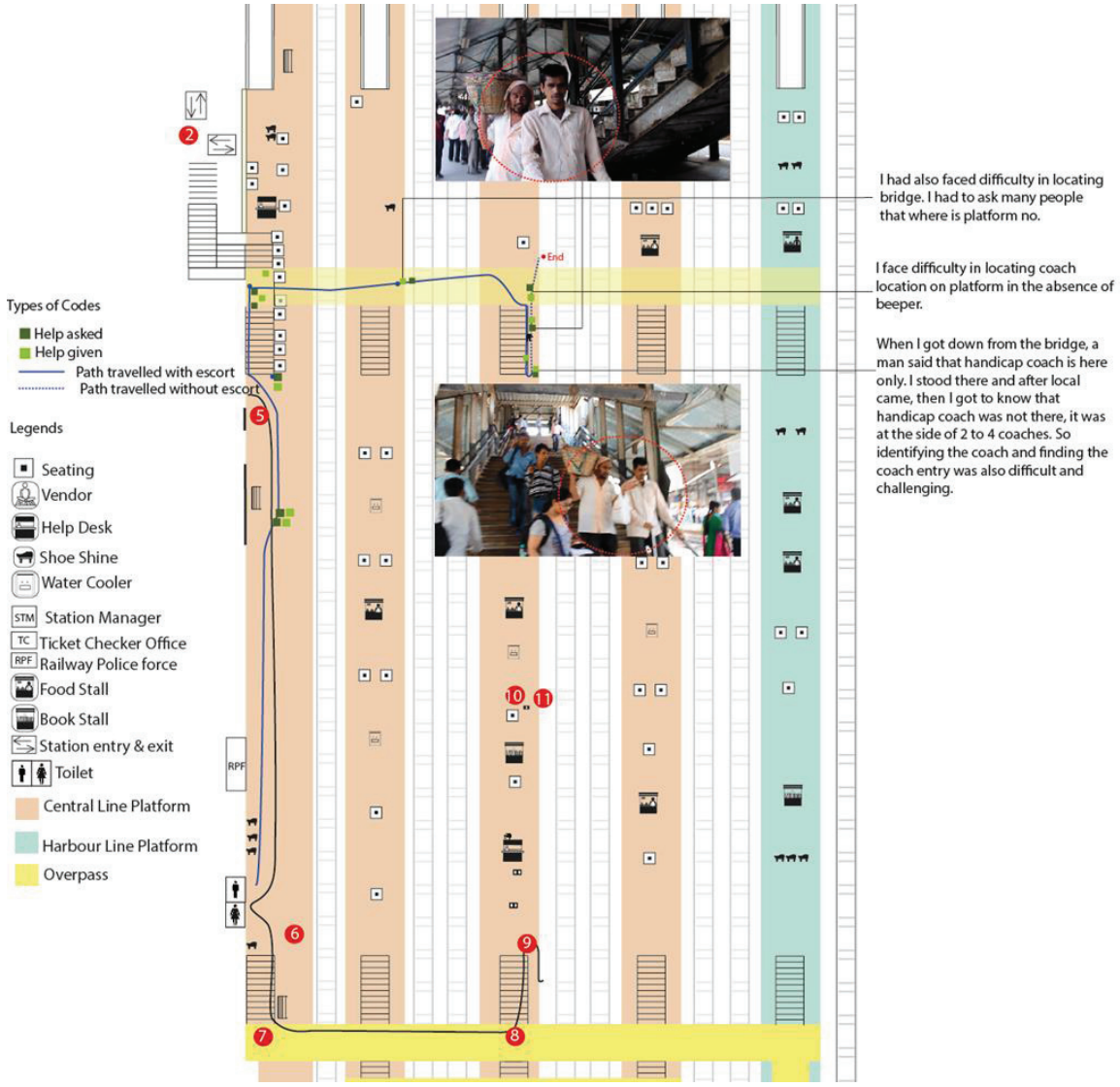


Figure 4.16 A section of a behavioural map of an unfamiliar participant with no vision with anecdotes of his experience of finding the waiting area for handicap coach on the platform.

Low vision participant (LV2): *"Handicap coach comes little ahead of the staircase this I knew". "I could see the yellow stripes on the handicap coach. That helped me to board the train. I was looking for yellow stripes on that coach".* (Figure 4.17).

No vision participant (NV1). *"Handicap coach comes a little ahead or back of where I stand on the platform to wait for the train"*. (Figure 4.18- 4.19 a,b,c).



Figure 4.17 A low-vision participant detected the handicap coach with the help of yellow stripes.



Figure 4.18 Misalignment of the handicap coach alignment with the participant's (with no vision) waiting position on the platform



Figure 4.19a,b,c Participants with no vision were spotted rushed by a sighted passerby, helping them to board the handicap coach.

This section highlights the challenges encountered by participants with varying levels of vision and familiarity with the Kurla station during wayfinding tasks. Reliance on verbal assistance from passersby poses risks of misunderstanding, contributing to errors among participants with low vision and sight. Familiarity with other stations only partially compensates for encountering new wayfinding situations. Participants with low vision made more errors on average than those without vision, except for tasks such as locating the ticket window and ticket hall exit, where they were more self-reliant than those without vision, who depended on human assistance for escorting.

The limitations of personal strategies highlight the lack of wayfinding support in the model station. Further, the study emphasizes the need for essential information provided through non-visual sensory modalities at crucial decision points throughout the station, including entry/exit points, platforms, bridges, ticket halls, and toilets. Directional and orientational signage in all sensory formats is crucial to address architectural differences and inconsistencies in layout and service deployment across railway stations. Redesigning prominent visual signage for accessibility by low-vision individuals is necessary, except for platform number boards and handicap coach indicators marked with yellow stripes. Moreover, communicating local train travel rules in all sensory formats is essential to avoid penalties.

These findings emphasize the significance of clear signage and built environmental aids in facilitating wayfinding for individuals with visual impairments in public spaces.

4.10.2 Deviation

Deviations are understood as slight veering in the path, though the wayfinder can still maintain the right direction on the path (Bradley & Dunlop, 2005; Carreon, 2000). From Table 4.9, deviations were observed in the entire wayfinding journey for all wayfinding tasks.

Table 4.9 Average no. of deviations made by all participants for each wayfinding task

Deviation	N	Ticket hall entry	Ticket window	Ticket Hall exit	Toilet	Platform	Waiting area	Coach entry	Total
All	22	0.9	0.0	0.2	0.3	0.4	0.2	0.4	2.5
NV	6	2.0	0.0	0.8	0.2	0.5	0.7	0.7	4.8
LV	6	0.7	0.2	0.0	1.0	0.7	0.2	0.5	3.2
S	10	0.3	0.0	0.0	0.0	0.1	0.0	0.2	0.6

Deviations were observed in the wayfinding journey of fifty per cent of the participants of this study. The average deviations are 4.83, 3.17 and 0.60 for no vision, low vision, and sighted participants, respectively, which reflects marked differences across user groups based on the level of vision.

However, these differences in average deviation vary across wayfinding tasks, as seen in Table 4.8. The average number of deviations is higher for both no-vision and low-vision participants for different wayfinding tasks. As expected, the sighted participant group recorded minimal deviation for all tasks. The most salient of all tasks is locating the ticket hall as the average number of deviations is seven times and three times higher for no vision group (ave.2.0) relative to the sighted (ave.0.3) and low vision user group (ave.0.7). Similarly, the average number of deviations for coach entry for the blind (ave.0.7) is three and a half times higher of the sighted participants (ave.0.2) and one and a half times higher of low vision group (ave.0.5). Only participants with no vision deviated while locating the ticket hall exit (ave. 0.8).

The average deviations are 3.4, 1.8, and 0.8 for unfamiliar, partially familiar, and fully familiar participants, respectively, which reflects marked differences across user groups based on the level of familiarity. The average number of deviations for all participants across all levels of familiarity was highest for locating the ticket hall from the station entry, followed by locating the train coach. This was the only task where deviation was recorded independently of the familiarity level of participants. However, unfamiliar participants made deviations all through the wayfinding journey.

Based on the total deviations, we can say that familiarity helps reduce the total number of deviations. However, it does not help reduce deviations while entering the ticket hall. However, having said so, some level of familiarity (whether partial/full) seems to reduce deviations.

There were 2 types of deviation that were observed in the station walkthrough study: path-based deviation and navigation-based deviation. The path-based deviation was logged as minor veers when the person had slightly digressed from the right path but retraced it. Path-based deviation depends upon the number of decision points in the path at the same floor level or more than one floor level. A high number of decision points creates more confusion when taking the right turn. Similarly, if the path can change floor level, that further adds to the confusion. ***Navigation-based deviation*** is when a person is unable to walk in a straight line. It happens when there are no spatial references for walking straight. The mean values of the no. of deviations made by each participant in the study accounted for both these types of deviations. We now discuss the factors that led to deviations by different participant groups for each wayfinding task.

(i) Path-based Deviation: From Figure 4.20, it can be observed that the probability of path-based deviations is high around decision points, including using a foot over a bridge. This kind of deviation was commonly observed among participants of all three groups. Path-based deviation was observed highest during the task to find the ticket hall from station entry (ave. 0.9), followed by a task to locate the platform (0.4) by participants from all three groups based on vision with partial and unfamiliarity with the station building as given in Table 4.9.

To find the ticket hall, the highest deviations were observed among wayfinding of participants with no vision independent of familiarity level (ave. 2), followed by those with low vision (ave. 0.7) and sighted (ave. 0.3). The shortest path to the ticket hall from the station entry

had three decision points: decision point 1, 2 and 3. At each decision point, there were four path possibilities, respectively. A high number of decision points and multiple path possibilities from each decision point, further absence of path guidance signs, and directional signs that lead to ticket hall from the decision points are the factors that led to the highest deviation for this task. Similarly, for the task to locate the platform, four decision points were involved (decision points 6, 7, 8, 9) with 4, 4, 4, and 3 path possibilities at each decision point, respectively. As a result, high deviation was observed, especially among participants with low vision, followed by those with no vision and sighted with unfamiliarity with the station building. Participants with low vision deviated more than those without vision as they were more self-reliant in performing this task. Low-vision participants' average number of help asked by other commuters to locate the platform was 1.8, and the received help was an average of 1.3. On the other hand, the no-vision participants' average total number of times help was asked for the same task was three, and the number of times they received help was 2.5.

The path-based deviation was also commonly observed among two unfamiliar participants with no vision inside the ticket hall to exit towards the platform (ave. 0.2) and on the platform itself to locate the waiting area of the coach (0.2). The entry/exit points inside the ticket hall are not earmarked with non-visual cues to detect them. On the platform, the audio beepers that earmarked the waiting area of the handicap coach location were not functional. Further, on double-sided middle platforms, without any tactile boundary, participants with no vision feel very confused between the platforms. A quote from the interview of a participant with no vision, explains the concern.

A participant with no vision who deviated 5 times to locate the waiting area on the platform expressed his wayfinding concern, “There is *confusion in understanding one's location on platforms where two platforms are together, whether it is 3 or 4. There should be some divider or other clue that helps us to distinguish between two platforms.”*

It was found in several videos of the participant’s wayfinding journey that the train coaches did not align with the position where the participants waited on the platform despite the correct position under the signage of the handicap coach. This is a severe concern for commuters with VI, especially among those with no vision. A high average of deviations was also observed to detect the entry of the handicap coach, as shown in Figure 4.20a, b.

A participant with no vision and partial familiarity with the station expressed his concern, *“The coach sometimes comes ahead or back from the position where we stand. In such*

cases, we board any coach. The coach does not need to come at the exact position. This creates a problem. Later, when the train stops at the next station, we ask the public and run towards our coach."

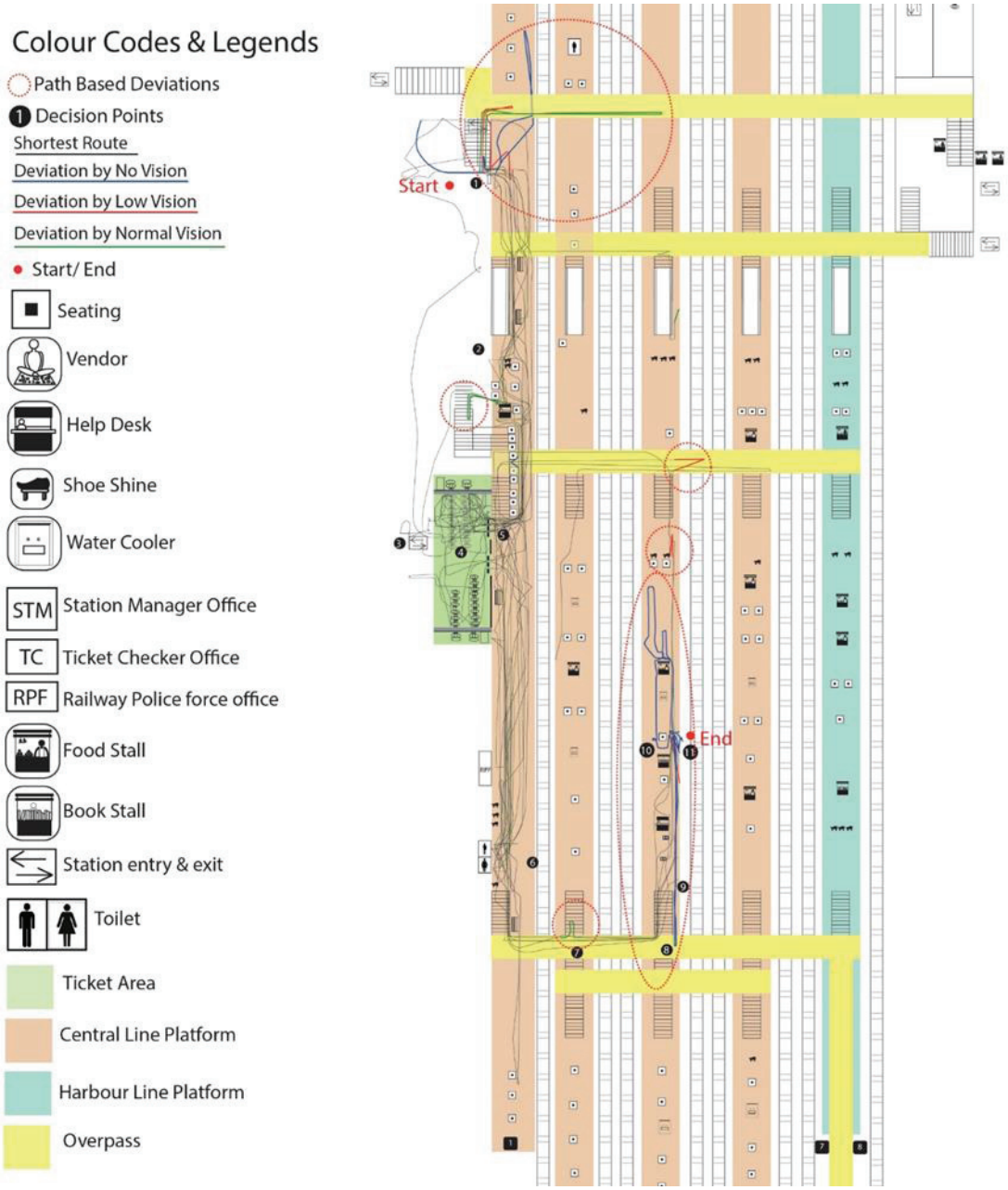


Figure 4.20 A section of a behavioural map of all participants highlights paths where participants have made path-based deviations.



Figure 4.19 a, b Participants with no vision escorted by the other commuters to handicap coach entry.

(ii) Navigation-based Deviation: Navigation-based deviations were maximum at decision points 1, 2, and 4, as shown in Figure 4.20. It was observed mainly among the no-vision group, especially with those who were unfamiliar with the spatial zones used during the walkthrough in Kurla station. At decision point 1, the station entrance, there was no guidance to enable a no-vision group to walk towards the station entrance. In the absence of a directed path at immediate station entry, blind commuters collided with vehicles, were completely disoriented outside the station building and lost much time in reaching the ticket area.

One of the participants with no vision and familiarity with Kurla Station reported, *"If you change our route, finding a counter will be difficult. The level of difficulty will depend upon the route taken. Had it been the route of our daily commute, then it would have been easy."*

The same phenomenon was observed inside the ticket hall, where they were found entirely unguided in reaching the ticket area exit.

A participant with no vision and unfamiliarity with the ticket zone expressed, "*At every station, the ticket hall is at a different location. It is like a room, and I had great difficulty in finding my way out of the ticket hall. I was colliding with each surface to find the ticket hall exit".*

On the platform, veering was observed with no vision, where they drifted either towards the platform edge or the girder, as seen in Figure 4.20. Both these scenarios are dangerous and subject to injury if not attended to. Navigation-based deviation led to poor safety, especially on island platforms, as railway tracks on both sides aid them. Island platforms with both-sided tracks are even more dangerous to walk. There was no navigation-based deviation observed on foot over the bridge because people with vision impairment use the reference of the side wall and handrails to walk straight (shoreline).

A blind commuter and a regular commuter of local trains shared his experience of platform use,*" I try to walk in the middle of the platforms as there is the possibility of falling on the tracks. I do get hit by stalls or poles and cannot help it".*

Only public help is a resort in saving participants in unsafe situations that may emerge due to deviation. Navigation-based deviations were observed among those with no vision due to a lack of a floor guidance system that acts as a reference in spatial zones such as immediate station entry, ticketing area and platforms.

To summarize, participants with no vision (4.8) experienced more deviations compared to those with low vision (3.2), while the sighted group exhibited the fewest deviations (0.6) as anticipated. Notably, the no-vision group encountered the most deviations when tasked with finding the ticket hall (2.0), exiting the ticket hall (0.8), locating the platform (0.5), finding the waiting area (0.7), and detecting the coach entry (0.5). Similarly, the low vision group exhibited significant deviations when asked to locate the ticket hall (0.7), find the toilet (1.0), locate the platform (0.7), and detect the coach entry (0.5). Familiarity with the station correlated with reduced deviations (unfamiliar - 3.8; partially familiar - 1.8; fully familiar - 0.8). Having a vision and complete familiarity significantly helped in reducing deviations.

Path-based deviations were commonly observed at decision points where multiple paths were possible, contributing to confusion, especially for all user groups independent of vision. Public help emerged as a key means of finding the correct path. Deviation faced while locating coach entry emerged as one of the most high-risk tasks for participants with no vision.

Navigation-based deviations, characterized by veering off course, were primarily observed among participants with no vision, particularly in areas lacking precise edges for reference, such as station entries, ticket halls, and middle platforms (high-risk zones). However, deviations were not recorded on foot over bridges, which offer precise edges for walking. The residual vision of the low-vision group was enough to help them walk without veering.

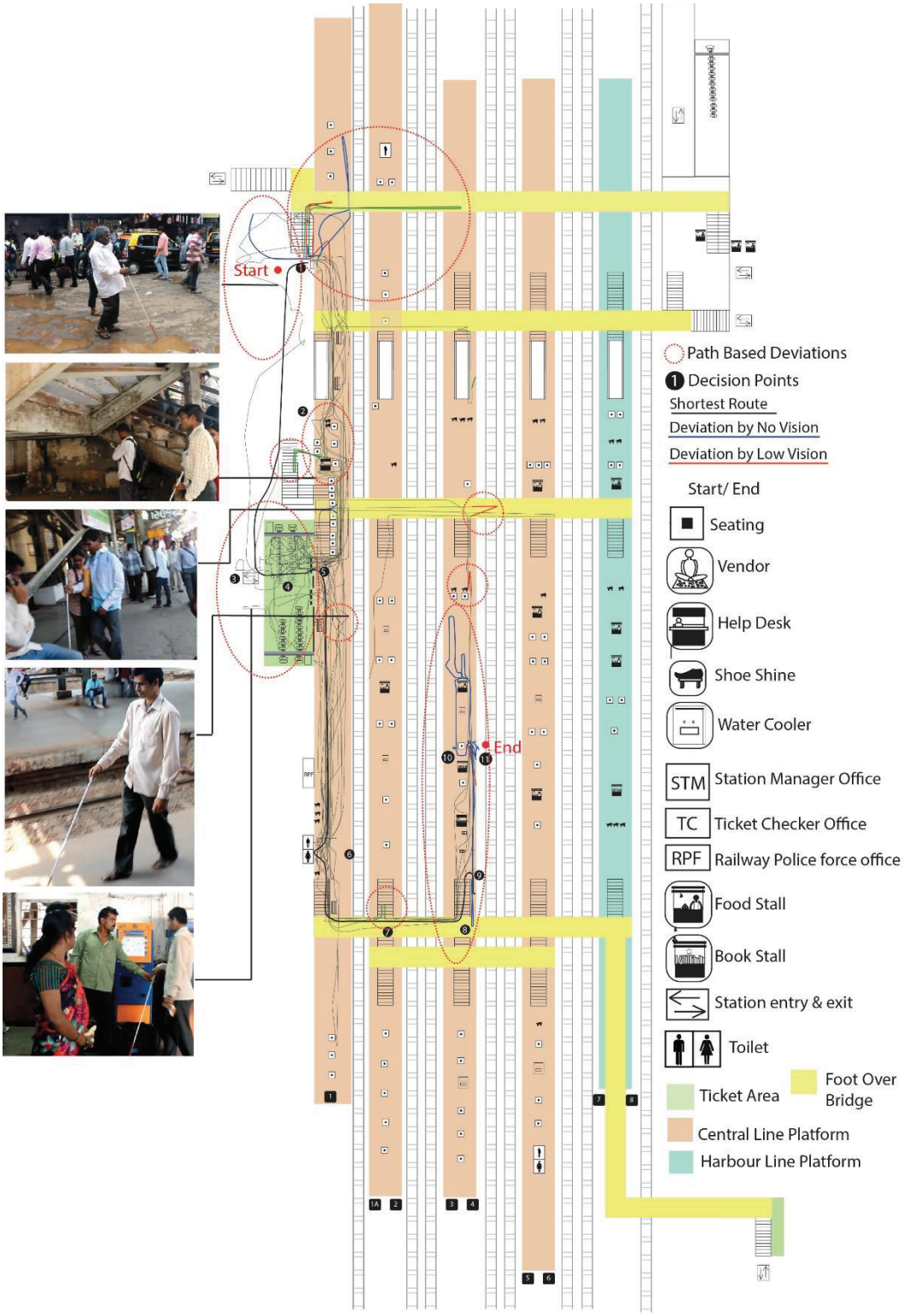


Figure 4.20 A section of a behavioural map of all participants highlights paths where participants with no vision have made navigation-based deviations on the platform, at the station entrance, and inside the ticket hall.

There is a pressing need for tactile boundaries to differentiate between combined middle platforms and establish safe tactile walking paths on all platforms, free from overhead, mid-level and ground-level obstacles, to ensure the safety of individuals with visual impairments. There is a need to install non-visual wayfinding support to enable commuters with no vision to detect entry for a coach for people with disabilities accurately. Additionally, multi-sensory wayfinding support, particularly at decision points, is essential to guide unfamiliar station commuters, regardless of vision, for wayfinding in the station efficiently and safely.

4.10.3 Halt

Halts are the point of confusion in path selection and identification of spatial elements, services, and facilities. From Table 4.10, we can infer that halts were made in the entire wayfinding journey for all wayfinding tasks except for coach entry. The average of total halts made by all participants is 1.6. The average numbers of halts are 0.8, 2.3 and 1.7 for participants with no vision, with low vision and with sight, respectively. Familiarity with the station reduces halts (Unfamiliar- 2.1; partial familiar 1.6 and fully familiar-0.2).

Table 4.10 An average number of halts made by participants across all levels of vision for each wayfinding task.

Halt	N	Ticket hall entry	Ticket window	Ticket Hall exit	Toilet	Platform	Waiting area	Coach entry	Total
All	22	0.3	0.1	0.1	0.4	0.4	0.3	0.0	1.6
No Vision	6	0.2	0	0	0.3	0.3	0	0	0.8
Low Vision	6	0.5	0	0.3	0.3	0.3	0.8	0	2.3
Sighted	10	0.2	0.2	0.1	0.6	0.4	0.1	0.1	1.7

The difference in the average total number of halts made by each participant group varies across wayfinding tasks. Against the assumption, the low-vision group made more halts for almost all tasks compared to the no-vision group. Unexpectedly, despite having full vision, the

average number of halts for the participants with sight is higher than the low-vision and no-vision group while locating the toilet and platform.

Let us investigate the reasons behind the halts observed among different participant groups during various tasks. Similar to deviations, halts predominantly occurred at decision points with multiple path possibilities (Figure 4.21). It is essential to consider such intersections when designing a sign system (Zheng et al., 2007). The reasons for halts include: 1) Identifying individuals whom participants feel comfortable asking for help with a specific task and waiting for assistance when requested. 2) Confusion arising from assistance received from passersby. 3) Assessing the location or identification of station facilities, such as toilets. 4) Determining the correct direction to proceed. 5) Searching for wayfinding signs.

Let us discuss some of the important wayfinding encounters by the participants to substantiate the reasons mentioned above for halting behaviour. Participants with low vision frequently paused to confirm the precise location or to ensure accurate identification of specific facilities, such as toilets and ticket windows, as part of the protocol. This is because the presence of a foul smell emanating from the toilet did not assist in accurately identifying the entrance to the female toilet stall. The participant with low vision also expressed confusion regarding whether the unpleasant odour originated from the male or female toilet. Consequently, another low-vision participant mistook the dimly lit area of the booking office for the toilet stall, as depicted in Figure 4.22. Other low-vision participants paused near the toilets because they could not discern the exact entry point due to the absence of non-visual signs or accessible visual signage. Such points of confusion highlight that the wayfinding ability and needs of low-vision commuters were not included in the signage system and the design of entry to various facilities such as the booking office and the toilet.

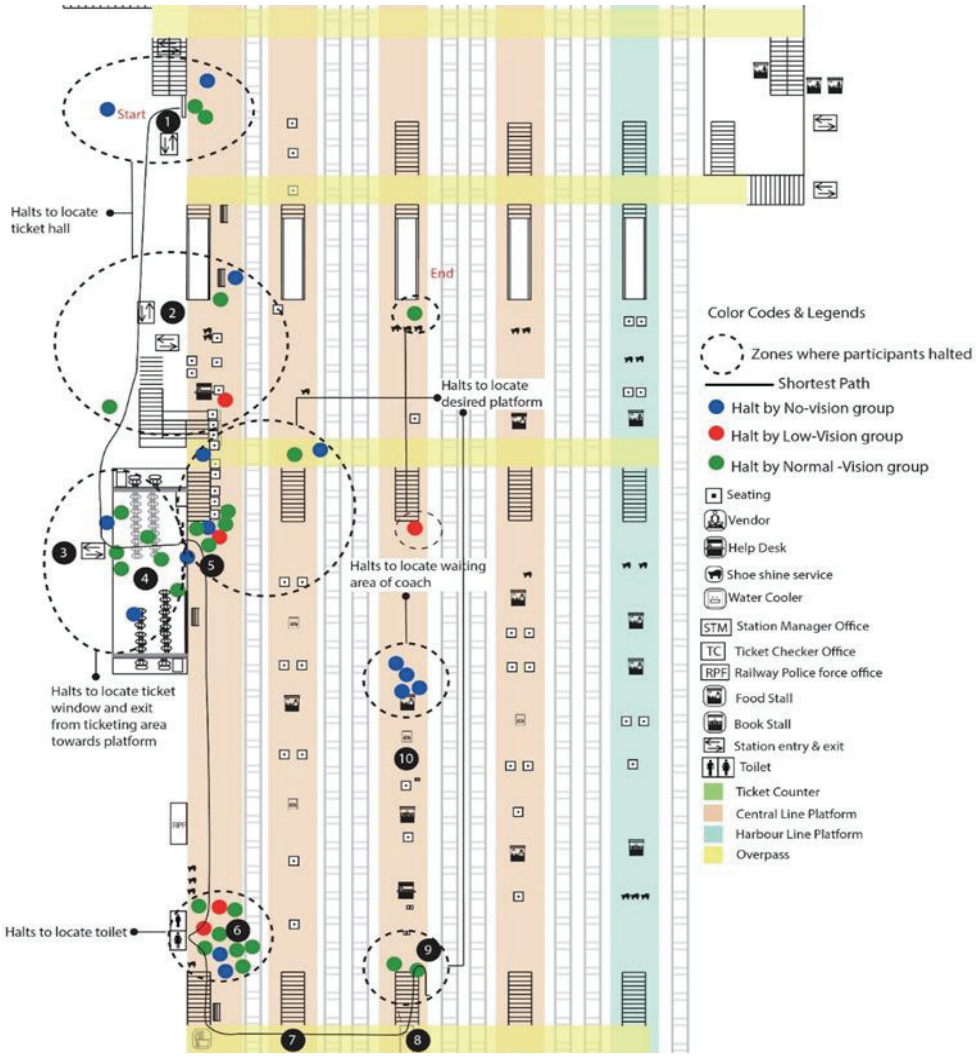


Figure 4.21 Section of a behavioural map of all participants, highlighting zones where they have halted while performing all the assigned wayfinding tasks.



Figure 4.22 A participant with low vision detected the ticket booking office as a toilet stall.

Participants frequently took pauses to locate individuals from whom they felt comfortable seeking assistance. For example, unfamiliar female commuters would momentarily stop to identify other female commuters in the crowd, specifically to ask for directions to the restroom to circumvent potential embarrassment. This practice aligns with Indian cultural norms, where women generally avoid asking men for directions to the restroom. In Figure 4.23 a,b, an unfamiliar female participant with low vision asks for help locating the toilet. She shared her experience, *"I had to ask a man, I am feeling very bad".*



Figure 4.23 a,b A female participant with low vision asking help from men to locate the toilet.

Further, participants with VI had great difficulty in understanding the help provided by the passersby. They halted at several spots on the station as they were confused. A participant with no vision shared his experience: *"I was confused by the help given by the public. That is why I stopped at several places."*

The above results and findings from the halt behaviour highlight the need for directional and orientational information at important decision points that help people, independent of the level of vision, to locate station zones, facilities and services on the railway station. The signage system has to be designed to consider the wayfinding needs and abilities of people with vision impairments. Further, their implementation must be devised so that different user groups thoroughly test it. The built environmental fixtures, such as facilities and services, must be designed and tested for visibility by low vision. Further, their implementation needs to be thoroughly tested by different user groups. The built environmental fixtures, such as facilities and services, must be designed and tested for visibility by low vision. Further, there is a need to strengthen social wayfinding and railway help desk services, enabling people to seek help

from the gender of their choice. Awareness must be created among general commuters, and help desk services must be provided to guide commuters with vision impairment.

4.10.4 Obstacles and Hazards

Obstacles are anything that blocks or impedes progress or movement. Obstacles can manifest in physical objects, architectural elements or human beings. Some obstacles are hazardous and, upon physical contact, pose risks of injury, harm, accidents, or even fatalities.

Obstacles were primarily observed in the wayfinding of participants with no vision, as indicated in Table 4.11. Moreover, these obstacles were encountered in various station zones, including the immediate station exterior, inside the ticket hall, on foot overbridges, and platforms. The walkthrough study identified three main physical obstacles: 1) Unlevelled Road and floor conditions, 2) Unmarked edges at floor transition, and 3) Obstructions.

Table 4.11 Frequency of physical obstacles faced by No Vision (NV) and Low Vision (LV) participants at different station locations.

Participant No.	Immediate station exterior	Ticket hall	Platform	Foot Over Bridge
NV 1	1	0	0	0
NV 2	0	1	1	0
NV 3	0	1	1	1
NV 4	0	0	2	0
NV 5	1	2	1	0
LV 1	0	0	1	0

(i) Unlevelled Road and floor conditions

Participants faced challenging road conditions at the station entrance, as illustrated in Figures 4.24 a,b,c. The entrance to Kurla station was observed to be muddy, riddled with potholes, and scattered with large rocks and pebbles. Because the surface was not paved, participants with vision impairments encountered significant difficulties navigating with their canes. Additionally, two participants with no vision appeared

utterly disoriented at the station entrance, likely due to the presence of large rocks. The quotes from the participants of the study substantiated the same:

NV (34): *"The floor conditions were terrible in Kurla Station. At some places, the flooring was muddy, and at the staircase and platform, the floor was broken. If a blind person steps on such a floor space, he/she may fall".*

NV (33): *"Platform no. 4 was not leveled."*



Figure 4.24 a,b,c Poor road condition at the immediate station building exterior, creating hardship for participants with no vision to walk safely.

Floor markings were missing at transitional points like platform edges, steps, ramps, and staircase edges, as illustrated in figures 4.34 to 4.36. Simply relying on a cane does not provide adequate assistance in preventing falls when there are no non-visual cues at these transitions. Participants were alerted about such floor transitions by the intervention of the researcher.



Figure 4.25 a,b,c Absence of tactile floor markings at edges of ramps, staircases, and platforms as a warning sign to alert them about the floor transitions.

(iii) Obstructions

During the walkthrough, architectural elements and people around were identified as obstructions. Potential head injuries can result from colliding with overhead obstacles, and relying solely on a cane might not adequately prevent collisions with such hazards. These obstacles are commonly encountered, like those positioned beneath staircases and girders within railway stations. In the study, two participants—one with no vision and another with low vision—were observed walking towards girders installed on the platform, as seen in Figure 4.26 a,b. They were alerted to such obstacles by the intervention of the researcher. People such as general commuters, cobblers, vendors, etc., sitting on the floor also obstructed people with no vision during their walkthrough (Figure 4.27).

To facilitate safe navigation within the station during wayfinding, it is crucial to maintain well-paved entrances and interior floors. Regular upkeep and repairs are necessary to address any damages promptly. Tactile warning signs should mark floor transitions, and the walking paths inside the station should be obstacle-free with easily distinguishable floor



Figure 4.26 Situation of head collision of participants with vision impairment with backside of staircase and girder on platform.

finishes. Additionally, all physical obstacles should be uniformly colour-coded for visibility especially for those with low vision, to indicate potential collision hazards.



Figure 4.27 People sitting on the floor serve as obstacles in the navigation of a participant with no vision.

4.10.5 Help Asked & Received

Social interaction, i.e. seeking and receiving assistance from fellow commuters, proved to be paramount for individuals with limited familiarity with the station and

commuting system. As depicted in Figure 4.28, the average frequency of assistance sought and received by all participants is illustrated. It can be discerned from the graph that commuters in Mumbai offer help when requested and sometimes even provide help voluntarily.

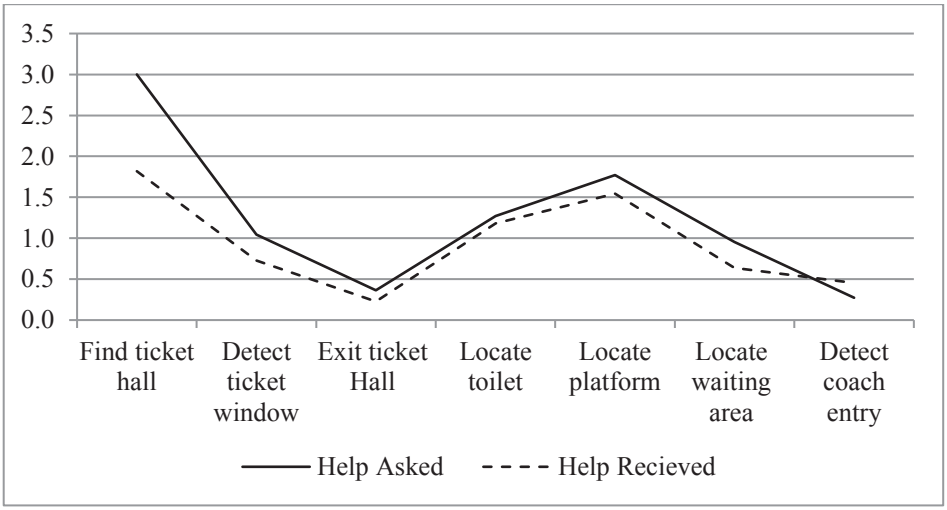


Figure 4.28 Average no. of times help asked & received by participants for all tasks

Table 4.12 highlights the significant reliance on public assistance for wayfinding across participant groups. Participants with no vision requested an average of 18.5 instances of help, notably higher than those with low vision (average 7.2) and participants with sight (average 3.7). Specifically, participants with no vision required more assistance in locating the ticket hall (average 6.5), toilet (average 3), and platform (average 3). Notably, they were voluntarily offered help finding coach entry, potentially due to safety concerns during brief train stops, as seen in Table 4.13.

Table 4.12 An average number of times help was asked for by participants for each task.

Help asked	N	Ticket hall entry	Ticket window	Ticket Hall exit	Toilet	Platform	Waiting area	Coach entry	Total
All	22	3.0	1.0	0.4	1.3	1.8	1.0	0.3	8.7
NV	6	6.5	1.8	1.2	3.0	3.0	2.3	0.7	18.5
LV	6	1.8	0.8	0.2	1.5	1.8	0.8	0.2	7.2

S	10	1.6	0.7	0.0	0.1	1.0	0.2	0.1	3.7

Table 4.13 Average no. of times help recieved by participants for each task.

Help recieved	N	Ticket hall entry	Ticket window	Ticket Hall exit	Toilet	Platform	Waiting area	Coach entry	Total
All	22	1.8	0.7	0.2	1.2	1.5	0.6	0.5	6.6
No Vision	6	3.0	1.0	0.7	2.8	2.5	1.3	1.0	12.3
Low Vision	6	1.8	0.8	0.2	1.3	1.3	0.8	0.3	6.7
Sighted	10	1.1	0.5	0.0	0.1	1.1	0.1	0.2	3.1

We will now discuss the wayfinder's questions asked during the walkthrough to fellow commuters to execute each task. These questions highlight the information they need on the station and the lack of adequate wayfinding support to make them self-reliant.

(i) Wayfinder's Questions Seeking Public Help

Table 4.14 delineates the wayfinding challenges participants encountered in locating the ticket hall. In contrast to the low-vision and sighted groups, participants with no vision required supplementary reassurance to confirm their arrival at the ticketing area.

Table 4.14 Wayfinding questions asked by participants across different levels of vision from other commuters to locate ticketing area (* highlights the participant type asking for help)

1	**Find Ticket Hall**					
	Questions Asked	**Type of Questions**	**Type of Questions**	**Participant Type**		
				NV	**LV**	**S**

1.1	Ticket hall	*Where is the ticket ghar (hall)?*	Direction	*	*	*
		How far is it?	Direction	*		
		Is the ticket ghar this side?	Direction			*
		Is it here?	Direction	*		

Unlike those with low or full sight, participants with no vision required assistance locating and identifying the ticket window without signage. Table 4.15 illustrates that participants, particularly females or those with disabilities, were unsure whether to queue for tickets. Moreover, confusion arose regarding the various ticket types sold at each window and whether separate queues were designated based on gender.

Table 4.15 Wayfinding questions asked by participants across different levels of vision from other commuters to detect ticket windows and buy a ticket (* highlights the participant type asking for help)

2	**Buy ticket**				
	Questions Asked	**Type of Questions**	**Participant Type**		
			NV	**LV**	**S**
2.1	*Where is the ticket window?*	Direction	*		
2.2	*Is this the path to the ticket counter?*	Direction	*		
2.3	*Is this the place to buy a ticket?*	Direction	*		
2.4	*Is there a line?*	Information	*		
2.5	*What is the difference between these two lines? Can we buy a ticket on any station from both the windows?*	Information			*
2.6	*I have to buy the ticket for Chinchpokli, can we stand in this line?*	Information			*

2.7	*Is there a separate queue for ladies to buy a ticket?*	Information			*
2.8	*If ladies go ahead then will the ticket vendor give a ticket?*	Information			*
2.9	*Do they take more money?*	Information			*

In Table 4.16, it is noted that participants without vision were particularly reliant on assistance to locate the ticket hall exit for entering the station building, as there were no tactile or auditory cues available to aid them.

Table 4.16 Wayfinding questions asked by participants across different levels of vision from other commuters to get out of the ticket hall (* highlights the participant type asking for help)

3.	**Get out of Ticket Hall**				
	Questions Asked	**Type of Questions**	**Participant Type**		
			NV	**LV**	**S**
3.1	*What is the route to go out?*	Direction	*		

Insufficient directional cues hindered the ability to locate the restroom beyond immediate perception. Individuals with vision impairment encountered challenges in discerning the entrance to the restroom stall and distinguishing between male and female stalls due to the absence of non-visual signage options. The existing visual signage proved inaccessible to participants with low vision (see Table 4.17).

Table 4.17 Wayfinding questions asked by participants across different levels of vision from other commuters to locate the toilet (* highlights the participant type asking for help)

	Questions Asked	**Type of Questions**	**Participant Type**

			NV	LV	S
4.1	*Where is the toilet?*	Direction	*	*	
4.3	*How far is it?*	Distance	*		
4.2	*Is there a toilet here?*	Identification	*	*	
4.4	*Where is Gent's toilet?*	Identification	*		
4.5	*Where is the lady's toilet?*	Identification		*	

At local train stations, there is a noticeable absence of information regarding the intermediate stops of upcoming trains. Consequently, commuters encounter challenges in discerning the trains and the corresponding platforms for these stops. Moreover, distinguishing between platforms of different train lines, such as Central and Harbour at Kurla Station, proves difficult. This difficulty is compounded for individuals with varying levels of vision impairment, especially those unfamiliar with the station layout, as they struggle to locate the connecting bridge between platforms (see Table 4.18).

Table 4.18 Wayfinding questions asked by participants across different levels of vision from other commuters to locate the platform (* highlights the participant type asking for help)

5.	**Find Platform**				
	Questions Asked	**Type of Questions**	**Participant Type**		
			NV	**LV**	**S**
5.1	*Train for Chinchpokli will come on which platform?*	Information	*	*	*
5.2	*Will the train for Chinchpokli go from this platform?*	Identification			*
5.3	*Will both trains from platforms 3 and 4 go to Chinchpokli?*	Information			*
5.4	*Is this platform of a central line?*	Identification			*

5.5	*Where is platform no. 1?*	Direction	*		
5.6	*Where is platform no. 4?*	Direction	*		
5.7	*Are they platforms 3 and 4?*	Identification	*		
5.8	*Is this platform no. 4?*	Identification	*	*	
5.9	*This is which platform?*	Identification	*		
5.10	*Where is the platform no. written in this ticket?*	Information			*
5.11	*Should I need this bridge to reach platform no. 4?*	Orientation			*
5.12	*Where is the bridge?*	Direction	*	*	

In Table 4.19, it is noted that, individuals with visual impairments requested assistance from the public to navigate to the designated waiting area on the platform for the reserved coach for people with disabilities. This was necessary due to the malfunctioning of audio beepers during specific periods, or when they were operational, the sound was insufficiently audible to guide them from a distance to the waiting area on the platform.

Table 4.19 Wayfinding questions asked by participants across different levels of vision from other commuters to locate the waiting area on the platform (* highlights the participant type asking for help)

6.	**Find a waiting area on the platform**				
	Questions asked	**Type of Questions**	**Participant Type**		
			NV	**LV**	**S**
6.1	*Where is the handicap coach location?*	Direction	*	*	
6.2	*Is this handicap coach location?*	Identification	*	*	

In Table 4.20, it is noted that participants at all levels of vision found it challenging to identify the train bound for Chinchpokli station, as no information was available for this intermediate stop at the railway station. Neither public announcements nor train indicators displayed the en route station stops for upcoming trains on the platform. Furthermore, participants with no vision requested confirmation of coach entry reserved for people with disabilities due to the absence of non-visual cues.

Table 4.20 Wayfinding questions asked by participants across different levels of vision from other commuters to locate the waiting area on the platform (* highlights the participant type asking for help)

7.	**Find the route to coach entry**				
	Questions Asked	**Type of Questions**	**Participant Type**		
			NV	**LV**	**S**
7.1	*Will this train go to Chinchpokli?*	Identification	*	*	*
7.2	*In how much time the train will come*	Information	*	*	*
7.3	*Will this train go in this direction?*	Identification			*
7.4	*Is there a handicap coach here?*	Identification	*		

From the tables, it is inferred that public help was inevitable for all wayfinding tasks in the absence of adequate wayfinding support, not just for the VI group but also for those with sight. Help was mostly asked for direction prompts followed by information and identification purposes. Participants with vision impairments required greater information depth compared to those with sight.

We will not delve into the experiences shared by the participants regarding seeking public help during the walkthrough study.

(i) Perception of Participants on receiving public help

a. Gender Dynamics

Participants encountered challenges in accessing public assistance, particularly in relation to gender dynamics. As highlighted in section 4.10.3, gender significantly influences navigation, particularly for female participants tasked with locating and identifying female restrooms in the Indian social context. Female participants with visual impairments found it especially challenging to distinguish women in crowds when seeking help. This difficulty is vividly expressed in the following quote from a female participant with low vision. LV (21), *"I was looking for a lady commuter, who could help me properly to locate the toilet"*.

b. Use of Cane to signal disability

Cane is used for low- vision, not for navigation but to serve the purpose of signaling their visual impairment, thereby enabling them to receive assistance from fellow commuters. Additionally, the use of a cane facilitates obtaining tickets from the window without having to wait in line, in accordance with station regulations. These were illustrated in the following quotes of participants with low vision:

LV (23), *"I opened the cane to locate the toilet, looking at the cane some women might help."*
LV (23), *"I opened the stick as this is a rule that disabled can buy the ticket without standing in the queue, so people who are not aware of the rule, fight with us. To avoid the fight, I opened the stick."*

LV (23), *"I don't use stick usually; when I am buying a ticket, then I have to tell them that I am a handicap. Prefers stick when travelling alone."*

c. Probability of receiving help is dependent upon time of the day and crowd behaviour

The likelihood of receiving public assistance in different station zones is influenced by crowd dynamics and time of the day. It is generally more feasible to seek help from fellow commuters waiting in the ticket queue or on the platform in non-peak hours, compared to those

navigating quickly across bridges and platforms for boarding and disembarking from trains. These were illustrated in the following quotes of a participant with low vision:

LV (24), *"It is easy to get help from people near the ticket window as they are waiting in line."*
LV (24), *"It is difficult to get help from people on the bridge. It is easier to get help from people on the platform as they wait for the train and have time. whereas those on the bridge are in a hurry, so it is difficult to ask them for any information."*
LV (24), *"I avoid taking help from ticket vendors, as there is a lot of rush; if one asks them, they answer back in a very rude manner.*

c. Effectiveness of Public Help is dependent on to whom and how it is provided

During the wayfinding study involving twenty-two participants, we observed that commuters at the station primarily utilized six types of responses to assist:

Type 1: Offering verbal information (Figure 4.29 a,b)
Type 2: Indicating directions with hand gestures (Figure 4.30, 4.31)
Type 3: Setting aside the cane to avoid collision with the obstacles (Figure 4.32)
Type 4: Gently touching the hand or shoulder of PVIs to show direction (Figure 4.33, 4.34)
Type 5: Holding their hand or arm and walking with them as escorts (Figure 4.35, 4.36)
Type 6: Offering their shoulder for guidance as escorts (Figure 4.37)



Figure 4.29a,b Verbal help provided by commuters on station to participants with low vision (Type 1)



Figure 4.30 Gesture of Hand Direction used to give help by a passerby to a participant with no vision (Type 1, 2)



Figure 4.31 Verbal help with hand pointing in the direction of the ticket hall, the help provided by the passerby to a participant with sight (Type 1, 2)



Figure 4.32 Commuters around directed the cane of a participant with no vision towards the ticketing area and to avoid obstacles (Type 3)



Figure 4.33 Gesture of Hand Support used to give help by a passerby to a participant with no vision (Type 4)



Figure 4.34 Gesture of Hand Support used to give help by a toilet caretaker to a participant with no vision (Type 4)



Figure 4.35 An unknown commuter with VI voluntarily escorted a participant with no vision towards the ticket hall (Type 5)



Figure 4.36 Unknown children present at station voluntarily escorted a participant with no vision towards the ticket hall (Type 5)



Figure 4.37 A person with no vision offering help to another no-vision commuter (Type 6)

Type 1 and 2 gestures were demonstrated for all participants independent of the level of vision, especially if the nature of the help is for information. Type 2 gesture is used primarily if the seeker, independent of the level of vision, asks for route directions. Type 3,4,5 and 6 gestures were used explicitly by sighted commuters to extend help to participants with vision impairment. Type 3 and 4 gestures are used voluntarily to free the way of people with vision impairments from physical and human obstructions. Type 5 and 6 gestures are used by sighted commuters to physically escort people with vision impairments from points A to B inside the station building.

Verbal guidance (Type 1) suffices for individuals without vision when seeking general wayfinding information, but when specific directions are requested, gestures from sighted commuters (type 2) are ineffective. Verbal commands such as "go ahead," "turn right," or "turn left" can be confusing, as they don't clarify whether they refer to the perspective of the helper or the seeker. These were illustrated in the following quotes of two participants with no vision & low vision:

NV (34)*: "I was confused with the help the public gave. That is why I stopped at several places. I was not confident about whether I would reach the goal or not. Difficulty in understanding help given by the public further adds to the stress level."*

LV (21): *"I had difficulty in understanding help from the public, especially while taking help for the ticket hall."*

LV (22): "*Some people help, but it is not a help for us. People give directions which we don't understand."*

LV (22)*: "I used the hand direction to confirm direction because it becomes very confusing".*

Type 3 and 4 marginally help people with no vision to avoid obstructions. Type 5 is an improved form of help as, in this case, a helper volunteers to escort the seeker to the desired destination. However, the ideal gesture of giving help is Type 6, which only peers with vision impairments or personal escorts use. All other general commuters lack awareness of Type 6 forms of help. Participants with VI found a way to overcome this challenge by using hand gestures to confirm the direction provided by the sighted commuters, as seen in Figure 4.38. Further language differences and pronunciations created additional challenges in understanding verbal help from other commuters. This was illustrated in the following quote of a participant with no vision:

NV (34): *"I was confused with the help given by the public, which is why I halted at several places. Difficulty in understanding help given by the public further added to my stress level. People gave verbal commands like go ahead, turn left and turn right. Since we are blind, we cannot understand their hand directions; we show our hand, and they tell us to use it. We*

use our hands to confirm direction. We had difficulty understanding people's voices; sometimes there are language differences".

Based on the observations above and responses from the study participants, it can be concluded that guidance provided by general commuters has limitations, particularly for individuals with vision impairments. Effective guidance in wayfinding primarily comes from physical escorting by fellow commuters. Verbal and gestural assistance, while offered with good intentions, is less effective, especially when providing directions for those with no vision. There is a need to create awareness among general commuters about how to guide people with vision impairments.



Figure 4.38 A participant with no vision used the hand gestures to confirm the help provided by the sighted commuters of type 2.

4.10.6 Time

The time taken to complete the entire wayfinding protocol varied significantly across participant groups with different levels of vision. On average, participants with no vision, low vision, and sight took 14.29 minutes, 11.08 minutes, and 6.92 minutes, respectively. Notably, participants with low vision took longer to complete tasks such as locating the ticket hall, toilet, and platform than those with no vision, as shown in Table 4.21. Despite assistance from other commuters, participants with no vision generally took more time for other wayfinding activities. However, participants with low vision had the advantage of residual vision, enabling

them to be more self-reliant, mainly as seen for halts (section 4.10.4) and seeking public assistance (section 4.10.5), compared to those with no vision.

Table 4.21 Average time (in minutes) taken by participants for each task.

Halt	N	Ticket hall entry	Ticket window	Ticket Hall exit	Toilet	Platform	Waiting area	Coach entry	Total
All	22	2.30	0.45	0.44	1.92	2.47	0.65	0.24	8.48
NV	6	3.69	1.07	1.95	1.76	2.89	2.68	0.26	14.29
LV	6	2.54	0.63	0.58	2.85	3.36	0.91	0.21	11.08
S	10	2.16	0.34	0.36	1.37	1.94	0.49	0.27	6.92

4.10.7 Sensory Cue

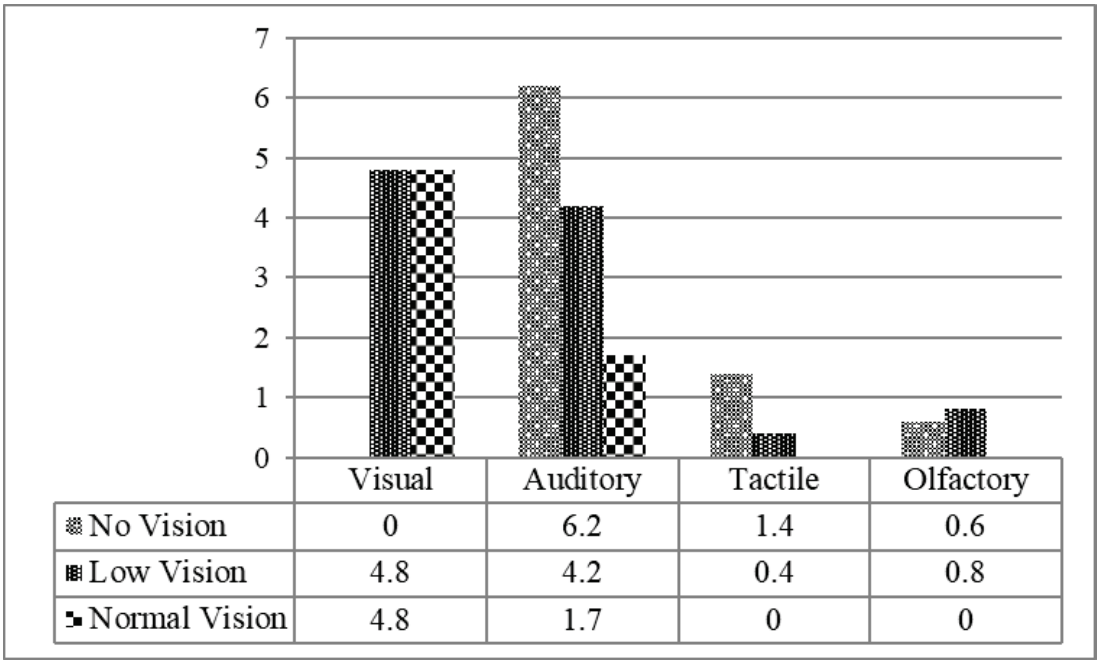
Sensory cues serve as landmarks for navigating spaces, allowing individuals to orient themselves. These cues are ingrained through personal experiences, triggering memories of similar settings. This study examines the role of sensory cues in guiding wayfinding decisions. By qualitatively analyzing how individuals utilize various sensory modalities during their journey, insights are gained into how people perceive and interpret their surroundings (Passini et al., 1988). Furthermore, the study delves into the challenges and constraints of relying on sensory cues within built environments. The findings of the walkthrough are presented in this section, focusing on the utilization of sensory modalities by different participant groups, the purpose of their use, and the difficulties encountered.

This section reports the use of sensory modalities based on the interviews conducted by the participants immediately after the walkthrough.

a. Use of Sensory modality

Figure 4.39 explains the average of no. of sensory cues used by different participants. These average values exclude help provided by commuters and railway staff and signage used. From the table below, the following inferences can be made: Participants with no vision gather

the highest no. of sensory cues (ave 7.33) followed by low vision (ave. 7.17) and sighted (ave 6.80). Participants with no vision gather the highest no. of units of information using auditory modality (ave 6.2) in comparison to low vision (ave. 4.2) and sighted group (1.7) when compared to all other sensory modalities of visual, tactile and olfactory. Participants with low vision and sighted equally rely on vision modality for spatial information with an average of 4.8 respectively. Unlike PVIs, sighted participants solely rely on visual and auditory modalities for spatial information.



	Visual	Auditory	Tactile	Olfactory
No Vision	0	6.2	1.4	0.6
Low Vision	4.8	4.2	0.4	0.8
Normal Vision	4.8	1.7	0	0

Figure 4.39 The mean value of the average of no. of sensory cues using different senses by participant groups.

Purpose of Use of Sensory Cues

We can explore how many sensory cues each participant utilized for various wayfinding objectives. As discussed in section 3.7.1 of chapter 3, wayfinding decisions encompass diverse purposes, including a) Identifying spatial elements and features, b) Determining direction, c) Navigating without deviation, d) Avoiding obstacles and hazards, e) Orienting oneself, and f) Obtaining information.

Table 4.22 delineates the utilization of sensory cues by participants for these distinct purposes. Analysis reveals that sensory cues predominantly facilitate the identification of spatial zones, facilities, and services (64%). However, minimal cues are employed for other wayfinding objectives, such as direction (19.5%), safe navigation (11.5%), and maintaining a straight path and orientation, averaging around 2.7%. Sensory cues are more useful for identification purposes because of the proximity. This highlights the participants' challenges in using spatial references for diverse wayfinding decisions. Furthermore, the table highlights the areas where bolstering the wayfinding support system is imperative.

Table 4.22 Percentage of sensory cues used by participants for different purposes: a) identification of spatial elements and features, b) finding direction, c) Walking without deviation, d) avoiding obstacles and possible hazards, e) orientation, f) Information

Purpose of cues	**Code**	**no. of cues used**	**% of cues used**
Identification	a	23	64%
Direction	b	7	19.5%
Walking without deviation	c	1	2.7%
Safe Navigation	d	4	11.1%
Orientation	e	1	2.7%
Information	f	0	0

Next, we will delve into using sensory modalities for different purposes. Sensory cues in this study are discussed under the categorisation, i.e., social, spatial, and object-based cues.

1.10.7.1 Auditory

As depicted in Table 4.23, individuals with visual impairments (PVIs) utilized auditory cues to discern spatial information through their sense of hearing. The efficacy of these auditory cues depends on the volume of the sound. A sufficiently loud sound aids in guiding individuals towards a destination from a considerable distance. Conversely, a lower intensity allows for identifying or detecting objects, architectural elements, or individuals within proximity. In the walkthrough study, participants with vision impairments employed social and object-oriented auditory cues.

Table 4.23 Participant’s use of auditory cues to gather various kinds of spatial information (category of use: a. identification of spatial zones, facilities and services and b. direction d.

safe navigation by No vision (NV), Low Vision (LV), Sighted (S) (* highlights the user group using the cue)

Type of cue	Cue	Purpose of Use	Code	NV	LV	S
Social	The noise level of the public	To reach ticket window	b	*	-	-
		To walk away from the platform edge	d	*	-	-
	Sound of public footsteps	to detect the staircase	a	*	*	-
Object	Beep sound of the CCTV camera	to identify ticket hall entry/exit point	a	*	*	-

In a bustling ticket hall, two visually impaired individuals navigated the queue with the help of crowd noise. While on the platform, they relied on the sound of the crowd to gauge their distance from the edge but remained vulnerable to falling onto the tracks. The footsteps of people on stairs signaled the footbridge (Figure 4.40). Additionally, a faint sound from a CCTV camera marked the entry/exit point, showcasing the ability to discern subtle auditory cues in a noisy environment. This was illustrated in the following quotes of a participant with low vision with partial familiarity with the station building.

LV (25): *"When I was getting out of the ticket hall, there was sound coming at the ticket hall door. The sound is very mild. That sound helped me to take the turn to get out of the ticket hall. It became a landmark for me."*



Figure 4.40 Figure 4.40 Commuters climbing and getting from the staircase are considered auditory markers to detect the stairs or ramp of the bridge by participants with vision impairments.

1.10.7.2 Tactile Cues

specifically, encompass sensory information perceived through touch, specifically by the hands and feet. These cues provide details about the immediate surroundings within one's physical reach. Primarily relied upon by individuals without vision, tactile cues serve as vital aids for navigation. Table 4.24 elucidates the tactile cues identified by participants experiencing vision impairment.

Table 4.24 Participants using tactile cues to gather various kinds of spatial information (category of use: a= identification of spatial elements and features, b=finding direction) (* highlights the user group using the cue)

Type of Cue	Cue	Reasons for Use	Code	NV	LV	S
Spatial	Pole	To identify train coach reserved for people with disabilities	a	*	*	-
Spatial	Window	To detect the ticket window	a	*	-	-
Object	Help desk	To detect the location of the waiting area on the platform for coach reserved for people with disabilities	a,b	*	-	-
Spatial	Book stall		a,b	*	-	-

The positioning of the pole installed at the entrance of the coach served as a key indicator to distinguish whether it was designated for people with disabilities or not. Specifically, this identification relied on corner poles for wheelchair access in the reserved coach, as depicted in Figure 4.41, while all other coaches featured centrally located poles, as shown in Figure 4.42. This unique detail in pole placement has become a crucial marker for commuters with visual impairments who are familiar with local train travel and those unable to access visual signage on the exterior of the handicap coach. However, relying on this cue also presents limitations, as it often results in time being lost in identifying the appropriate coach.



Figure 4.41 The corner pole is used as a tactile cue to differentiate coaches for people with disabilities from other coaches.



Figure 4.42 Middle pole at the center of the Ladies' coach entry (whatshot.in (2021)

Participants familiar with station building reported how, over the years, they had memorized the station zones with repeated use. This was illustrated in the following quotes of one such participant.

NV (31): *"There is a help desk and then a book stall ahead; after that, there is a pole. Near the pole, there is a handicap coach. The bookstall is made of plywood and has an angle, which helps locate the coach's location. These references help balance and maintain the right track."* (Figure 4.43 a,b,c,d).

These tactile cues were developed because the sound of the beeper was not audible when the waiting spot of the handicap coach was located away from the bridge. The cues developed were fixed and permanent so that they could be repeatedly used in the future for path direction and identification of desired locations.



Figure 4.43 a,b,c,d The participant with no vision found his way on the platform using tactile cues from the help desk and book stall.

1.10.7.3 Olfactory Cues

Participants with vision impairment utilized olfactory cues to perceive spatial information using their sense of smell. These cues aided in identifying spatial elements, individuals, and objects, as well as in determining the type of environment from a distance.

However, they did not guide individuals with vision impairment directly to the exact location. During the walkthrough at Kurla station, only two olfactory cues were reported by participants as helpful in wayfinding as seen in Table 4.25.

Table 4.25 Participants use olfactory cues to gather various kinds of spatial information (category of use: a= identification of spatial elements and features) (* highlights the participant type using the cue)

Type of Cue	**Cue**	**Reasons for Use**	**Code**	**NV**	**LV**	**S**
Spatial	Bad smell	Indicate toilet is close by	a	*	*	-
Object	The smell of boot polish	To detect cobblers nearby	a	*	-	-

Olfactory cues played a pivotal role in guiding individuals from a distance towards the source emitting the smell, but they did not facilitate precise detection. This was illustrated in the following quotes from an unfamiliar low-vision participant.

LV (24): *"I could smell the toilet. The smell does not indicate the exact location of the toilet. The smell can also come from another platform."*

Cobblers served as a very important source of verbal wayfinding information to all commuters. They sat at multiple locations on the station. For a familiar participant with no vision, their presence helped in memorizing the paths. They were detected by the smell of the boot polish and the sound emitted from their brush while polishing the shoe (Figure 4.43).



Figure 4.43 Participant with low vision seeking help from a cobbler to locate the toilet.

4.10.7.4 Visual Cues

In the study, we found that out of all the sensory cues utilized in wayfinding performance, the majority, totaling 14 distinct cues, were visual. These cues were extensively utilized by both participants with low vision and sight, as indicated in Table 4.26.

Table 4.26 Percentage of participants using visual cues to gather various kinds of spatial information (category of use: a= identification of spatial elements and features, b=finding direction, d=safe navigation, e=orientation) (* highlights the participant type using the cue)

Type of Cue	Visual Cues	Reasons for Use	Code	NV	LV	S
Social	Public queue	Indicate ticket window	a	-	*	*
	Group of ladies on the platform	To detect location of the coach reserved for people with disabilities	a	-	*	-
		to detect waiting area of general coach	a	-	*	*

	Amount of rush inside a train coach	distinguish between 1st class and general coach	a	-	-	*
	Crowd movement	to detect the staircase of the bridge	b	-	*	-
		to get inside the reserved coach for people with disabilities	b	-	*	-
	Caretaker	helped to detect toilet	a	-	*	-
Spatial	Door	detected as a toilet stall	a	-	*	-
		triggered the memory of a door of a ticket hall visited in the past	a	-	*	*
	Window Design	helped to detect ticket hall	a	-	-	*
	Shop signs outside the station	to detect station east and west side	e	-	-	*
	Building design	helped to detect ticket hall	a	-	-	*
	Change in light	detect ticket hall interiors	a	*	-	-
	Shadow of the roof of the platform	To walk safely on the platform	d	-	*	-
	Voids in the wall of the bridge	to detect the turn for the desired platform on foot over bridge	b	*	*	-
	Ladies coach	as a landmark for ladies' toilet	a	-	*	-
Object	ATVM machine	helped to detect ticket hall	a	-	-	*

(i) Social cues: Various visual cues from the body language of individuals were relied upon to navigate through different pathways. Participants with low vision and sighted gathered spatial

information through social cues. For instance, observing a public queue aided in identifying the ticket window when there was no marked ticketing area or windows accessible to individuals with low vision (see Figure 4.44).



Figure 4.44 Commuters waiting in the queue for tickets were considered as a reference guide to reach the ticket window directly by participants with low vision and sight.

Similarly, a group of women on the platform assisted in recognizing the waiting area for the female coach when there was no discernible signage system for coach identification tailored for individuals with low vision (see Figure 4.45).



Figure 4.45 The presence of a group of ladies standing on the platform helped to identify the waiting area of the female coach by participants with low vision.

The sighted participants utilized social cues to make several wayfinding decisions. Familiar ones recognized unmarked zones as secondary waiting spots for general coaches on the platform. Additionally, they memorized the general coach order concerning the ladies' coach, which had a designated waiting area on the platform. Those with some familiarity with the commuting system differentiated between first-class and second-class coaches based on the density of commuters. They observed that second-class general coaches were overcrowded, while first-class coaches were less populated due to the significant difference in ticket fares (Figure 4.46 a,b).



Figure 4.46 a,b Variation in the crowd density for first-class and second-class coaches helps to differentiate them.

(ii) Spatial cues: Participants utilized various spatial cues that ultimately proved ineffective in facilitating correct decision-making. These cues triggered associations with past encounters at different station buildings. For instance, darkness was mistakenly interpreted as a toilet stall. Additionally, a particular window design, reminiscent of ticket windows from other stations, led two sighted participants astray, culminating in discovering a nonfunctional ticket window. Furthermore, the building's design and colour triggered memories of a similar structure used for purchasing tickets. This can be illustrated with a quote from a partially familiar sighted participant:

S (17): *"When I looked outside the station, there was a blue structure. I thought it would be a ticket hall, but it was a temple, so I returned. Generally, the ticket hall is located outside. Since the blue structure is close hence, I went outside the station".*

Participants with vision impairment utilize light and shadows as spatial cues, enabling them to discern changes in their surroundings. Variations in light conditions assist in identifying different spatial zones. The following quotes illustrate this:

NV (35): *"...I could sense the change in lighting conditions from the station immediately outside to the ticket hallway environment. Ticket hallway was dark"* (Figure 4.47).

LV (23*): "...when I was walking on the platform, I could make out the difference in light, due to the absence of a rooftop."*



Figure 4.47 A participant with no vision detects the ticketing with the help of a change in lighting conditions from exterior to interior.

(iii) Object cues: The visibility of the ATVM machine on the platform facilitated the easy identification of the ticket hall from afar (refer to Figure 4.48). Additionally, the presence of shop signs outside the railway station aided in distinguishing between the east and west sides of the station for sighted individuals, especially in the absence of other visual cues.

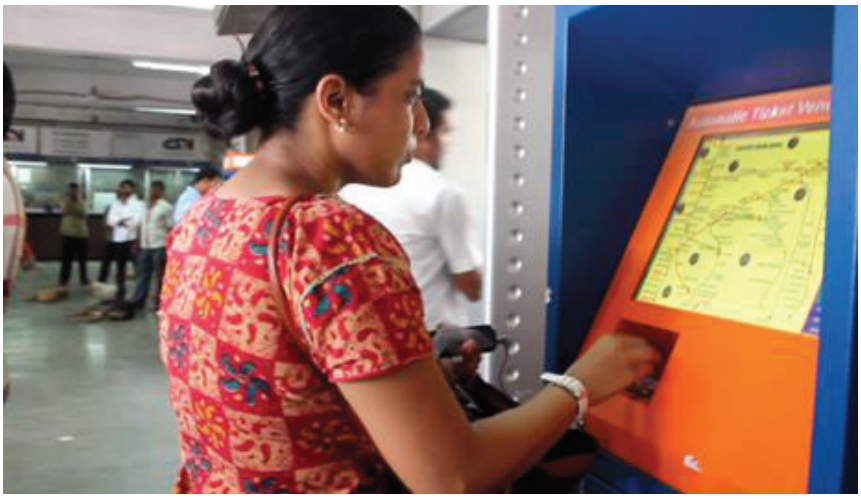


Figure 4.48 A sighted participant used the ATVM machine to buy the ticket.

White Cane use

The cane is vital for individuals with vision impairment, offering auditory and tactile feedback (Jenkins et al., 2015; McIntyre, 2011). Its versatility extends to various functions, such as identifying objects or locations, maintaining direction, and detecting obstacles along the path.

1. *Identify landmarks:* During wayfinding tasks, participants with no vision rely on their cane to locate landmarks like poles on platforms, which serve as cues for nearby staircases. Remembering the position of these poles aids in estimating distances and reaching desired destinations.
2. *Detect floor transitions:* At railway stations, poles positioned at regular platform intervals guide no-vision individuals to navigate safely away from platform edges. Additionally, the cane helps detect small steps or staircases, reducing the risk of falls in areas lacking warning signs, as stated in section 4.10.4 (ii)
3. *Detect Floor conditions:* Moreover, the cane facilitates awareness of floor conditions, including depressions and elevations, and assists in walking straight by using walls as reference points. as stated in section 4.10.4 (i).
4. *Shorelining:* By tapping their cane against walls, they establish directional cues, marking each interruption in contact as a choice point in their journey, as seen in Figure 4.50.

5. *Self- Identification:* Cane is also used by low vision to signal disability, to invite the attention of other commuters to provide help and buy tickets without standing in queue as stated in section 4.10.5 (ii)

This section presents the walkthrough findings, focusing on the utilization of sensory modalities by different participant groups, the purposes of their usage, and the difficulties encountered. It sheds light on how individuals with and without vision impairment gather spatial knowledge using their senses and navigate within their limitations. The study highlights opportunities for enhancing the design of spatial, service, and signage systems to cater to the diverse abilities and perceptions of individuals with varying levels of vision. Improvements are suggested, particularly in direction, orientation, information, and safety, as participants often rely on limited sensory cues for such purposes.



Figure 4.49 A participant with no vision used a cane to detect the edge of the bridge and walk straight.

Participants with vision impairments exhibited the highest utilization of sensory cues compared to other groups, compensating for losing their dominant sense. Auditory cues were trendy among those without vision due to the bustling sounds in semi-open station environments. There is an opportunity to enhance the use of tactile and olfactory cues through

the conscious design of sensory plugins to aid in wayfinding decisions. Additionally, the study indicates a need to improve visual signage systems to be more inclusive to individuals with low vision, given the high reliance of this group on visual cues.

4.10.8 Wayfinding Aids

This section outlines the wayfinding information system, encompassing digital and physical signage and human assistance services to aid commuters within the station. Presently, the majority of station signages are visual. However, the study scrutinized three specific signage types utilized by individuals with vision impairment during their walkthrough of the entire station: Public Announcements and beepers as auditory signs and floor surface indicators as tactile signs. Additionally, help desk services, manned by railway staff, are stationed at various locations within the railway buildings of the Mumbai Rail Commuting System to assist commuters with any queries related to commuting.

Participants in the study were asked to evaluate the usefulness of the provided wayfinding support system by the Railways during their station walkthrough, using a 3-point Likert scale: 1 = not useful, 2 = somewhat useful, 3 = very useful. Sixteen information sources provided as part of the wayfinding system design of the station were reported to be used in the study by the participants. However, the average no. of information sources used by the participant groups was quite low, i.e. No vision (0.8), Low vision (1.2), and Sighted (3.2). Figure 4.50 represents the percentage of participants who had used diverse wayfinding information during the walkthrough. Figure 4.51 represents the average of the ratings provided by participants who used the information sources as part of the wayfinding support system on the 3-point usefulness scale.

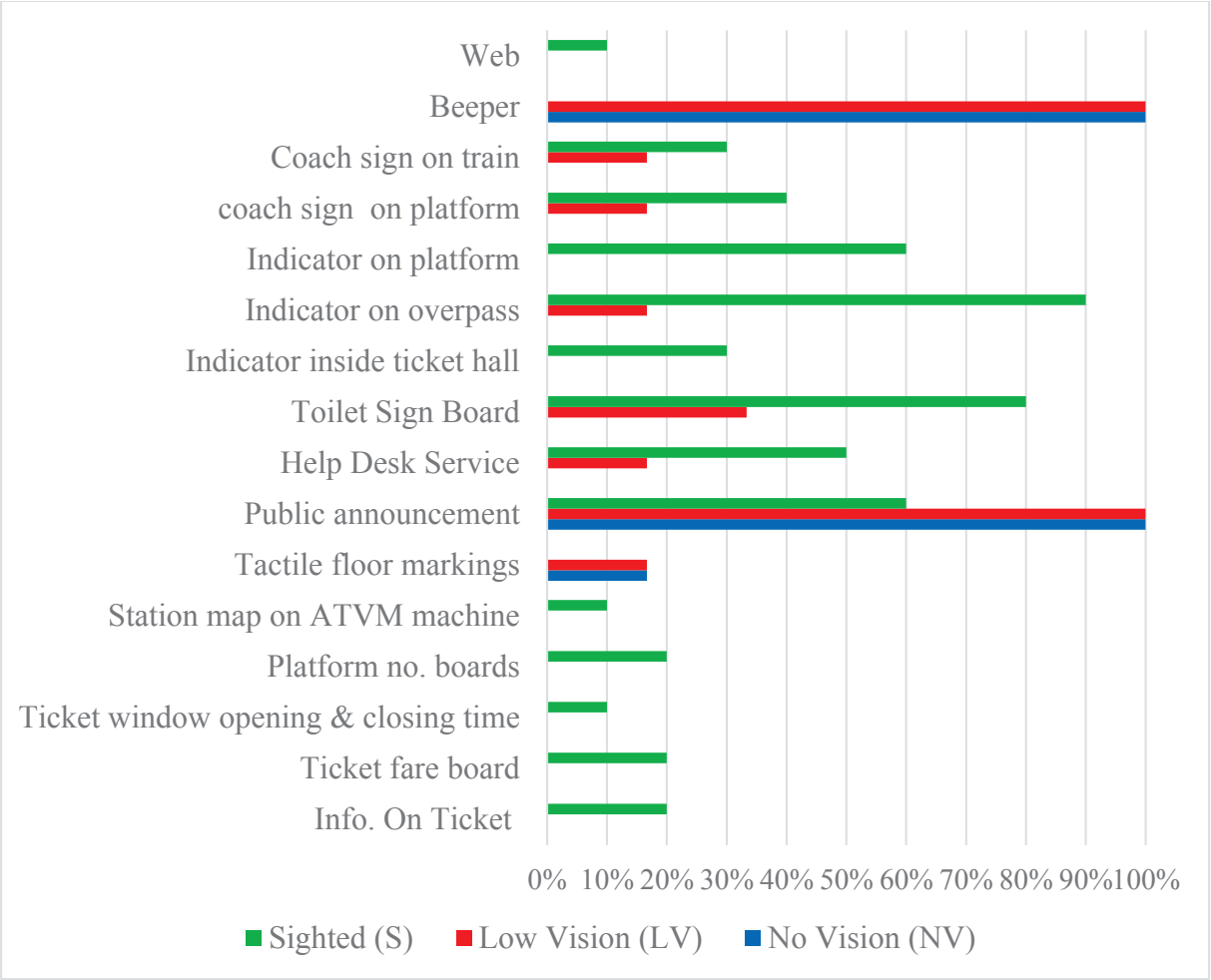


Figure 4.50 Percentage of participants reported the use of information sources as part of the wayfinding information system provided by Railways (No vision (n=6); Low Vision (n=6); Sighted (n=10))

According to Figures 4.50 and 4.51, the wayfinding support system was predominantly utilized by sighted individuals, consistent with expectations due to its non-multisensory nature. Among this group, the usage was primarily observed for train indicators inside the station and toilet sign boards. However, other informational resources, including web-based information, were scarcely utilized by sighted participants during the walkthrough. Interestingly, the current visual signage system saw minimal engagement from participants with low vision. For instance, participants with low vision notably underused the visual coach identification signage. Surprisingly, low-vision participants who utilized the visual coach identification signage found it more beneficial than their sighted participants.

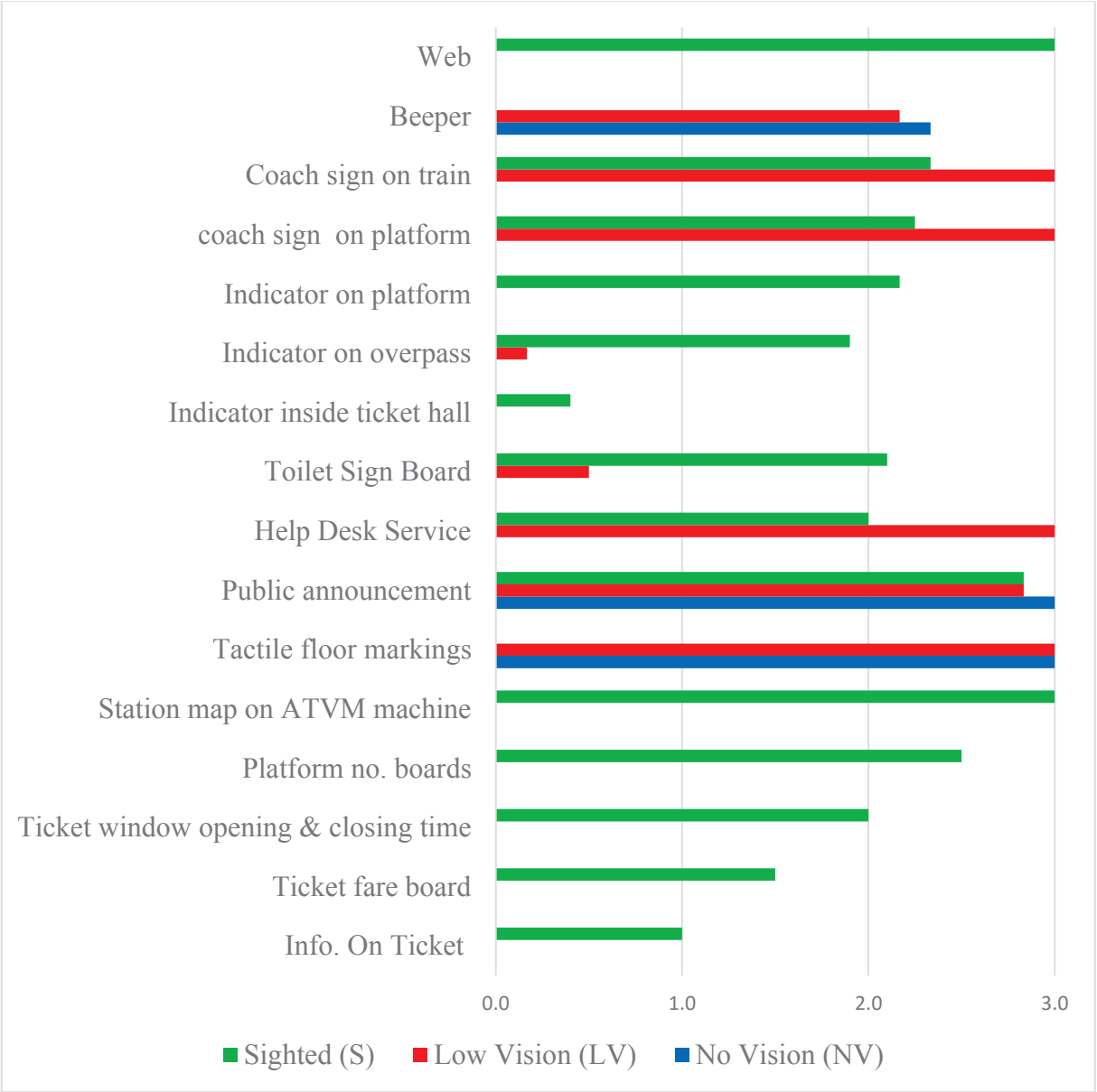


Figure 4.51 Figure 4.52 Average of ratings given by the participants on the use of diverse information sources used as part of the wayfinding information system provided by Railways (No vision (n=6); Low Vision (n=6); Sighted (n=10)) on a Likert scale: 1= not useful, 2= somewhat useful, 3=very useful.

Tactile floor markings were utilized by only twenty per cent of participants with vision impairments, yet those who did use them found them helpful. Conversely, all participants with

vision impairments used auditory signage, such as beepers and public announcements during the walkthrough, indicating their utility.

The sighted participants predominantly utilized help desk services, while those with low vision made minimal use. Individuals without vision did not utilize help desks due to the absence of non-visual identification signals. Additionally, the shifting placement of help desks within the station challenged individuals without vision to memorize their locations. Unfamiliar commuters often lacked awareness of the purpose of the help desk, while regular commuters used the desk for seating when no staff were present.

Auditory announcements such as beepers and public announcements were rated very useful by people with vision impairments and utilized by all participants.

Partial and unfamiliar participants did not find the coach guidance system on the platform and trains particularly helpful. They reported that the size of the signboards on the platform was too small. Additionally, the signage for the second-class ladies' coach was not legible enough. Moreover, the second-class general coach lacked any signboard on the platform, making it challenging for unfamiliar participants to predict the waiting area. One participant suggested that distant signage, beyond perceptual access, should be accompanied by additional orientation signs on the platform to guide commuters towards the waiting area.

A sighted, partially familiar participant points out, *"Signs painted on the train were not so helpful. I can identify the coach once the train stops on the platform. The signs are flat painted; hence, these are difficult to read while standing on the platform. If the sign is at an angle, then it is easy to read. When the train moves, I cannot see the sign."*

Another unfamiliar-sighted participant noted that platform number boards installed on the platform were not within visual range upon arrival from the foot overbridge, leading to confusion about the direction to the waiting area. Similarly, another partially familiar-sighted participant observed that the toilet sign was not positioned appropriately within the visual field.

Familiarity with the station reduced the use of signage, and unfamiliarity increased dependency on the public for wayfinding information. As a sighted familiar participant pointed out, *" I ignored signage as I was aware of the route. When I was new, I used to ask people. That was more comfortable as signage was sometimes confusing"*. A familiar participant suggested that railways should use colour intelligently to give wayfinding information.

From the above discussion, we can infer that auditory signage is perceived as very useful by participants with vision impairment. In summary, the visual signs were underutilized by sighted participants due to design concerns. Further, visual signage is not designed for people with low vision. The role of help desk services on the station needs to be strengthened for effective wayfinding.

4.11 Conclusion

During the data analysis, significant differences and similarities emerged among the three participant groups regarding their wayfinding performance, shedding light on how individuals interacted with the railway station environment and how various factors influenced their experience and performance.

Table 4.27 provides a comprehensive overview of the performance measures for all three participant groups. The findings indicate that while all participants, including sighted ones, encountered wayfinding challenges, individuals with vision impairments faced more pronounced difficulties, as anticipated (as also identified in an earlier study reported in Chapter 3). Compared to sighted, participants with no vision performed less favorably across most performance measures, including errors, deviations, obstacles encountered, and time taken.

Notably, participants with low vision exhibited a higher average number of errors and halts compared to those with no vision. This discrepancy can be attributed to the low-vision group's greater self-reliance and reduced dependence on assistance from fellow commuters. Conversely, participants with no vision relied more heavily on human assistance, particularly escorting, resulting in fewer wayfinding errors, halts, and overall time spent navigating the station (as also identified in an earlier study reported in Chapter 3). However, despite receiving assistance and possessing varying degrees of familiarity with the commuting system, individuals with no vision still faced challenges not fully compensated for by their reliance on human assistance.

Furthermore, sighted participants also demonstrated instances of wayfinding errors, deviations, and halts and utilized fewer wayfinding aids provided by the Railways at the station. This comprehensive evaluation of the wayfinding performance of participants with different levels of vision highlights the limitations of the current wayfinding support available at the railway station.

Table 4.27 Average of occurrences of wayfinding performance measures (HA-Help Asked, HR-Help Received)

Overall Average	Error	Deviation	Halt	Obstacles	Time	HA	HR	Wayfinding Aids	Sensory Cues
No Vision (NV)	2.00	4.83	0.83	3.17	14.29	18.50	12.33	0.81	7.33
Low Vision (LV)	2.67	3.17	2.33	0.17	11.08	7.17	6.67	1.19	7.17
Normal Vision (NM)	1.20	0.60	1.70	0.00	6.92	3.70	3.10	3.19	6.80

Let us discuss the wayfinding performance of the participants for each performance measure.

(i) Error: A thoroughly familiar-sighted commuter made no error in wayfinding. However, if the access to vision is partial or none, all thoroughly familiar participants will tend to make errors. Participants experienced wayfinding errors for three main reasons. Firstly, the architectural differences among stations, including variations in spatial layouts and numerous decision points to navigate station zones such as ticket halls and toilets, caused confusion in finding the shortest route. Secondly, the lack of perceptual accessibility, compounded by the absence of directional, orientational, and station-related information in a single sensory format—most notably visual—further complicated the navigation process. Without non-visual aids to designate station zones, facilities, and services, individuals with no vision often relied on public assistance to confirm their location, leading to a dependency on external help. Thirdly, the reliance on public assistance increased the likelihood of wayfinding errors, particularly if the assistance provided was misunderstood or incorrect as also pointed out in Chapter 3.

(ii) Deviation: The no. of deviations increases with the decrease in the level of vision. However, partial familiarity with the station did not reduce the deviations across all levels of vision. Only full familiarity with the station correlated with reduced deviations for all participants, regardless of their level of vision. Path-based deviations were frequently observed at decision points where multiple paths were possible, leading to confusion among all participant groups. Public assistance emerged as a crucial resource for navigating the correct path, particularly in complex environments like railway stations. Locating the coach entry emerged in particular, a challenging task for participants with no vision, consistent with findings from previous study reported in Chapter 3.

Navigation-based deviations, characterized by veering, were predominantly observed among participants with no vision, especially in areas of the station lacking clear edges for orientation, such as station entries, ticket halls, and middle platforms. Middle platforms were identified as the most hazardous spatial zone for all commuters, particularly those with visual impairments as also pointed out in Chapter 3.

Interestingly, deviations were not observed on foot over bridges, which provide distinct edges for walking. The residual vision of the low-vision group seemed to aid them in walking without veering. Additionally, the station architecture, with its grid pattern and right-angle intersections between bridges and platforms, facilitated orientation, as noted in prior research studies (Vision Australia, 2006; Rousek et al., 2010; Li & Klippel, 2012).

(iii) Halts: Only full familiarity with the station led to no halting during wayfinding across all levels of vision. Sighted participants exhibited a higher average number of halts than those without vision. This difference can be attributed to the greater independence of the former two groups in wayfinding, whereas the latter group relied more on assistance from other commuters, particularly as escorts. Similar to deviations, halts primarily occurred at decision points where multiple path options were available, underscoring the importance of considering these intersections when designing a sign system. The reasons for halts varied and included: 1) Identifying individuals whom participants felt comfortable asking for help and waiting for assistance when requested. 2) Confusion arising from assistance provided by passersby. 3) Assessing the location or identification of station facilities, such as toilets. 4) Determining the correct direction to proceed. 5) Searching for wayfinding signs. All the aspects were also pointed out in Chapter 3

(iv) Obstacles: Obstacles were primarily observed during the walkthrough of participants with no vision. The walkthrough study identified three main obstacles: 1) Unlevelled Road and floor conditions, 2) Unmarked edges at floor transition, and 3) Obstructions (as also discussed in the earlier study reported in Chapter 3).

(v) Help Asked & Received: Seeking and receiving help from fellow commuters emerged as crucial for individuals with limited familiarity with the station and commuting system, regardless of their level of vision. Unfamiliar participants with no vision depend on the public

for assistance four times more than unfamiliar-sighted participants. However, the dependency on the public for assistance did not change between partial and unfamiliar participants, irrespective of the level of vision change. Fully familiar sighted commuters tend to assist in the wayfinding activity of other commuters, especially in potentially unsafe situations, as discussed in Chapter 3. The participants with no vision, females and elderly, received significantly more help than others. Directional guidance is the most commonly sought form of help, followed by information and orientation, by participants across all vision levels. Notably, participants with no vision often required additional reassurance to confirm their arrival at the intended destination within the station, indicating their need for more detailed information compared to sighted participants.

As discussed in the study presented in Chapter 3, in social wayfinding, factors such as physical appearance, gender, occupation, and demeanor play a crucial role in instilling confidence and a sense of safety in the information provided by strangers. In this study we specifically highlight the role of gender in social wayfinding. Female participants exhibited a preference for seeking help from other female commuters, regardless of their vision status. This behaviour was consistently observed among all female participants, reflecting a sense of comfort and security in seeking assistance from other female commuters. However, identifying female commuters amidst the crowded environment posed a challenge for female participants with vision impairments. This highlights the pressing need to have a choice to seek wayfinding support, especially escorting from the preferred gender.

Crowd dynamics and the time of day also influenced the probability of receiving public assistance in different station zones. Assistance was more readily available from commuters waiting in ticket queues or on platforms during non-peak hours compared to rush hours. This point highlights the limitations of social wayfinding in peak-hours when most help, especially in the form of escorting is desired especially by those with no-vision with unfamiliarity. Commuters including Rail staff lack the awareness and etiquette to extend help particularly those with vision impairments.

(vi)Time: The duration of the walkthrough is influenced by both the distance covered and the level of performance across all measures. Time correlates with the frequency of errors, deviations, and halts. However, practical assistance when requested and the usability of signage and sensory cues can mitigate these factors, leading to time savings. The study revealed that

fully familiar sighted participants took the least time to perform wayfinding tasks compared to participants with low vision and no vision as expected. However, the difference in time taken between partial and unfamiliar commuters was insignificant across all levels of vision.

(vii)Sensory Cues: Participants with no vision demonstrate using the highest no. of sensory cues compared to other user groups, indicating their thorough exploration of the environment. Unlike low-vision and sighted participants, who predominantly rely on visual cues (as noted in a previous study outlined in Chapter 3), the no-vision group heavily utilizes the auditory modality during wayfinding. Analysis indicates that sensory cues primarily aid in identifying spatial zones, facilities, and services, with limited utilization for other wayfinding objectives such as direction, safe navigation, and maintaining orientation. This highlights the pressing need to enhance design support for all aspects of wayfinding. Tactile and auditory cues assist in both identification and direction, while olfactory cues aid in identification. Visual cues are beneficial for various purposes including direction, identification, and marginally for orientation and safe navigation, particularly for individuals with low vision.

In addition to environmental sensing and safe navigation, individuals with low vision uniquely utilize their cane to signal their visual impairment to sighted commuters, seeking assistance and averting collisions, as also highlighted in a previous study outlined in Chapter 3. Additionally, using a cane facilitated obtaining tickets from the window without having to wait in line, in accordance with station regulations to avoid quarrels with sighted commuters and ticket vendors. This highlights the need for creating awareness at ticket windows among sighted commuters of special provisions for ticket purchase for people with disabilities. Further, a need to increase the visibility of people with vision impairments in crowds.

(viii)Wayfinding aids: Mumbai Suburban Railway station signages are primarily visual, designed considering daily sighted commuters as intended viewers. There is a potential to include low-vision commuters in the re-design of the visual signages. Only two auditory signages, i.e. public announcements and auditory beepers, were available for individuals with visual impairments, which were rated highly beneficial by the participants. Tactile floor markings were present at a few places but proved to be effective when utilized. At the same time, sighted participants found visual signage somewhat helpful, while others with low vision rated toilet signboards and train indicators as not applicable. Only the train coach identification

system designed for the reserved coach for people with disabilities was perceivable by participants with low vision. Interestingly, help desk services were underutilized by all commuters, with unfamiliar sighted participants mistaking them for station police. Additionally, in the absence of non-visual cues, these services went unnoticed by participants with no vision. There is a potential to increase the effectiveness of the help design services on railway stations.

4.11.1 Implications of the performance on participant's experience of wayfinding

Our study showed that wayfinding in a railway station of Mumbai Suburban Railways evoked strong emotional reactions from participants. The intense emotional reactions are linked to specific locations and behaviors, and significant events experienced during the walkthrough study.

Negative emotions stemmed from various factors such as unlevelled road and floor conditions, unmarked edges at floor transition, obstacles, rude behaviour of railway staff and commuters, and inability to understand help provided by sighted commuters. Locations like platform-train interfaces evoke negative emotions like fear of falling on rail tracks, anxiety of finding the coach entry in seconds, confusion of which side the coach will come to, and fear of colliding with architectural elements, people and their belongings. Our findings revealed that participants' heightened anxiety is due to the lack of effective wayfinding visual and non-visual aids that do not enable people to make wayfinding decisions. People with no vision struggle to board the desired coach and face difficulty in maintaining a path on the desired platform when two platforms are joined and locating foot over the bridge from the platform.

Moreover, the persistent sense of exploration within these environments leads to participants' negative responses, indicating a feedback loop wherein the space elicits adverse emotional reactions, exacerbating feelings of confusion and anxiety, thereby amplifying the likelihood of 'being trapped'. This overwhelming feeling is heightened, with unfamiliarity and severity of vision impairment when people climb the wrong foot over a bridge, reach the wrong platform, board the wrong coach, wrong train, or exit the undesired station side.

Further participants faced discomfort by the foul odor coming from the toilets. Female participants with vision impairments were embarrassed of seeking help for toilets from men,

they were highly insecure of revealing their unfamiliarity to men. People with impairment sometimes face rude behaviour from other people when bypassing the queue to buy tickets or when they come in the way of the fast-paced crowd.

The ineffective use of gestures and verbal commands by sighted commuters further contributed to feelings of confusion and stress among participants with vision impairments.

On the other hand, finding landmarks and relying on sensory cues for orientation enhanced positive emotional experiences and comfort during navigation tasks, especially for those familiar with the station and train routes. Effective assistance, such as escorting provided to participants with no vision, elicited feelings of gratitude.

Negative experiences deter individuals from using the commuting system, affecting user retention for public transit systems. Recalling these negative moments overshadows the entire journey, leaving a lasting negative impression of the transit system as a whole.

4.11.2 Implications of Findings

Improving the permeability of existing station infrastructure, train facilities, and services is imperative. This entails a comprehensive overhaul of station interiors, signage, digital and physical services, facilities, and social wayfinding. The findings from error and halt behaviors emphasize the necessity for directional and orientational information at crucial decision points to assist individuals, regardless of their vision level, in locating station zones, facilities, and services. Signage systems must evolve to be more multi-sensory, considering the needs and abilities of those with vision impairments. Further, there is a need to make visual signage systems more inclusive to individuals with low vision, given their reliance on visual cues.

Tactile boundaries are essential to differentiate between combined middle platforms and ensure safe navigation in open-ended areas. Non-visual wayfinding support is crucial for individuals with no vision to accurately detect coach entry points for people with disabilities. Additionally, maintaining well-paved entrances and interior floors, implementing tactile warning signs, seamless train boarding and disembarking, ensuring safe transfers, and provision of obstacle-free walking paths are vital for safe navigation within the station.

Participants with vision impairments demonstrated a heightened reliance on sensory cues, particularly auditory cues, compensating for the loss of their dominant sense. There is an opportunity to enhance tactile and olfactory cues through the deliberate design of sensory aids.

Unlike existing international literature on wayfinding research and design, our study highlights the importance of strengthening social wayfinding within Mumbai Suburban Railways. Enhancing awareness among general commuters about provisions for people with disabilities, promoting etiquettes for offering assistance, creating identification markers for recognition of VI amidst over-crowded environments to safeguard them from collision with other commuters and other architectural details, and improving help desk services and staff training are crucial steps toward fostering effective and safe wayfinding experiences within stations.

The significance of the studies reported in Chapters 3 and 4 lies in their novelty, as there is no previous research on rail transit environments comparing wayfinding experiences of individuals with and without vision impairments. Consequently, the findings hold particular relevance for Indian Railways, disability advocacy groups, NGOs, designers, and architects, informing future initiatives aimed at enhancing accessibility and inclusivity within railway stations.

The study had certain limitations. The performance criteria of distance travelled were not included in the study. Since participants were aware that they were observed and recorded, the presence of the researcher and cameraman may have influenced their performance. The presence of a cameraman may have influenced the behaviour of other commuters towards our study participants, provoking them to extend help. The study's sample size was small as it was challenging to find participants with specific criteria, willing to participate.

Studies presented in Chapters 3 and 4 identified several wayfinding problems, and participant suggestions were consolidated in Appendix D1 and D2. As a next step, it was essential for us to understand how commuters prioritized wayfinding concerns so that their priorities could inform the action plan for improvement of the wayfinding scenario of Mumbai Suburban Railways. It is widely acknowledged in the usability evaluation literature that the severity of the negative impact of a problem is a commonly used criterion for assigning priorities by users. The following study in the forthcoming Chapter discusses the severity assessment of 70 wayfinding problems (from studies presented in Chapters 3 and 4) involving 30 new participants.

Chapter 5 Prioritization of the Wayfinding Problems

5.1 Introduction and Background

Severity assessments enable the prioritization of problems encountered during usability evaluations, thereby guiding the utilization of design resources. Severity assessments guide designers, planners and policymakers on how issues should be addressed. They are typically expressed by ratings provided by evaluators, usability specialists, or users. The reliability of such assessments improves if users are involved, and their assessments are supported by the criteria/ reasoning/ personal experiences. The severity of a usability problem is an assessment of the amount of trouble and inconvenience users experience because of a specific aspect of a system (Hertzum, 2020).

Wayfinding is essential to building usability (Kuliga et al., 2016). Wayfinding is one of the usability problems identified in Preliminary research in Appendix A1 and A2. Severity assessment, a specific step within the process of usability evaluation (Nielsen, 1994; Hertzum, 2006), is used in this study to categorize identified wayfinding problems by their impact level (e.g., critical, moderate, minor) to determine the priority of resource allocation to make MLTCS wayfinding friendly for PVIs. Severity assessments help arrange the problems through a wayfinding problem severity matrix. The matrix typically assigns numerical values to different levels of severity, with higher numbers indicating more severe or critical conditions.

In the context of this inquiry a wayfinding problem severity matrix could be applied to evaluate the impact of each identified wayfinding issue. For instance, the severity rating might range from low to high, represented through numerical values where higher values signify greater severity. This matrix helps prioritize and address problems based on their perceived impact or seriousness.

Till now, we have identified wayfinding challenges and participant suggestions from Preliminary Studies, Chapter 3 and Chapter 4. However, we do not yet know the commuter's perception of how they perceive the wayfinding challenges from the point of view of severity and priority. To build an understanding of the same, a field study was conducted to identify the most critical concerns, either shared or specific to user groups. This study addresses research question no. 3: **What is the *order of priority* of wayfinding problems faced by people with different levels of vision?**

Face-to-face structured interviews were employed as the data collection method, with thirty participants recruited through snowball sampling. Participant subgroups were established based on three levels of vision: No vision, Low Vision, and Sighted, with ten participants selected for each subgroup in this study. The participants recruited in this field study differ from those involved in the field study reported in Chapters 3 and 4. The engagement of new participants in this study confirmed the wayfinding problems identified based on the experiences of an earlier set of participants. Seventy Wayfinding problems were identified in earlier studies. Chapters 3 and 4 were categorized under the following tasks: 1. Station entry & exit 2. Ticket purchase 3. Use of station facilities and services 4. Foot over bridge uses 5. Platform use 6. Train boarding and disembarking 7. Non-specific or General (wayfinding concerns not specific to a single task category). They were evaluated for their severity impact, which was relevant to various participant sub-groups. Among 70 wayfinding problems, there were typical and unique concerns among participant subgroups. Rating and Ranking methods were used to form the matrix of prioritization of wayfinding problems. Additionally, qualitative responses from participants were transcribed to understand the criteria employed for rating and ranking assigned by them. This approach allows researchers to better understand the issues and the rationale behind the participants' assessments. The novelty of this study is the involvement of commuters with vision impairments in the severity assessment process.

The following section builds on a review of past severity assessment studies that deal with problem prioritization.

5.2 Severity Assessment Studies

As per Nielsen (1994), the severity of a usability problem is typically assessed as a composite of three key factors: Impact- Measuring the extent of trouble experienced by affected users. Persistence- Determining how frequently a user encounters the problem. Frequency- Assessing the number of users affected by the problem. Further, Sauro (2013) clearly distinguished between problem frequency and severity. According to him, problem frequency refers to the number of participants who encounter a problem divided by the total number of participants. Problem severity relates to the rating users give based on their perception of the problem's impact.

The literature on usability evaluation features a significant debate regarding whether problem severity is correlated with the number of users encountering a problem (Hertzum, 2006; Sauro, 2014). Most literature concludes that the severity of a problem remains independent of the number of users it is likely to affect (i.e., frequency) (Sauro, 2014). Sauro (2014) stated that six studies provided an average correlation between frequency and severity of r = 0.22 (Fisher transformed values of 0.46 (Virzi, 1990), 0.06 (Lewis, 1994), 0.46 (Virzi, 1992), -0.29 (Hertzum, 2010), 0.46 and 0.10 (Law & Hvannberg, 2004), for each study respectively), suggesting a slight positive relationship between problem frequency and severity. The correlation between frequency and severity results from Sauro's (2014) study was also insignificant (r =0.6). Sauro (2014) further states that there is as much evidence that critical problems happen less frequently, and minor problems occur more frequently. He adds that practitioners should never assume that high-impact problems will necessarily have a high frequency. The severity of a problem is independent of how many users a problem will likely affect (frequency). For example, it could be that 1 out of 10 participants had a problem with an educational website (low frequency and high severity). Furthermore, 9 out of 10 participants in the same study might have been mildly irritated by the website design (high frequency and low severity). To prioritize issues, the frequency and severity of problems should be considered (Sauro, 2013). Benini (2013) elucidates the difference between severity and priority. He explains that the degree of severity is an inherent property of every unmet need and, statistically, is unrelated to the severity of other needs. In contrast, priorities emerge from comparisons among two or more needs. A strong positive correlation between the severity and priority of a specific need across the assessed areas enhances confidence in the assessment.

There is also an ongoing debate about the involvement of user evaluators or both in the usability test. Law & Havnnberg (2004) (also cited in Hertzum, 2010) stated that severity ratings given by evaluators are biased as they are based on their own experiences and intuition. Hertzum (2006) emphasized that severity assessments are influenced by a subset of users who closely resemble the individual evaluators, making them unrepresentative of the entire user population. He further stated that severity impact could be achieved if severity assessments were either derived from user data or made by users rather than evaluators (Hertzum, 2010). Sauro (2014) reported that low reliability is observed between and within evaluators in earlier studies (e.g., Catani & Biers, 1998; Jacobsen et al., 1998; Lesaigle & Biers, 2000). The low level of agreement in the usability specialists' severity assessments during the experimental study indicates a significant need to obtain more reliable severity assessments. Hassenzahl (2000), Law and Havnnberg (2004), Hertzum (2006, 2010), and Sauro (2014) noted that the involvement of users in assessing problem severity has remained largely unexplored thus far, highlighting a significant demand for discovering methods to obtain more dependable and democratic severity assessments than those performed by usability experts. Furthermore, when multiple users assess the severity of reported problems, it is likely to enhance the reliability of severity assessments compared to assessments made by a single evaluator (Nielsen, 1994; Sauro, 2014). Most systems have multiple subgroups of users rather than one homogeneous user group. Caulton (2001) emphasized that in the context of heterogeneous user subgroups, some problems may be encountered with equal probability across subgroups, while others may be unique to specific subgroups. Therefore, it is essential to identify a strong correlation between the severity and frequency of specific problems within a particular subgroup and across different subgroups. If subgroups are carefully handled, the frequency provides some severity information. Thus, subgroups should be a primary consideration in the planning and analysis of evaluations, mainly if frequency data will be used to support severity assessments or substitute for having multiple evaluators assess severity. Subgroups should be considered in the selection of users for usability evaluations. The following section builds on a review of the problem prioritization techniques.

5.2.1 Problem Prioritization Assessment Techniques

Analyzing people's propensity to collaborate during data collection is crucial for selecting assessment techniques. The choice of technique will affect the quality of the collected data. Fabbris (2013) reported five techniques for prioritization and severity assessments- fixed total partitioning, paired comparison, rating, ranking and picking the best/worst. These techniques were reviewed to find their suitability for assessment for p items = 70, which should not consume significant respondents' time or add to their mental fatigue, especially in the case of PVIs. Out of the five techniques, rating and ranking were the most suitable for this study.

(i) Ranking: The method can be applied in different formats to establish a hierarchy of several items *(p)* based on choice sequences, usually without ties. Ties might be permitted if the task is perceived as too challenging for respondents, and the difficulty rises significantly with the number of items *(p)* (Fabbris, 2013). The advantage of this technique is that it forces differentiation. Data collection using the Ranking method is effective if p is small (Benini, 2013).

(v) Rating: The respondent is instructed to assign independent values to each item (i = 1, . . . , p) using either an ordinal (Likert-type) or an interval scale, with the same measurement scale applied to all items. The advantage of this technique is that the degree of differentiation can be expressed on a scale. Further, it is less time-consuming and confusing even if p items are large (Benini, 2013).

Assigning severity ratings helps prioritize resource allocation to address the most critical issues. Over the past few decades, various severity rating systems have been proposed, generally sharing a standard structure: a series of ordered categories indicating the perceived impact of a problem on the user, ranging from minor to primary (Hertzum, 2006). Nielsen (1993) introduced a 5-point scale from cosmetic (0) I disagree that this is a usability problem at all (1) Cosmetic problem only: need not be fixed unless extra time is available on the project (2) Minor usability problem: fixing this should be given low priority (3) Major usability problem: essential to fix, so should be given high priority (4) Usability catastrophe: imperative to fix this before the product can be released. Sauro (2013) proposed a three-level scale, offering ample differentiation in problem severity values. (1) Minor: Causes some hesitation or slight irritation (2) Moderate: Causes occasional task failure for some users; causes delays and moderate irritation (3) Critical: Leads to task failure. Causes user extreme irritation. Further, he

also collected data on users, mentioning an idea, insight, suggestion, or observation that does or could enhance the overall experience. According to him, an effective strategy involves obtaining independent severity ratings from multiple evaluators, determining the agreement, and averaging the ratings. This range of participants, from 5 to 20, increases the chances of detecting a correlation between frequency and severity if one existed.

5.2.2 Review Summary

Severity assessments are used for problem prioritization. They are typically expressed by ratings provided by evaluators, usability specialists or users. As Sauro (2014) and Nielsen (1994) suggested, problem frequency and severity should be tracked. There is either a low or insignificant correlation found between problem frequency and severity in the studies done so far in the field of usability assessments; one of the reasons is that evaluators or usability specialists are involved in the studies, who either assessed based on user observations or intuition. There is an opportunity to study their correlation with user involvement in the severity assessment study, as Hertzum (2006) and Sauro (2014) advocated. Multiple user involvements will increase the reliability of the assessment as compared to individual usability specialists. Heterogeneity among users and severity assessments based on subgroups of users is advocated by Cauton (2001). Ben-Akiva et al. (1994) (cited in Fabbris, 2013) point out that mixed data collection methods in severity assessment provide richer data. Adopting a ranking-based or a picking-the-best/worst technique before a rating may induce the respondents to adopt comparative response logic. Further, mental effort is the least important in data collection techniques like ranking, rating, and picking the best/worst. Rating and picking the best/worst work best when p items are large. Ratings of usability problems are one of the most used methods to categorize usability problems based on their severity of impact (Nielsen, 1994; Hassenzahl, 2000; Hertzum, 2006; Sauro, 2014) and ranking for priority (Benini, 2013). Ordinal rating scales are primarily used in severity assessments with values between 0-4 or 1-4.

From the review of the existing literature, we understood that studies need to engage users in severity assessments. Except for Hertzum (2006), no study has involved the user in the problem prioritization process. The user involvement has been limited to the problem identification stage only. However, their involvement has been advocated by Hertzum (2010)

and Sauro (2014) for better reliability of severity assessment than evaluators or usability specialists. Further, there is a dearth of usability studies that have involved PWDs, such as people with vision impairments, in the severity assessment process of wayfinding. Existing studies fail to explain the criteria, reasoning, and experiences that govern user or usability expert decisions while assigning any value to the p item under assessment. So far, no study has been done on prioritizing wayfinding problems in general and transit environments.

Building on the understanding of how severity assessment leads to problem prioritization and identification of research gaps, a field study was designed based on the learnings provided by the literature review.

5.3 Study Design

This section explains how the field study was designed, conducted and analyzed.

5.3.1 Sample Strategy, Size and Profile

In this study, Mumbai local train commuters are involved in the wayfinding issues and task prioritization advocated by Hertzum (2010) and Sauro (2014). Preliminary data on their background profile was collected before the assessment. Participants were recruited for the study based on the level of vision as a primary criterion, followed by the level of familiarity, gender (male, female) and age (all adults aged 20-60) (Table 5.1). Participant subgroups were established based on three levels of vision: No vision, Low Vision, and Sighted, with ten participants selected for each subgroup in this study. Familiarity level was defined as follows: Novice or rare commuters should have travel frequency of not even once in a month; Occasional commuters should have travel frequency equal to or more than once but less than five times in a month; Regular commuters should have travel frequency equal to or more than five times in a month.

Table 5.1 Average Age, gender, and familiarity with MLTCS of participants' subgroups: No-vision (NV), Low-vision (LV), Sighted (S)

Groups		**Gender**	**Familiarity Level**

	Ave. Age	Male	Female	Rare	Occasional	Regular
NV	35.8	7	3	2	3	5
LV	29.2	5	5	1	2	7
S	29.1	5	5	5	2	3

Table 5.1 shows the participants' distribution per their age and vision variation. The average age of participants with no vision is 35.8. They were in the age group of 22-54. The average age of low-vision participants is 29.2. They were in the age group 19-42. The average age of sighted participants is 29.1. They were in the age group 19-47. The minimum education in the no-vision group was 4th class, and the maximum was masters. In the low vision group, the minimum education was 10th class, and the maximum was masters. In a sighted group, the minimum education was 10th standard, and the maximum was of a participant doing post-doctoral studies. Two participants were late blind; the rest had been blind since birth.

Except for two participants, all other blind participants had mobility training. None of the low-vision commuters has mobility training. They do not prefer to use a cane to hide their disability. One late low vision reported that she is not trained enough to use a cane for outdoor mobility. Five no-vision and three low-vision participants only knew how to read and write in braille.

5.3.1.1 Type of visual impairments among the participants

The participants of the study had various kinds of visual impairments. One participant had a condition called Diabetic Retinopathy. He had a retinal detachment. He has a light perception and is comfortable in daylight vision. He cannot see figures and spaces.

One participant has Night Blindness (nyctalopia). It is an inability to see well at night or in poor light. It is not a disease but rather a symptom of an underlying problem, usually a retina problem. It is common for myopic patients to have some difficulties with night vision, but this is not due to retinal disease but rather to optical issues (Cleaveland Clinic Foundation, 2017). People with night blindness cannot see outside at night under starlight or moonlight or

in dimly lit interior areas such as movie theaters or restaurants (American Optometric Association, 2017).

Four participants have Retinitis Pignemtosa (Loss of Peripheral (side) vision). This condition occurs during childhood or adulthood. Retinitis pigmentosa is a genetically inherited eye disease. Its onset can occur during childhood or adulthood. Its first symptom is usually night blindness. Later, peripheral (side) vision is lost. The inability to see small details can occur in the advanced stages of the disease. It is a slowly progressive disease that can lead to total blindness in some individuals (The Chicago Lighthouse, 2017).

People who lose their peripheral vision cannot distinguish anything to one side or both sides or anything directly above and/or below eye level. Central vision remains, however, making it possible to see directly ahead. Typically, loss of peripheral vision affects mobility. It can slow reading speed if severe because the person can only see a few words. This is sometimes called "tunnel vision" (American Optometric Association, 2017). One participant with no peripheral vision shared that he could read the text in red, black, and dark blue colours against a white background and prefers symbols and words in big fonts.

One participant has a condition called Macular Degeneration. In this condition, the loss of central vision creates a blur or blind spot, but a person's side (peripheral) vision remains. This makes it difficult to read, recognise faces, and distinguish most details at a distance. With side vision intact, however, mobility is usually unaffected (American Optometric Association, 2017). The participant has difficulty reading from a distance. The font size and colour contrast influence readability. He prefers a black background with white text on it.

One participant had a condition called Albinism. There is a lack of normal pigmentation. It can affect eyes with or without affecting skin and hair. People with albinism usually have nystagmus (a shaking movement of their eyes), reduced ability to see small details and difficulty in bright light conditions (The Chicago Lighthouse, 2017).

One participant had a condition called Myopia Nystagmus. He can see both at night and daytime. He can only see very close things. His eyeball shakes, hence, he cannot concentrate while reading.

One participant suffered from a condition called Amblyopia. A condition in which a person's vision does not develop properly in early childhood because the eye and brain do not work together correctly. Amblyopia, which usually affects only one eye, is also known as "lazy eye." A person with amblyopia experiences blurred vision in the affected eye (American

Foundation of the Blind, 2017). The participant suffering from this condition can see things that are very close to her eyes. The participants have 36% blindness. All other participants with low vision had 75% disability. The following section explains how the field study data was collected.

5.3.2 Data collection

All participants signed a consent form in Hindi, English, and Braille. Structured interviews were employed as the data collection method, with thirty participants recruited through snowball sampling. A structured questionnaire was created in Hindi and English, covering seven broad wayfinding task categories: 1. Station entry and exit, 2. Ticket purchase 3. Use of station facilities and services 4. Foot over bridge use 5. Platform use 6. Train boarding and disembarking 7. Non-specific or General (wayfinding concerns not specific to a single task category). These tasks encompassed many wayfinding problems identified in Chapters 3 and 4. In total, 70 wayfinding problems were evaluated for their severity impact, relevant to various participant sub-groups. Participant subgroups were formed for data analysis, as Caulton (2001) advocated. Among 70 wayfinding problems, there were common and unique concerns among participant subgroups (Caulton, 2001) (Table 5.2). Out of 70 issues, 42 (60%, i.e. 42) were common to all three subgroups, 17 (24.28%, i.e. 17) were common among the VI group (no vision & low vision), and 11 (15.71%, i.e. 11) problems were common among participants with low-vision and sighted individuals.

Table 5.2 *p* items in each task category for all users and subgroups No-vision (NV), Low-vision (LV), Sighted (S)

No.	**Task Category**	**No. of *p* items**			
		Total	NV	LV	S
1	Station entry & and exit	8	8	8	6
2	Ticket purchase	6	6	6	5
3	Use of station facilities and services	11	8	7	8
4	Foot over bridge use	5	5	5	2
5	Platform use	13	11	13	8

6	Train to board and disembark	15	12	11	12
7	Nonspecific/ General	12	7	12	12
	Total	**70**	**57**	**62**	**53**

The face-to-face interviews were chosen over telephonic or web methods for data collection due to the inclusion of participants with vision impairments, reducing the burden on participants in terms of time and effort. This approach also enhanced participant comfort, facilitating open sharing of past experiences and influencing rating and ranking measures. Interviews were conducted at participants' homes or workplaces, lasting 1 to 1:30 hours, with meticulous attention to ensuring understanding of issues in the researcher's presence, and all interviews were voice recorded.

Wayfinding issues and task categories were verbally described in a predetermined order. Rating and ranking were selected as data collection techniques based on the nature of the data, i.e., seventy wayfinding problems divided into seven task categories. The study employed the rating and ranking techniques in the following data collection process:

Severity Rating: In the first step, participants were asked to rate the severity of wayfinding problems within each task category. The rating technique enabled an understanding of the absolute severity impact of each problem within its specific context. It was considered suitable for this study due to a significant p-value of 70, making it less time-consuming and mentally taxing (Fabbris, 2013; Benini, 2013). Participants were likely given a 4-point Likert scale to assign severity scores to these problems.

0 - Not a problem for me
1 - Minor: low priority for fixing
2 - Moderate: medium priority for fixing
3 - Critical: high priority for fixing.

The interpretation of the values from 1-3 value is borrowed from the scale developed by Sauro (2013), 0-Not a problem for me, borrowed from the scale developed by Nielsen (1994).

Task Category Ranking: Participants were instructed to rank the wayfinding task categories after becoming familiar with each category and the associated wayfinding problems. In this ranking process, participants were assigned a rank of '1' to the category they considered to have the most severe wayfinding issues. This ranking step helps identify the relative severity of categories and allows for prioritization.

Qualitative Feedback: Participants shared their past experiences that governed their responses throughout the rating. This feedback offers valuable insights into the participants' thought processes, providing context for their ratings.

The frequency of participants who did not encounter problems was documented, in line with Nielsen (1995). This suggests that specific wayfinding issues covered in the questionnaire did not negatively affect specific participants in this study. Furthermore, the frequency of participants unaware of specific wayfinding issues was also considered. Respondents were encouraged to share new wayfinding concerns outside the questionnaire (Benini, 2013). Positive responses regarding currently functioning wayfinding aids and services in the MLTCS were also welcomed during the assessment (Dumas et al., 2014). This data collection process combines quantitative (severity ratings of p item in each task category, category ranking) and qualitative (participant feedback) methods to comprehensively assess and prioritize wayfinding problems in different task categories. This approach allows researchers to better understand the issues and the rationale behind the participants' assessments.

5.3.3 Data Analysis

Ranking data was organized based on subgroups. Weights were assigned to each rank. Rank '1' is the task category with concerns that severely impact the commuter's wayfinding experience. Rank '7' stands for the least essential or manageable task category. The averages were calculated for the weighted rank of each task category and each participant subgroup. The most problematic perceived category had the lowest average compared to the rest. The final ranking order of all task categories was computed based on the averages calculated for 30

participants. Similarly, rating data was also organized based on participant subgroups. Averages were calculated for each wayfinding challenge by the severity impact factor formulated below:

Severity Impact Factor (IF): This factor gauges how significantly commuters are affected by a particular wayfinding concern. It was calculated for each problem using the formula (0 * n0 + 1 * n1 + 2 * n2 + 3 * n3) / (n0 + n1 + n2 + n3), n stands for no. of participants affected by the problem. This approach is consistent with Sauro (2014), Nielsen (1994), and Hertzum (2006). A predefined range for the IF value was used to categorize concerns as mild (0-1), moderate (1.01-2), or critical (2.01-3) in terms of their impact.

*Note: Rating and Ranking values are in the opposite order of severity.

Problem Frequency (PF): This metric assesses the number of participants affected by a specific wayfinding concern, following the methodology proposed by Nielsen (1994). In this case, the number of participants aware of the problem divided by the total number of participants was considered when calculating problem frequency. All concerns in each task category were sorted based on the largest to the smallest value of IF, followed by problem frequency to form a severity matrix. The task categories were arranged based on the lowest to highest average values that emerged from ranking data. The minimum and maximum range of PF is 0-1.

Statistical tests: Pearson correlation coefficient test was performed to measure the linear correlation between problem frequency and severity impact. The same test was also performed to find the correlation between the number of usability problems in each task category and the severity ratings. The inter-rater reliability test, Fleiss Kappa (Fleiss, 1971), was performed on the rating data to find the level of agreement between the raters for each wayfinding problem and the task category. This statistical test is recommended in the literature on inter-rater reliability tests (Lang, 2011; McHugh, 2012).

Qualitative Responses: Participants' direct responses were transcribed and parallelly indexed against different rates assigned to different wayfinding issues. Similarities and dissimilarities in reactions were analyzed. Criteria that govern the assigning of rates were analyzed based on the experiences shared by the participants. The ranking and rating data results are reported with

qualitative data that explains why specific wayfinding issues and task categories are essential to participant sub-groups or across groups.

5.4 Results & Discussion

This section discusses the rating and ranking results, followed by results from statistical tests.

5.4.1 Ranking Results

The weighted ranking system considers every rank assigned by the participants to each of the seven categories. The ranking results followed an expected order: 1) Train boarding and disembarking 2) Platform Use 3) Foot Over Bridge Use 4) General 5) Use of station facilities 6) Station entry & exit 7) Ticket Purchase (Fig 5.3). Overall, train boarding and disembarking was perceived to be the most problematic task category, as expected, because the task category involves wayfinding problems that are life-threatening due to infrastructure design, poor management of crowd, time pressure, lack of information, and less possibility of getting public help being high crowd dynamic movement. The task category was perceived to be the most challenging for participants with no vision compared to those with low vision and those in the sighted group, as expected. This activity is most dangerous to conduct without vision in the current socio-environmental context. Similarly, as expected, wayfinding problems within the platform task category exhibited the second most problematic category for all subgroups. This is because of the high uncertainty associated with which platform to visit, where to wait for the train, which train, and which coach to board. The presence of countless crowds on platforms and inside trains, especially during peak hours, makes these task categories perceived to be most challenging for all participant subgroups.

Ticket purchase, as compared to the other tasks, is considered the least problematic task category as there is no life risk associated with it. The chance of getting help inside the ticket hall is higher than other station parts. The crowd is slow-moving, available to ask for help, and willing to help. In addition to these reasons, the VI group (no vision 6, low vision 5) found ticketing less challenging than the sighted group (rank 2) because the VI user group avoided ticket purchases to save time and anxiety from finding ticket counters inside the station building.

Table 5.3 The average of ranks assigned by all participant groups to all task categories.

No	**Task Category**	**Participant Groups and Ranks**							
		NV	Rank	LV	Rank	S	Rank	**All**	**Rank**
1	Station entry and exit	4.4	4	4.5	4	4.1	2	**4.33**	**6**
2	Ticket purchase	5.4	6	5.7	5	4.1	2	**5.07**	**7**
3	Use of station facilities and services	4.4	4	3.5	2	4.9	5	**4.27**	**5**
4	Foot over bridge use	3.6	3	3.4	1	4	1	**3.67**	**3**
5	Platform use	2.6	2	3.5	2	4.1	2	**3.40**	**2**
6	Train boarding and disembarking	2.3	1	3.9	3	3.3	3	**3.17**	**1**
7	Nonspecific/ General	5.3	5	3.5	2	3.5	4	**4.10**	**4**

5.4.2 Rating Results

Tables 5.4 to 5.10 display the highest problem frequency (PF) and severity impact factor (IF) for each problem within each task category. Further, the tables for different task categories are also arranged in the order in which they are ranked. The most challenging task category, as perceived by participants, is arranged first, followed by the rest. No participants added further wayfinding problems to the list discussed in the questionnaire, indicating that the concerns addressed in this study were comprehensive.

The tables below give the matrix of each task category. The tables are arranged in the order of ranking results. Table for Rank 1, i.e. Train boarding and disembarking (category 6) the most severe and essential task category is kept first followed by rest in the ranking order. Furthermore, the problems in each task category are arranged based on the severity impact factor. Issues with the highest severity impact factor across all user groups are placed first, followed by the rest.

Table 5.4 *p* items with the highest problem frequency (PF) and severity impact factor (IF) in the train boarding and disembarking task category.

Wayfinding Challenges in the Journey Stage		**Problem Frequency (PF) (0-1)**				**Severity Impact Factor (IF)**			
6	**Train Boarding & Disembarking**					**0-1: Minor | 1.1-2: Moderate | 2.1-3: Critical**			
		NV	**LV**	**S**	**PF**	**NV**	**LV**	**S**	**IF**
6.1	Overcrowding general commuters in the coach reserved for PwDs, makes train travel difficult for PwDs.	10	10	0	1.00	2.90	**3.00**	0.00	2.95
6.2	The status of the train and any changes in the train arrival time and platform are not timely updated inside the train nor at the station.	10	9	7	0.87	2.40	2.44	2.86	2.54
6.3	If there is some connection between the motorman cabin and other coaches, then it will be better to detect the train about to start and stop.	10	10	10	1.00	2.20	2.80	2.00	2.33
6.4	There is no information inside trains about upcoming station names, platform directions, time left for the station to arrive, and the name of the platform on which the train is stopped.	10	9	10	0.97	2.30	2.56	2.10	2.31

6.5	There is no information inside the train to detect where the train is standing: signal or platform.	10	0	0	1.00	2.10	0.00	0.00	2.10
6.6	The gap between the platform and the train is unsafe; it creates difficulty climbing and getting down from the train.	10	9	10	0.97	2.60	2.22	1.40	2.07
6.7	Lack of ways to ensure boarding in the queue. As a result, boarding becomes problematic for everyone.	10	10	10	1.00	2.60	1.70	1.80	2.03
6.8	There is no information on the platform to anticipate the handicapped coach entry location of the upcoming train.	9	10	9	0.93	2.78	1.50	1.44	1.89
6.9	Lack of information about mega block date, timing, station and train routes affected the web and the station.	10	7	8	0.83	1.50	2.43	1.50	1.76
6.10	The station has no provisions to help commuters identify and differentiate local trains, such as slow/fast/ intermediate trains, their train lines, and train routes.	10	10	10	1.00	1.10	1.90	2.10	1.70

6.11	Local trains do not have provisions to save people from running trains.	8	10	9	0.90	1.75	0.70	2.44	1.59
6.12	There is no provision to avoid a fall in the gap between two coaches while boarding the coach.	8	9	0	0.85	2.50	0.67	0.00	1.53
6.13	The Pole in the centre of coach entry disrupts quick crowd transfer.	0	0	6	0.60	0.00	0.00	1.33	1.33
6.14	The sign painted on the train coach and installed on the platform does not look the same. Hence, it is difficult to follow them.	0	0	8	0.80	0.00	0.00	0.75	0.75
6.15	Not all train coaches have visual signs on platforms, e.g., Luggage or General coaches.	0	0	8	0.80	0.00	0.00	0.88	0.88
		Average				1.78	1.46	1.37	1.85

Table 5.5 *p* items with the highest problem frequency (PF) and severity impact factor (IF) in the platform use task category.

Wayfinding Challenges in the Journey Stage		**Problem Frequency (PF) (0-1)**				**Severity Impact Factor (IF)**			
5	**Platform Use**					**0-1: Minor | 1.1-2: Moderate | 2.1-3: Critical**			
		NV	LV	S	PF	NV	LV	S	IF

5.1	Beepers are not located on all platforms. Even if they are present, they are often not working or unheard of in peak hours. All these factors create difficulty in detecting waiting area of the reserved coach for PwDs.	10	9	0	0.95	2.80	2.33	0.00	2.58
5.2	The coach signage on the platform does not match the train coaches when trains of different train coach numbers come on the same platform. This creates confusion in both the direction and detection of the coach.	7	7	5	0.63	2.86	1.71	2.80	2.42
5.3	Train Indicators and public announcements are not synchronized.	0	4	6	0.50	0	2.50	2.00	2.20
5.4	There are no direction signs to walk in the right direction on the platform to locate the waiting area for the desired coach for the upcoming train.	10	10	10	1.00	2.20	2.10	1.70	2.00
5.5	Public announcements have limitations like poor audibility in peak hours, especially at platform ends	10	10	10	1.00	2.50	2.00	1.50	2.00
5.6	There are no provisions on the platform to avoid collision with physical	8	8	0	0.80	2.50	1.50	0.00	2.00

	obstacles like walls, poles, furniture, and stalls								
5.7	Lack of information at station entry and inside the ticket hall about the platform directions and numbers of upcoming trains	10	10	10	1.00	1.90	1.80	1.70	1.80
5.8	There are no warning signs on the floor transition from platform to track. As a result, people fall on the track.	10	10	0	1.00	**3.00**	0.60	0.00	1.80
5.9	Difficulty in understanding train indicators due to the use of acronyms. Sometimes, there is a lack of timely updates, or they are not working.	0	8	10	0.90	0	2.00	1.80	1.89
5.10	There is no way to identify platforms based on train lines, local and intercity platforms, slow and fast trains	10	10	9	0.97	1.50	2.00	1.78	1.76
5.11	Platforms have overlapping numbers, or platforms of two train lines have the same numbering system.	8	8	6	0.73	1.50	1.75	1.33	1.55
5.12	While walking on a shared platform, there is no confirmation to maintain walk on the desired platform	9	10	0	0.95	2.11	0.90	0.00	1.47

5.13	There is a lack of timely updates through public announcements on the station whether the train is standing on a platform.	10	10	0	1.00	1.70	1.00	0.00	1.35
		Average				1.89	1.71	1.12	1.91

Table 5.6 *p* items with the highest problem frequency (PF) and the severity impact factor (IF) in the Foot over bridge use task category.

Wayfinding Challenges in the Journey Stage		**Problem Frequency (PF) (0-1)**				**Severity Impact Factor (IF)**			
4	**Foot over bridge use**					**0-1: Minor | 1.1-2: Moderate | 2.1-3: Critical**			
		NV	LV	S	PF	NV	LV	S	IF
4.1	There is a lack of information on what parts of the station each bridge connects before climbing it. As a result, people climb the wrong bridge	10	10	10	1.00	2.7	2.90	2.70	2.77
4.2	While walking on the bridge, people are unaware of each turn leading to different parts of the station.	10	10	0	1.00	2.6	2.60	0.00	2.60
4.3	There are no warning signs at the floor transition between steps to the slope and steps to the floor on the bridge, and as a result, people fall.	10	10	0	1.00	2.1	2.10	0.00	2.10

4.4	There are no walking guidelines for locating the staircase of the bridge from every platform and station entry.	10	10	0	1.00	2.5	1.70	0.00	2.10
4.5	The ramps are very steep. As a result, it isn't easy to use them.	10	9	7	0.87	0.5	1.11	0.71	0.77
		Average				2.08	2.08	0.68	2.07

Table 5.7 *p* items with the highest problem frequency (PF) and the severity impact factor (IF) in Non- stage-specific/ general task category.

Wayfinding Challenges in the Journey Stage		**Problem Frequency (PF) (0-1)**				**Severity Impact Factor (IF)**			
7	**Non-task Specific**					**0-1: Minor | 1.1-2: Moderate | 2.1-3: Critical**			
		NV	LV	S	PF	NV	LV	S	IF
7.1	Lack of awareness of provisions for instant help in case of emergency and security measures in running trains and on station.	9	4	9	0.73	2.89	**3.00**	2.22	2.64
7.2	There is a lack of a mobile service system to assist people with any train and station-related inquiry on mobile phones before reaching the station.	10	10	8	0.93	**3.00**	2.10	1.63	2.29
7.3	Walking surfaces at station entry, bridge and platform are subjected	10	10	10	1.00	2.40	2.20	2.20	2.27

	to elevations, potholes and breakage.								
7.4	The lack of rooftop cover leads to rainwater inside the station and makes walking difficult. Rainwater also comes inside the train, making commuters wet.	7	10	8	0.83	2.29	2.40	2.13	2.23
7.5	Lack of information on the station about the general station, train boarding and ticket rules and special provisions (for people with disabilities, health conditions and senior citizens). This leads to violation of rules and penalties.	10	10	10	1.00	2.10	1.50	2.10	1.90
7.6	Redundant old information boards are not removed from the station; people follow them and get misguided. Such boards add to the visual clutter.	0	1	6	0.35	0.00	**3.00**	1.67	1.86
7.7	The small font size of the information boards inside the station makes them challenging to read from a distance	0	8	10	0.90	0.00	**3.00**	0.90	1.83
7.8	Poor lighting at station entry and exit and other parts of the station, like the staircase and	10	10	9	0.97	1.30	2.10	1.89	1.76

	platforms, create unsafe walking conditions.								
7.9	Lack of good colour contrast on the information sign boards leads to poor readability.	0	9	10	0.95	0.00	2.56	0.80	1.63
7.10	Poor lighting leads to difficulty in reading information boards after sunset.	0	7	9	0.80	0.00	2.00	1.33	1.63
7.11	Information sign boards are challenging to locate due to poor placement	0	4	8	0.60	0.00	2.00	1.25	1.50
7.12	Advertisement posters create visual clutter on the station. As a result, difficulty is faced in locating and reading the train and station-related information.	0	7	10	0.85	0.00	1.14	1.70	1.47
		Average				1.16	2.25	1.65	1.92

Table 5.8 *p* items with the highest problem frequency (PF) and the severity impact factor (IF) in the use of station facilities task category.

Wayfinding Challenges in the Journey Stage		**Problem Frequency (PF) (0-1)**				**Severity Impact Factor (IF)**			
3	**Use of Station Facilities**					**0-1: Minor | 1.1-2: Moderate | 2.1-3: Critical**			
		NV	**LV**	**S**	**PF**	**NV**	**LV**	**S**	**IF**

3.1	There is a lack of information to inform new commuters of what facilities are available at each station (medical facilities, railway police office, ATVM machines, police office, book, water and food stalls) and where they are located.	10	9	9	0.93	2.8	**3.00**	1.56	2.46
3.2	Help desk services are not very effective as service providers are often not on the desk.	3	7	6	0.53	2.67	2.43	1.83	2.25
3.3	Lack of direction to reach the nearest toilet at the station	9	10	9	0.93	2.89	2.20	1.56	2.21
3.4	Help desks are challenging to locate as they are not at critical locations such as platforms and station entry points.	5	6	6	0.57	2.40	2.83	1.17	2.12
3.5	It is difficult to locate the help desk since their location is not fixed.	3	6	5	0.47	**3.00**	2.67	0.80	2.07
3.6	Help desks are very few. As a result, their reach requires a long walk.	5	6	5	0.53	2.20	2.33	1.40	2.00
3.7	The help desk service is unused due to non-visual signs.	6	7	0	0.65	2.67	1.14	0.00	1.85
3.8	There is a lack of clear/no information to differentiate between male and female toilet	10	10	8	0.93	2.8	1.50	0.63	1.71

3.9	All audio, visual signage, and help desk services are not available in three languages: Hindi, English, and Marathi.	0	1	3	0.13	0.00	2.00	1.00	1.25
3.10	There is a lack of information to detect the exact toilet door	9	9	0	0.90	2.00	0.44	0.00	1.22
3.11	Lack of provisions to create awareness among new commuters about the purpose of the help desk at the station.	6	5	6	0.57	1.00	0.00	1.17	0.76
		Average				2.22	1.87	1.01	1.81

Table 5.9 *p* items with the highest problem frequency (PF) and the severity impact factor (IF) in the enter and exit station task category.

Wayfinding Challenges in the Journey Stage		**Problem Frequency (PF) (0-1)**				**Severity Impact Factor (IF)**			
1	**Enter & Exit from the Station**					**0-1: Minor | 1.1-2: Moderate | 2.1-3: Critical**			
		NV	**LV**	**S**	**PF**	**NV**	**LV**	**S**	**IF**
1.2	The inability to see vehicles at the station entrance led to chances of collision.	10	10	0	1.00	2.80	2.70	0.00	2.75
1.3	There is a lack of ways to help people choose station exits based on the commuter's city destination.	10	10	10	1.00	2.40	2.40	2.60	2.47
1.4	Lack of information about the availability of public transit	10	9	9	1.00	2.60	2.56	2.22	2.46

	stops (Bus, auto, taxi stand) outside each station exit.								
1.5	No direction signs help you find the desired station entry/exit from each platform.	10	10	10	1.00	2.60	2.20	2.40	2.40
1.6	In stations where there is more than one station entry/exit point, there is a lack of information to differentiate one station entry/exit from another.	10	10	10	1.00	2.30	2.30	2.40	2.33
1.7	There is a lack of Information about which station entry is through which part of the station, whether from the platform, ticket hall or bridge.	10	9	0	0.95	2.70	1.44	0.00	2.11
1.8	There is a lack of information on the bridge, platform, and station entry/exit to detect the eastern and western sides of the station. This is crucial to get out of the station.	10	10	8	0.93	1.50	2.00	2.38	1.93
1.9	The lack of installation of station names at each station entry creates difficulty in the identification of station building	10	9	9	0.93	1.90	2.00	0.89	1.61
		Average				2.35	2.20	1.61	2.26

Table 5.10 *p* items with the highest problem frequency (PF) and severity impact factor (IF) in the enter and exit station task category.

Wayfinding Challenges in the Journey Stage	**Problem Frequency (PF) (0-1)**	**Severity Impact Factor (IF)**

2	Ticket Purchase					0-1: Minor | 1.1-2: Moderate | 2.1-3: Critical			
		NV	LV	S	PF	NV	LV	S	IF
2.1	Lack of direction signs to reach the nearest ticket hall from the platform, station entry and foot over the bridge.	10	10	10	1.00	2.20	2.50	2.00	2.23
2.2	Lack of information on different types of tickets sold at each window leads to standing in the wrong queue	7	7	8	1.00	1.71	2.29	2.25	2.09
2.3	If there is more than one way to get out of the ticket hall, there is a lack of information about which part of the station each one of them leads to so that people can select the right exit gate.	9	9	0	0.90	2.11	1.78	0.00	1.94
2.4	Lack of information to detect the ticket hall door.	10	9	0	0.90	2.30	1.00	0.00	1.68
2.5	There is a lack of walking guidelines to reach the ticket window.	10	10	0	0.90	1.40	1.00	0.00	1.20
2.6	There is a lack of information on the different ways local train tickets can be purchased.	10	10	9	0.97	0.90	1.10	1.11	1.03
		Average				1.77	1.61	0.89	1.70

Problem Frequency (PF): Out of the 70 wayfinding problems, 58 wayfinding problems were rated by participants with a high problem frequency ranging between 0.7-1, followed by ten problems with a moderate problem frequency between 0.69-0.4, and only two issues with a frequency between 0.39-0 as reported below:

i. All audio and visual signage and help desk services are not in three languages: Hindi, English, and Marathi (0.13) (pt. no. 3.9 of Table 5.8).

ii. Redundant old information boards are kept from the station; people follow them and get misguided. Such boards add to the visual clutter (0.35) (pt. no. 7.6 of Table 5.7).

These results also show that the participants in this study confirmed almost all wayfinding problems reported by the participants of earlier field studies, as reported in Chapters 3 and 4, with high problem frequency.

Severity Impact Factor (IF): Out of 70 wayfinding problems, 27 wayfinding problems were rated as critical, 38 had a moderate impact, and five were deemed to have a minor effect. The results show that most wayfinding problems identified in the earlier studies had a critical to moderate impact on the participants of this study. The task category order based on the average severity impact ratings across all participants is as follows: 1) Station entry & exit (2.26), 2) Foot Overbridge Use (2.07), 3) General (1.92), 4. Platform (1.91), 5. Train boarding and disembarking (1.85), 6. Use of station facilities (1.81), 7. Ticket Purchase (1.70). Contradictory order is found for station entry and exit, platform use, train boarding, and disembarking categories compared to the order generated from ranking results. However, since ranks were assigned to the entire task category after severity impact ratings, we used the task category order based on ranking data to derive the severity impact matrix final order, as stated in Tables 5.4 to 5.10. Next, we discuss the most critical problems rated highest by participants in each subgroup.

The most severe problems rated with a maximum average of 3 by participants with no vision are: 1) It is challenging to locate the help desk since their location is not fixed (pt. no. 3.5). 2) There are no warning signs at the floor transition from platform to track. As a result, people fall on the track (pt. no. 5.8). 3) a mobile service system cannot assist people with train and station-related inquiries on mobile phones before reaching the station (pt. no. 7.1).

The most severe problems rated (with a maximum average of 3) by participants with low vision: 1) Lack of information to make new commuters aware of what type of facilities are

available at each station (medical facilities, Railway police office, ATVM machines, police office, book, water and food stalls) and where are they located (pt. no. 3.1). 2) Overcrowding of general commuters in coaches reserved for PwDs, makes train travel difficult for handicapped people (pt. no. 6.1). 3) Lack of awareness of provisions for instant help in case of emergency and security measures in running trains and on stations (pt. no. 7.1). 4) Redundant old information boards are not removed from the station; people follow them and get misguided. Such boards add to the visual clutter (pt. no. 7.6). 5) The small font size of the information boards inside the station makes it challenging for them to read from a distance (pt. no. 7.7).

The sighted participants rated the most severe problems: 1) The coach signage on the platform does not match the train coaches when trains of different train coach numbers come on the same platform. This creates confusion among the commuters about the coach's direction and detection (average 2.80) (pt. no. 5.2). 2) The status of the train and any changes in the train arrival time and platform are not updated promptly inside the train nor at the station (average 2.86) (pt. no. 6.2). Among all wayfinding problems, the average rating results of four wayfinding problems demonstrated unexpected results such as:

(i) Despite the provision of train indicators and public announcements, sighted participants perceived differentiation of local trains based on no. of stops they halt (as slow/fast/ intermediate) and their train lines as a more severe wayfinding problem (2.10) compared to the low-vision group (1.90) and the no-vision group (1.10), who only have access to public announcements as a source of information. This also shows the high attention and sharp use of the auditory sense among subgroups with VI compared to those with sight.

(ii) Lack of information on bridge/ subway, platform, and station entry/exit to detect the eastern and western side of the station was perceived as a more severe concern by the sighted (2.38) as compared to the low-vision group (2) and the no-vision group (1.5). This demonstrated that the low-vision and no-vision groups had a better sense of spatial orientation concerning cardinal directions than the sighted group.

(iii) Low-vision (2.29) and sighted (2.25) subgroups perceived standing in the wrong ticket queue due to a lack of information on different types of tickets sold at each window as a more severe problem compared to the no-vision group (1.71). This confirms our earlier finding, as reported in Chapters 3 and 4 that no-vision participants refrain from buying tickets to save time lost in locating ticket halls and buying tickets, as also stated in section 5.4.1. The ticket checkers are also lenient towards them, not charging them a penalty out of pity.

(iv) Both the no-vision (2.86) subgroup and the sighted (2.8) identified the mismatch between the coach signage deployment and the parking position of the coach when trains of different train coach numbers come on the same platform as a more severe problem compared to a low-vision subgroup (1.71), despite that this problem is faced by all commuters independent of vision.

5.4.3 Statistical Test Results

5.4.3.1 Fleiss Kappa Test

Table 5.11 stated the interpretation of values of Flies Kappa. Table 5.12 overviews the inter-rater reliability for different task categories. It suggests that the level of agreement varies across the tasks, with some showing low to moderate agreement among the raters for wayfinding problems in different task categories. For some task categories, the raters have relatively low agreement (e.g., Station entry and exit, with Kappa = 0.05; Ticket purchase, with Kappa = 0.16). For other task categories, there is moderate to substantial agreement among the raters (e.g., Use of station facilities and services, with Kappa = 0.23; Foot over bridge use, with Kappa = 0.30; Train Boarding and Disembarking, with Kappa = 0.27; General category, with Kappa = 0.21). The reasons for low agreement among the raters within the subgroup in general for all task categories could be due to the difference in familiarity levels with the commuting system among the raters in each subgroup. This difference could have impacted their severity ratings. Furthermore, when more participants assess the severity of reported problems, the reliability of severity assessments will likely be enhanced (Nielsen, 1992; Sauro, 2014).

Table 5.11 states the interpretation of values of Flies Kappa.

The value of Fleiss' Kappa ranges from -1 to 1, where: - A value of 1 indicates perfect agreement among all raters beyond what would be expected by chance. - A value of 0 indicates agreement occurring by chance alone. - A negative value indicates agreement is worse than chance. Interpretation of Fleiss' Kappa values can vary, but generally: - Values below 0.4 are considered poor agreement. - Values between 0.4 and 0.75 are considered fair to good agreement. - Values above 0.75 are considered excellent agreement.

Table 5.12 Kappa values for participant subgroups for each task category.

No.	Task Category	NV	LV	S	ALL
1	Station entry & and exit	0.01	0.06	0.13	0.15
2	Ticket purchase	0.03	0.11	0.09	0.16
3	Use of station facilities and services	0.34	0.38	0.10	0.23
4	Foot over bridge use	0.19	0.10	0.14	0.30
5	Platform use	0.22	0.12	0.15	0.20
6	Train to board and disembark	0.16	0.22	0.17	0.27
7	Nonspecific/ General	0.17	0.24	0.08	0.21

5.4.3.2 Pearson correlation coefficient test

The Pearson correlation coefficient test measured the linear correlation between problem frequency and severity impact. The same test was also performed to find the correlation between the number of usability problems in each task category and the severity ratings.

The Pearson correlation coefficient ranges from -1 to 1, where: 1 indicates a perfect positive linear relationship, -1 indicates a perfect negative linear relationship, and 0 indicates no linear relationship between the variables.

The Pearson correlation coefficient results, when performed between no. of issues in all task categories and average severity ratings given by subgroups to each task category, are the following: The Pearson Correlation coefficients for all 30 participants (-0.24); No Vision (-0.01), Low Vision (-0.12) indicate that despite differences in the number of wayfinding problems in each task category, there is a weak and negligible linear relationship with the average severity ratings given by each participant subgroup. This means that differences in the number of wayfinding problems in each task category do not influence the severity ratings. However, a relatively strong and positive correlation was observed between them for the sighted group (0.71). This is because there were fewer problems concerning sighted participants in all other six task categories except for the general task category.

Further, the Pearson correlation coefficient test was performed between severity and problem frequency for different subgroups and all participants. Previous studies conducted by

Virzi (1990, 0.10), Woolrych & Cockton (2001, -0.29), Law & Hvannberg (2004, 0.10), Hertzum (2006, 0.29), Sauro (2014, 0.06) found a negative and a weak relationship between severity and frequency. Our study results contradict with those of earlier studies that found no correlation between problem frequency and severity in usability problem sets. Like Viriz (1992, 0.46), Lewis (1994, 0.6), Nielsen (1994, 0.46), and Jacobsen et al. (1998, 0.46), **this study also identified a moderate positive linear correlation between frequency and severity for all participants (0.35).** This means that all participants perceive high-frequency problems to be more severe despite the heterogeneity based on the level of vision and familiarity subgroups.

Additionally, as Caulton (2001) pointed out, severity and frequency may be strongly correlated within individual subgroups with unique problems compared to the overall correlation performed on all problems for all user groups. A reasonably strong positive correlation is observed in this study between problem frequency and severity for the No Vision (0.74) and Sighted (0.82) subgroups, with a weak correlation for the Low Vision group (0.29). This could be due to the variations in the visual abilities within the low-vision subset, which may have affected the severity of ratings and problem frequency compared to the sighted and no-vision subgroups. Homogeneity- Heterogeneity does play an essential role in influencing the correlation, as confirmed by Virzi's study on homogeneous groups (1992, 0.46) and Law & Hvannberg study on heterogeneous groups (2004, 0.10).

5.4.4 Criteria Used by the Participants for Rating & Ranking

Participants determine the rating and ranking based on specific criteria. Those with no vision and low vision particularly consider the availability and effectiveness of public assistance. Tasks with a low probability and accuracy of getting help, like detecting a handicapped coach entry, are assigned higher ratings. Commuters universally assess concerns by whether they occur in a familiar or unfamiliar station. Issues at both types of stations, such as the lack of timely updates on changes in train timings and platform numbers, are deemed unpredictable and receive high ratings. No-vision and low-vision commuters prioritize safety criteria, giving heightened importance to all wayfinding concerns that pose life-threatening risks or lead to injuries, such as tasks related to boarding and disembarking. Time is a crucial criterion for regular commuters regardless of vision. Tasks involving destinations beyond perceptual access, such as station exits, ticket hall locations, and facilities from a specific self-

location, result in extended walks due to path errors and are rated high. The station scale emerges as a primary rating criterion for all participants, irrespective of their vision level and familiarity. Larger stations present more significant challenges in wayfinding, with increased choice points, paths, and infrastructure. This complexity intensifies the severity of the impact as individuals struggle to develop mental maps and face orientation-related challenges, making it difficult to navigate without information support. On the other hand, specific problems are considered "manageable" with the existing wayfinding support systems like public announcements, the M-indicator mobile app for local train routes, tactile floor indicators, audio beepers on platforms and most importantly, public help. Additionally, self-reliant coping mechanisms, such as using multiple senses, developing directional awareness, and employing preference and avoidance strategies, influence responses indicating lower severity.

5.5 Conclusion

The study confirmed real-life wayfinding issues, with average problem frequency ranging from 0.7-1 for 58 problems (critical), 0.69-0.4 for 10 issues (moderate) and 0.39-0 for 02 issues (low). These results also show that the participants in this study confirmed almost all wayfinding problems reported by the participants of earlier field studies, as reported in Chapters 3 and 4, with high problem frequency. Out of 70 wayfinding problems, 27 wayfinding problems were rated as critical with a severity impact factor ranging from (2.01-3), 38 had a moderate impact (1.01-2), and five were deemed to have a minor effect (0-1). Most issues identified had a critical to moderate impact, emphasizing the need for Railway planning body intervention.

The relative ranking of the most challenging task category based on the associated wayfinding problems follows an expected order: 1) Train boarding and disembarking 2) Platform Use 3) Foot Over Bridge Use 4) General 5) Use of station facilities 6) Station entry & exit 7) Ticket Purchase.

Our study shows that differences in the level of vision impacted the rating and ranking results. Participants, including those with no and low vision, evaluate wayfinding concerns based on specific criteria. Factors like the availability and effectiveness of public assistance, the likelihood and accuracy of help, and the familiarity of the station influence ratings. Safety concerns are prioritized by no-vision and low-vision commuters, particularly for tasks with life-threatening risks. Time is crucial for all commuters, with extended walks for tasks beyond

perceptual access. Station scale, especially in larger stations, emerges as a significant criterion, intensifying wayfinding challenges. However, existing support systems and self-reliant coping mechanisms mitigate the severity of specific problems.

The purpose of the wayfinding problem severity matrix is to prioritize wayfinding problems through severity assessment. The matrix provides a strategic framework for designers, planners, and policymakers to systematically address the wayfinding problems in the order of severity, enabling gradual yet significant improvements. The matrix is formulated from the average of ratings for (p) items in each task category and the average of the weighted rank of each task category.

From the matrix, we can infer two types of high-priority problems. 1) With average ratings across users ranging between 2.1-3 and 2) Average rating given by any specific user group ranging between 2.1-3. Problems with the highest average ratings, i.e. 3, given by all participants of all user groups or any specific user groups, demand priority in terms of them getting addressed first compared to the rest.

Another inference from the matrix is that ranking results should be followed to bring incremental changes in the task category or spatial zone. In this case, the train boarding and disembarking category should be highly important, followed by the rest of the task categories. As a second order of preference, all high-priority problems with an average of 3 (of one or two user groups or across user groups) should be addressed first in the ranked task category order, followed by moderate and minor rated problems in task categories. Improvements should commence at large-scale stations with complex layouts and overcrowding to address the most significant wayfinding challenges.

This study has a few limitations. The no. of problems to be assessed was relatively high. This may have created a cognitive load, especially for participants with vision impairments. Despite this, all participants patiently completed the study. The limited sample size means the results may not be generalizable to a larger population. Another limitation is that the rating technique used in the study often led to most wayfinding problems being perceived as having moderate or severe impact, making it challenging to discriminate between item scores. Differences in levels of vision and familiarity may have impacted the wayfinding problems assessment by the participants. Since the item list was long, severity and priority were not treated separately but merged in a rating scale. Rating scales were designed based on the premise that items with a severe impact will be of high priority to the participants.

In this study, we have found that many commuters experienced problems with high-severity impact factors. This study is the first to involve commuters with vision impairments in the assessment process. Unlike other severity assessment rating ranking usability studies, this study can explain the reasons for and experiences of evaluators behind decision-making, in this case, train commuters. This study plays a crucial role in designing wayfinding guidelines for all three commuter groups, no-vision, low-vision, and sight, as part of the scope of the next chapter.

Chapter 6 Wayfinding Guidelines

6.1 Introduction

This thesis chapter builds upon prior knowledge concerning the wayfinding experiences of individuals with vision impairments as reported in Appendix A1, A2; & Chapters 3 and 4. Till now, we have understood that the current scenario of Mumbai Suburban presents a challenging wayfinding context for train commuters with or without vision impairments. The severity of the negative impact increases with the decline in vision and familiarity. Commuters have further provided an order of priority, based on the severity of impact of the wayfinding problems. Guidelines serve as a basis for any design implementation strategy and solution.

As a next step, we reviewed the existing Indian Railway guidelines to understand what is missing as knowledge that has led to minimal, inadequate and partial implementation of guidelines, because of which, the commuters have strong negative wayfinding experiences and poor wayfinding performance. The review of the existing Indian guidelines was done to answer the **RQ 4: What design support may improve the wayfinding experience and performance of people with different levels of vision?**

The examination of Indian Railways guidelines highlights a clear focus on enhancing accessibility, with comparatively less attention given to addressing the specific wayfinding needs of individuals with vision impairments. Although advancements like the adoption of digital technologies for standardized signage, real-time mobile applications, and online feedback systems demonstrate progress, there persists a significant gap in comprehending the behavioral and social aspects through user-centric qualitative research, which is crucial for

refining guideline development. Furthermore, the current guidelines do not adequately address the unique challenges of suburban train commuting systems, characterized by high population density and complex station layouts. Furthermore, they prioritize non-suburban stations in their implementation strategy based on passenger footfall and commercial importance, neglecting the specific needs of suburban stations, leaving many underdeveloped. This approach overlooks the significant impact on commuters' wayfinding experiences, indicating a need for a more nuanced and prioritized implementation strategy that considers the severity of negative impacts on commuters. While there has been progress in enhancing accessibility in Indian Railways, there is still considerable room for improving the wayfinding experience of commuters based on more profound qualitative research into guideline development.

The proposed guidelines in this chapter address these gaps and present wayfinding design guidelines categorized under design parameters, informed by commuters observed and shared wayfinding experiences. The guidelines are formed using a systematic framework that addresses all the wayfinding problems identified from the empirical and evidence-based research reported in previous chapters. The intended users for these guidelines are rail transport operators, station managers, architects, designers, disability advocates and others involved in the planning, designing and implementing passenger wayfinding signage for Mumbai Suburban Railways. The proposed guidelines aim to improve the existing guidelines by focusing on the wayfinding needs of people with vision impairments (no vision and low vision). They intend to make information dissemination platforms, signages, and physical and digital services more responsive and sensitive to the needs of people, including those with vision impairments. Further, they aim to propose a unique strategy to strengthen social wayfinding in Mumbai Suburban Railways.

Section 6.2 reviews past and current wayfinding and accessibility guidelines proposed by Indian Railways. The review helped identify the limitations of the guidelines and methods of forming and implementing them. Section 6.3 discusses the need for revisions in the current wayfinding guidelines. This further led to discussing the scope for additional and modified guidelines in Section 6.4. Section 6.5 presents the framework for the development of wayfinding guidelines. Section 6.6 presents the complete set of existing, modified and new guidelines. Section 6.7 discusses the notable differences between the guidelines proposed in the thesis and the International and Indian guidelines. Section 6.8 Implementation Strategy of the guidelines. Section 6.9 presents the chapter summary.

6.2 Review of Accessibility Guidelines of Indian Railways

In this section, the evolution of accessibility and wayfinding guidelines made for people with vision impairments in the Indian context are reviewed and discussed in chronological order.

In 1995, when India passed the Persons with Disability act- the need for accessibility was first addressed in the ***Guidelines and space standards developed for the barrier-free built environment for people with disabilities and elderly population by the Centre for Public Works Department*** (CPWD, 1998). The access standard codes considered the diverse requirements of different disability groups, focusing on aspects such as access, safety, convenience, and usability. These guidelines and space standards were intended for implementation in various public buildings, including railway stations. The overarching goal of the guidelines and space standards was to ensure that they are designed and constructed to promote accessibility and inclusivity, aligning with the principles outlined in the aforementioned legislative framework.

The proposal encompasses various measures to enhance the accessibility of railway stations and train travel for individuals with vision impairments and other disabilities. These measures include the installation of tactile ground surface indicators at key points such as station entry/exit points, platform edges, staircases, lifts, and escalators. Additionally, anti-skid materials were recommended for flooring, and braille signs were proposed for ticket vending machines. To further assist individuals with disabilities and senior citizens, a dedicated ticket window and signage featuring large text sizes, colour contrast, and illumination were suggested. The train travel schedule was proposed to be available in braille. Earmarked seats near the train doors were recommended.

The proposed guidelines were accessibility-focused for wheelchair users. Minimal modifications were proposed in a discontinuous manner. The proposed measures, however, represent small incremental steps toward improving physical accessibility to the rail commuting system for individuals with disabilities.

Following India's ratification of the United Nations Convention on the Rights of Persons with Disabilities in 2007 and the subsequent implementation of the Rights of Persons with Disabilities Act in 2016, there has been a notable expansion in the scope of commitments to realizing Universal Design across all mass transit public transport systems in India.

India signed the UN Convention in 2007. The Government of India is committed to the realization of full participation, protection of rights, and equal opportunities for all, including people with disabilities. In pursuance of the provisions of UNCRPD, the PwD Act, and the National Policy of the Govt. of India, several steps have been taken to provide a barrier-free and accessible environment for Persons with Disabilities.

The Indian Manual of Standards and Specifications for Railway Stations, 2009 (Ministry of Railways, Govt. of India, 2009) adheres to accessibility guidelines for disabled individuals, as outlined in the 'handicap accessibility' section. These guidelines align with the Americans with Disabilities Act (ADA) of 1990. Nevertheless, Raheja (2016) highlighted in an audit report on the New Delhi Railway Station that the ADA guidelines for transport facilities may not be the sole reference for accessibility in the Indian context. He emphasized the need for contextual research on Indian wayfinding challenges and the railway commuting system, considering cultural, social, and economic differences. Additionally, the 2009 manual proposed additional recommendations beyond those suggested by CPWD in 1998, following American with Disability Act Accessibility guidelines. However, it reinstated most of CPWD's 1998 recommendations.

Some of the new additional guidelines proposed in the manual, especially for the benefit of PVIs, are presented as follows: Staircases will be replaced at a few critical points with escalators in non-suburban, NSG-1 and NSG-2 stations. Escalators must be fitted with audible indicators to warn the visually impaired passengers about the direction. The train doors should be detectable using contrasting platform floor finishes and signage. Some wayfinding guidelines were proposed, such as wayfinding signs indicating the location of elevators, ramps, and other accessible facilities, which must be placed at all decision points within a station. The advertising system on railway stations should follow uniform installation to avoid visual pollution. There should be standardization regarding architectural material finishes, building colour, communication aids such as help points, public address devices, etc. Sufficient unobstructed space for embarking and disembarking from the train should be provided so the passengers can queue and pass on their way to and from the train coach. Every part of the station should be well-lit. The station entrance shall have clear and direct access to the surrounding pedestrian network and should be visible and identifiable within the surrounding urban context. Further station entrance shall not get negatively influenced by adjacent pedestrian flows, activities, or events unrelated to the station.

The Manual incorporated standards and specifications predominantly for accessibility design, with a limited focus on signage design. The signage design guidelines were limited to proposals on a few identification signs, whereas the need for instructional, directional, orientation and safety signages were not represented in the manual. Further, the signage guidelines were proposed for the implementation in the visual format; the need for a non-sensory mode of wayfinding information communication was not specified in the guidelines.

The Rights of Persons with Disabilities Act of 2016 is a significant legislation promoting equity and non-discrimination for individuals with disabilities. It mandates accessibility across various sectors, including transportation (RPWD, 2016).

India lacked a comprehensive plan for accessibility until the launch of the Accessible India Campaign (*Sugamya Bharat Abhiyan*) in 2015. This initiative, by the Department of Empowerment of Persons with Disabilities (DEPwD), Ministry of Social Justice & Empowerment (MSJE) of People with Disabilities, Govt, of India, aimed to make 50% of all railway stations fully accessible by 2022 (DEPwD, 2024). Access audits were conducted in collaboration with NGOs and government institutes, on suburban and non-suburban trains and railway stations to guide the process of making stations accessible based on the audit reports as discussed in section 2.7.1 of Chapter 2.

In 2021, Indian Railways proposed ***Harmonized guidelines for PwDs****,* aligning with the RPwD Act, 2016, to enhance services for disabled people (Ministry of Railways, Government of India, 2021). The guidelines categorized into Information System, station, platform, train coach accessibility, and monitoring, follow a Universal Design philosophy and the "Reasonable Accommodation" principle of the Rights of Persons with Disabilities Act, 2016. Applicable to both suburban and non-suburban trains and stations, the guidelines prioritize implementation from high to low-population-density locations. These comprehensive guidelines surpass previous ones, particularly addressing commuters' wayfinding requirements. Some of the unique guidelines added to make the stations more wayfinding friendly for people with vision impairments are:

To enhance platform accessibility, painting structural elements (e.g., columns, coach position indicator poles) in contrasting colours for better visibility for individuals with low vision or colour blindness were suggested. Additionally, protruding objects on the platform are proposed to have adequate clearance from the finished floor level to provide an uninterrupted path, particularly for those with low vision or blindness.

Proposed initiatives aim to develop mobile apps for informing all commuters, including Persons with Disabilities (PwDs), about station amenities. Additionally, on-site PA system announcements should convey the same information within station buildings.

Indian Railways is advancing towards "Digital India, Digital Railways" by utilizing digital technology for transparent and accountable operations. Key initiatives include the development of the 'Rail *Madad*' mobile app for grievance redressal, with plans for enhancement through CRIS (Centre for Railway Information System) for improved accessibility and assistance for persons with disabilities. Additionally, the 'Rail Drishti' mobile app consolidates rail-related information from various sources, offering citizens access to critical statistics and parameters through 15 user-friendly sections, including a public grievances section. The app encourages feedback and complaints via the Indian Railway website and Rail Drishti App, allowing crowdsourcing through photo uploads. Its objective is to showcase railway transformation, engage citizens in shaping future developments, and implement policy modifications based on their suggestions, particularly to enhance the effectiveness of the Accessible India Campaign (Vikaspedia, 2024).

Sahayaks stationed at Help booths in the railway station will receive training to offer information and physical assistance to individuals with disabilities. The help booths will be equipped with signage for accessibility, including facilities for wheelchairs and assistive devices. The location, marked prominently with informational and directional signs at the main entry of the Railway Station, will ensure easy identification for the convenience of persons with disabilities and others.

While the harmonized guidelines address the wayfinding needs of commuters with disabilities, including those with vision impairments and poor station familiarity, they lack inclusiveness. The proposed guidelines also lack a clear implementation plan for content, deployment, and format, and their implementation strategy lacks prioritization from the commuters' perspective.

Indian Railways recently released the ***Guidelines on Standard Signages at Stations on Indian Railways, 2023*** as part of the ***'Amrit Bharat Station Scheme'*** (Ministry of Indian Railway, Govt. of India, 2023b). The scheme aims to transform railway stations into vibrant city centres with roof plazas, fostering local economies and supporting Transit Oriented Development. The scheme aims to enhance the facilities beyond minimum essential amenities (MEA). It focuses on upgrading and modernizing stations, enhancing accessibility, providing

waiting areas, increasing toilet facilities, installing lifts and escalators, improving cleanliness, offering free wifi, promoting local products through initiatives like 'One Station one product,' upgrading passenger information systems, establishing executive lounges for business meetings and providing facilities for people with disabilities. Landscaping and promoting art and culture will be initiated to provide a pleasant experience for the station users and close the drainage of platform areas.

Guidelines on Standard Signages at Stations on Indian Railways, 2023*,* provides explicit guidelines for designing standardized signages at railway stations. These guidelines are for all users, including the elderly and people with disabilities rail passengers. Some unique non-overlapping guidelines proposed in this new document are that commercial boards/hoardings should be placed so that they do not obstruct the visibility of the wayfinding signage. Further, the colours chosen for commercial boards shall not interfere with the signages.

Installation of 'You are here' orientation maps are proposed in 3D Isometric view, indicating the relative position of all utilities concerning the location of these orientation maps. It shall help passengers to build a mental model of the entire station. The orientation map shall preferably have braille dot embossing placed at an accessible height for PwD commuters.

Digital signages are recommended for station signage due to their flexibility in reconfiguring wayfinding messaging, seamless integration of customer information with wayfinding, and ease of connecting information. Consideration of screen usability factors is crucial as the prevalence of digital information in spaces increases. In particular, touch screens, including new technologies that allow interactive adjustment of the usable portion for different user heights, should be configured to accommodate individuals with vision impairments, wheelchair users, and people of short stature. These digital touchpoints can also feature audio output and options to increase font size and screen contrast. The use of abbreviations is proposed to be kept to a minimum. Further abbreviations used should be easily understandable.

Reviewing existing Indian guidelines on accessibility and wayfinding suggests that greater emphasis is given to accessibility than wayfinding. Only recently, the harmonized guidelines proposed in 2021 have represented a few wayfinding needs of people with disabilities, including those with vision impairments in Indian Railways. The guidelines have moved ahead from creating provisions of ticket concessions and limited accessibility to strengthening human assistance through help booths, standardizing signages using digital technology, designing mobile applications to increase accuracy in real-time train updates,

saving time through digital ticketing, and increasing accountability through passenger online feedback/suggestion/complaint mechanisms. There is progress, but there is still scope for improvement when the guidelines are informed through much deeper user-centric qualitative field research. The understanding of user variables such as vision, familiarity, gender, and literacy cannot be ignored when developing wayfinding guidelines inclusive of population diversity in India. The proposed harmonized guidelines for passengers with disabilities in 2021, Guidelines on Standard Signages at Stations on Indian Railways, 2023 and Standard Signages at stations on Indian Railways in 2023 do not propose guidelines that represent the wayfinding needs of commuters with such intersectional differences. The methods adopted to understand real-life issues are still limited to quick and highly objective methods like access audits conducted by NGOs and academic institutions with the help of experts. Such methods lack an understanding of behavioural and social dimensions that unravel how people respond to the system and their behaviour towards each other.

Further, the guidelines proposed are generalized to all rail commuting systems, including suburban and non-suburban trains and stations, ignoring that both types of commuting systems differ in many aspects. Suburban train commuting systems are far more complex due to high population density in peak hours. Commuters witness high cognitive load in memorizing paths inside station building as each station differ from the other in terms of spatial layouts. For example, Mumbai has 150 stations, all with different architectural layouts. In contrast, any other city with non-suburban stations varies between 1 and 3. Hence, in addition to the generic guidelines proposed by Indian Railways in 2023, we also need tailor made wayfinding guidelines for suburban rail commuting systems that are more responsive to the travel pattern, behaviour, population footfall and wayfinding information needs of train commuters. Further, the latest guidelines released in 2023 are mainly limited to wayfinding inside the station building, ignoring train route travel information and commuters' other safety and security needs in the suburban rail commuting system.

Non-suburban train stations are prioritized over suburban train stations in the implementation strategy. The implementation strategy prioritizes stations based on the criteria of passenger footfall and commercial importance (Dey, 2017). Indian Railways have grouped Indian Railway stations based on non-suburban (NSG), suburban (SG) and halt stations. The three groups of stations are further categorized based on the number of passenger footfalls and passenger earnings of the stations (Panel, 2023). As a result, guidelines are implemented only

on a very few suburban stations (SG) that fall under grades 1 and 2 in Mumbai. All other stations that fall under the category of grade 3 are left to the scope of future development. The implementation strategy for the proposed guidelines is not governed by priorities based on the severity of the negative impact on commuters' wayfinding experience.

6.3 Scope of the Guidelines

The guidelines primarily suggest wayfinding requirements of commuters with different needs based on vision, familiarity, and gender differences to perform wayfinding tasks. The guidelines do not state any standards or specifications for signage or architectural or interior design. Although tailored explicitly for the Mumbai Suburban Rail Commuting System, they can be adopted by Indian Railways for Non-Suburban Trains and stations and other transit agencies like metro, monorail, buses, etc. The guidelines are also proposed for all types of suburban train stations in Mumbai, such as terminal and interchange stations. The guidelines primarily focus on the wayfinding needs inside the station building and trains. The guidelines are not proposed for the exterior areas that connect the station building. The guidelines are proposed for three user groups: People with no vision, those with low vision, and those who are sighted. There are standard and specific guidelines for each user group. The guidelines are not specific to the percentage of visual impairment. The proposed guidelines do not include wayfinding and accessibility needs of other disabilities.

Rather than prescribing rigid design standards and specifications, the guidelines suggest wayfinding requirements that can be addressed using different design strategies and approaches to enhance the usability of Mumbai's local train system for individuals with and without vision impairments. Qualitatively, these guidelines seek to inspire design solutions that enhance the wayfinding experience for all users, laying the groundwork for future research on design approaches and solutions.

6.4 Framework for Guideline Development

Guidelines were developed and presented using a three-dimensional framework consisting of *wayfinding stages, design principles and enabling aspects* (Figure 6.1). The guidelines emerged from the findings of the empirical research.

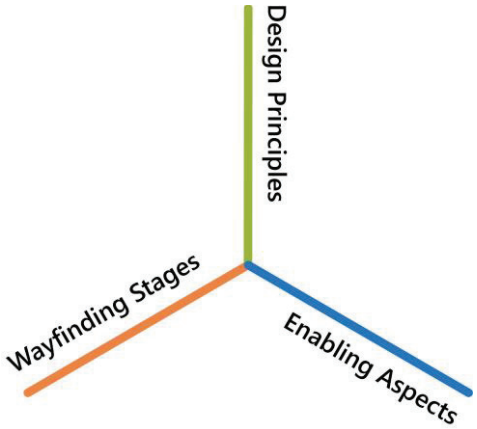


Figure 6.1 Three-Dimensional Framework for Wayfinding Guideline Development

(i) Wayfinding Stages

In a transit environment, there are different wayfinding stages. Each stage has a set of task components that need to be conducted. A Wayfinder has information needs – what they require to accomplish a specific task component within a specific wayfinding stage. If the needs are unmet, commuters develop alternate strategies to acquire information. In the process, they may face challenges in accomplishing wayfinding tasks.

Figure 6.2 Explains the journey stages involved in wayfinding in Mumbai Suburban Railways. Commuters enter the station building through a footbridge, subway, ticketing area, or platform. They purchase tickets from the ticketing area or online, proceed to the designated platform, wait for the train, board the specific coach, and travel to the destination station. Upon arrival, they disembark on the platform, where they may exit the station building, transfer to another platform for a different train line, switch to a non-suburban train, or reach the terminal of another transit system.

The studies reported in Chapters 3 and 4 resulted in several wayfinding challenges, strategies and needs of commuters for the wayfinding tasks involved in each journey stage. The analysis of them has resulted in wayfinding guidelines.

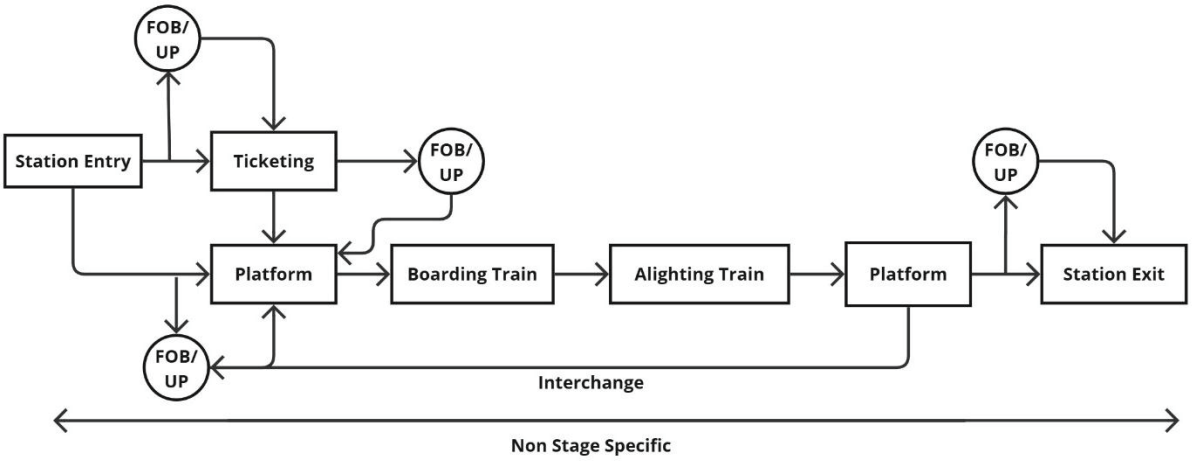


Figure 6.2 Journey stages involved in Mumbai Suburban Railways

(ii) Wayfinding Design Principles

These guidelines are categorized into seven broad design principles and reported for each wayfinding stage (Table 6.1):

- Develop an accessible and comprehensible identification system: This principle explains the need for designing to enable people to identify or recognise the origin and the destination place or an object, a person, etc (Apelt et al., 2007)
- Ensure continuous path guidance for the desired destination: This principle states the need for continuous reinforcement of people traveling in the right direction (Apelt et al., 2007).
- Provide orientation to cultivate a spatial perspective: The principle elicits the need to develop people's mental map of the layout of the building or an external space to identify their location within a building or an external space.
- Provide additional information and instructions: This principle explains the need for providing updated information and instructions about how to use a building, facility or service, for example, rules and regulations, operational timings, awareness about the purpose of any new service, etc.
- Ensure safety of commuters: This parameter explains the need for ensuring safety and security, understanding of potential hazards, provision to seek help or knowledge about escape in case of emergency, etc. (Apelt et al., 2007)

- Increase the effectiveness of rail services: This parameter explains the need to make the existing rail service effective and introduce new relevant services, notably to support the wayfinding of people, especially those with vision impairments, in need of assistance from Railway staff.
- Devise strategies to strengthen social wayfinding: This parameter explains the need to enhance the social dimension of wayfinding, wherein approaches are required to design interventions where humans can help each other in wayfinding effectively.

Table 6.1 Problem Category and Wayfinding Design Principles

Wayfinding Problem Category (P)	Design Principle (D)
P1: Unable to identify spatial zones, architectural features, services etc	**D1: Develop accessible & comprehendible identification system**
P2: Not knowing which direction to go, whether one has reached the right location or not.	**D2: Ensure continuous path guidance for the desired destination**
P3: Poor orientation for entire station and train routes	**D3: Provide orientation to cultivate a spatial perspective**
P4: Insufficient & lack of timely update of information about the system rules and use of services	**D4: Provide static and dynamic information and instructions related to station and train use**
P5: Poor sense of safety and security	**D5: Ensure safety and security of commuters**
P6: Ineffective Rail services	**D6: Increase the effectiveness of the Rail Service Design**
P7: Ineffective human assistance	**D7: Devise strategies to strengthen social wayfinding**

(iii) Enabling Aspects

The proposed guidelines have four aspects: *Architecture and Interior Design, Information Design, Service Design and Social Wayfinding Design* (Figure 6.3).

a. The *Architectural and Interior Design aspects include* guidelines for built environmental spatial interior elements such as accessible and defined parking, lighting, flooring, handrails, step-free movement, and safe and guided navigation.

b. The *Information Design aspect* includes guidelines for identification, directional and orientational, instructional and safety information systems disseminated through various sensory channels in digital and physical modes.

c. The *Service Design aspect* includes guidelines to strengthen wayfinding support provided by railway staff and other offsite and digital services.

d. The *Social Wayfinding Design aspect* includes guidelines to strengthen wayfinding support provided by commuters to each other and by shopkeepers and vendors inside railway station buildings and trains.

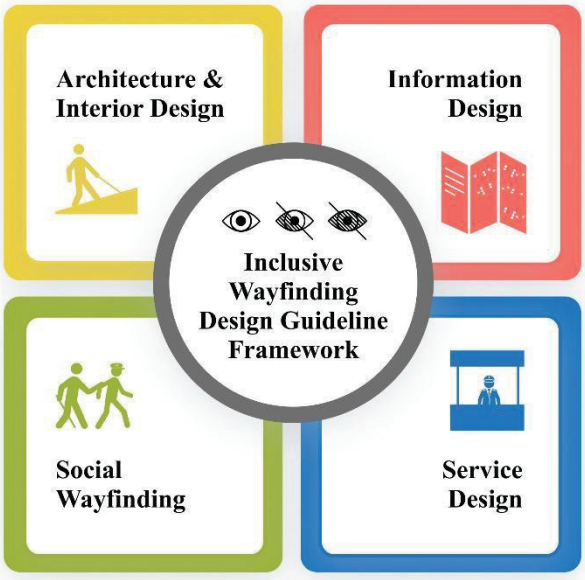


Figure 6.3 Framework for Inclusive Wayfinding Design Guidelines

The next section provides detailed guidelines to address the wayfinding requirements of commuters with and without vision impairments for each wayfinding task involved in seven journey stages: 1. Station entry and exit 2. Ticketing 3. Foot over bridge/ Subway 4. Platform 5. Station facilities and services 6. Train boarding and disembarking 7. Non-Stage-Specific.

6.5 Wayfinding Guidelines

This section states the wayfinding guidelines in a travel chain for all wayfinding tasks involving the Mumbai Local Train Commuting System. The guidelines are developed to address the wayfinding needs, behaviour, strategy and challenges experienced by people with different levels of vision, i.e. no vision, low vision and vision. The most recent national and international guidelines from developed nations also inform the guidelines—countries such as the United States, United Kingdom (U.K.), France, and New Zealand. For the guideline development, the following sources were used (Table 6.2).

Table 6.2 List of sources referred and reviewed for wayfinding guideline development.

Sr. No.	**Indian**	**Year**
1	Harmonized Guidelines & Standards for Universal Accessibility in India, Ministry of Housing & Urban Affairs Government of India (Raheja, 2021)	2021
2	Standard Signages at Stations on Indian Railways, Ministry Of Railways, Govt. Of India.	2023a
3	Guidelines on accessibility of Indian railway stations and facilities at stations for PwDs and passengers with reduced mobility, Ministry Of Railways, Govt. Of India.	2023b
Sr. No.	**International**	**Year**
1	Design Guidelines for the Visual Environment, National Institute of Building Sciences, United States	2015
2	International Railway Solution, International Union Of Railways, Paris, France	2018
3	Signage and Wayfinding Design Guide, Auckland Transport, Auckland, New Zealand	2018

4	Wayfinding Design Manual, Network Rail, U.K.	2022
5	Transit Universal Design Guidelines Principles and Best Practices for Implementing Universal Design in Transit, American Public Transportation Association, American Public Transportation Association (APTA), United States of America	2020

Table 6.3 presents the categorization of guidelines in each task category among existing, modified and novel guidelines. Our research has added 70 new guidelines to the existing guidelines on wayfinding in the rail commuting system.

1) Novel guidelines were developed to address the challenges uncovered in empirical research.

2) Modified guidelines, derived from existing Indian or international standards, adapted to suit the context of Mumbai Suburban Railways' wayfinding requirements.

3) Existing guidelines are those already proposed in Indian or international guidelines. Additionally, any guidelines proposed internationally that are absent in Indian guidelines but deemed relevant to India upon adoption are also added to the guidelines for completeness.

Table 6.3 Categorization of Guidelines into Existing, Modified and Novel

Task Categories	**Existing**	**Modified**	**Novel**
Station entry & and exit	9	3	4
Ticket purchase	5	0	10
Use of station facilities and services	12	4	14
Foot over bridge use	10	1	6
Platform use	13	3	8
Train to board and disembark	9	0	15
Nonspecific/ General	18	3	13

Total	**76**	**14**	**70**
Grand Total	**160**		

In the following section, wayfinding guidelines are presented for each journey stage and wayfinding task.

6.5.1 Station Entry & Exit

6.5.1.1 Enable identification of the railway station building.

a) Stations should have a distinct presence in the urban landscape (APTA, 2020). This guideline is applicable to upcoming station sites or station sites that are under architectural modifications *(Existing)*.
b) All commuters with and without vision impairment should be able to identify the railway station building by its name. They should get a visual and non-visual confirmation that they have reached the desired station building entry. (APTA, 2020) *(Existing)*.

6.5.1.2 Enable selection and identification of the railway station entry and exit.

a) Where the stations have more than one entry and exit point, provide a comprehensive identification system, both in visual and non-visual sensory modalities to distinguish each station entry and exit point (Network Rail, 2022; Ministry of Railway, Govt. of India, 2023a) *(Existing)*.
b) The identification system may consider the following *(Novel)*:
   -The cardinal directions, i.e. the east or west side of the station, with an additional unique code that could be numeric or alphabetical to distinguish between more than one station entry or exit in the same direction of the station. This information is a must for all commuters independent of vision.

-PVIs should be informed about the spatial zones such as platform, foot over bridge, subway and ticketing zone through which one can enter or exit the station.
-Further, if the station entry & exit is by foot overbridge or a subway, provide the information about the availability of a staircase or ramp cum staircase or full ramps or escalators or lifts etc.,

for that specific station entry point & exit. This information must be provided to commuters with no vision through non-visual design intervention.

-In addition to onsite information, existing digital mobile applications such as Rail *Yatri* (Passenger) and M-Indicator may also give station-specific information, enabling people with and without vision impairment to help people select the station side from which they would like to enter or exit a station building.

6.5.1.3 Provide a safe and accessible navigation experience while entering and exiting the station building.

a) Mark boundaries between pedestrian and motorized vehicle paths using barriers or buffers (APTA, 2020) to avoid collisions of commuters with vision impairment with vehicles parked on the pathway to the station entrance and exit. Random parking of vehicles on or near the path to the station entrance and exit should be restricted to avoid collisions with people with no vision *(Modified)*.

b) Station entrance and exit pathways should be paved and easily identifiable through non-visual cues like architectural or landscape features, such as smell-emitting plants and distinct flooring (APTA, 2020), aided with handrails on both sides that lead commuters with no vision to the station entry point from the drop-off point *(Existing)*.

c) Minimize elevation changes or bridge them with gentle slope to avoid tripping hazards (APTA, 2020) for all commuters *(Existing)*.

d) Provide bollards on the paved pathway with downward lighting and contrasting colour and value of height not more than 1m to guide commuters with a low vision towards the station entry after sunset (National Institute of Building Sciences, 2015) *(Existing)*.

e) The commuters should be restricted from trespassing on rail tracks to enter and exit the station building *(Novel)*.

6.5.1.4 Guide commuters from the station entry to reach the desired platform and ticketing zone.

Upon entering the station building, commuters may either proceed directly to the platform if they have purchased the ticket using the Unreserved Ticketing System (UTS) app or would like to visit the ticketing area to purchase the physical ticket.

a) Commuters with and without vision impairment must be guided to the desired non-suburban or suburban train platform if they have online tickets. Sighted commuters can be guided with the help of train indicators and commuters with vision impairments can be guided by Rail *Sahayaks* (Ministry of Railways, Govt. of India, 2023b) *(Existing)*.

b) Wherever possible, separate station entrances or pathways for non-suburban and suburban trains can be created to direct the daily commuters and non-suburban train passengers to desired ticketing zones. This guideline applies to upcoming station sites or station sites that are under architectural modifications *(Novel)*.

c) Use visual directional signages to guide sighted commuters to reach the desired and nearest ticketing zone (Auckland Transport, 2018).

Addition: To enable detection, the directional signages should be repeated at each decision point involving bridge/ subway and station entry. Furthermore, Rail *Sahayaks* should be deployed at each station entry to assist people with directions *(Modified)*.

d) Ticketing areas must be deployed close to the station entry on both sides of the building to avoid long walks in construction sites. This guideline applies to upcoming station sites or station sites that are under architectural modifications *(Novel)*.

6.5.1.5 Provide selection and path guidance to exit from the station building

a) Upon alighting from the train, a commuter with and without vision impairments should be provided with the following information to select among the following types of station departures *(Modified)*:

-Exit the station building to take road transport such as Auto/bus/taxi/cab (Ministry Of Railways, Govt. Of India, 2023b).

Additionally:

- Cardinal directions to the station (east/west) should also be provided.

-Change the platform to board the train of another suburban train line

-Exit towards the interconnected metro or a monorail

-Change the platform to board the non-suburban train.

b) Wayfinding design interventions should be developed to guide people with vision impairments towards the desired station exit based on the above considerations. Braille handrail

signage can guide people towards the station exit from the foot over a bridge or a subway (Anuprayaas, 2019) *(Existing)*.

c) Visual sign boards for route guidance on all the above information should be installed at decision points such as lifts/ escalators/ ramps/ staircase/ ramp cum staircase of skywalk, foot over bridge/ subway; before using them and later should be repeated at the relevant decision points guiding station sighted unfamiliar people (Ministry Of Railways, Govt. Of India, 2023b; Network Rail, U.K., 2022) *(Existing)*.

6.5.2 Ticketing

6.5.2.1 Provide knowledge about the ticket fare collection system.

a) Provide the latest information on ticket rules, penalties, and purchase methods on the Unreserved Ticketing System (UTS) mobile app *(Novel)*.

6.5.2.2 Ticket vending machine (TVM)

a) Using a TVM can pose challenges for various users, especially newcomers and those who do not frequently use the system. Individuals with -vision impairments, language barriers, or other impairments may encounter specific difficulties using them. To enhance universal accessibility in ticket dispensers, adhere to the following design principles (APTA, 2020) *(Existing)*:

- Ensure machines are intuitively usable with minimal instruction.
- When instructions are essential, employ graphic illustrations whenever possible.
- If text is unavoidable, minimize the wording, incorporate Braille and raised text, and translate the instructions into languages commonly used by the system and station's users.
- Instructional signage, commonly linked with ticket vending machines, should facilitate users' intuitive comprehension of machine usage. The design process should include testing the signage's effectiveness with users.

6.5.2.3 Improvise Unreserved Ticketing App

a) The Unreserved Ticketing System (UTS) mobile app should be tested for use by people with vision impairments. The app should provide all the information about special concessions, queue-free tickets, reserved ticket window purchases (if any on specific stations), and any other onsite facilities and services regarding ticket purchases for people with disabilities *(Novel)*.

6.5.2.4 Provide an identification sign system to earmark all ticketing areas

a) Use distinct identities for non-suburban trains and Mumbai local trains to distinguish ticketing zones where ticket zones sell tickets for both or any one type of train ticket. The same information should be provided to people with vision impairment using a non-visual format *(Novel)*.

6.5.2.5 Provide information support to select the correct ticket window.

b) Design and implement a standardized and consistent visual method of displaying the information on the types of tickets/ passes available at each ticket window. An identity system can be developed for each ticket window in such a way that it informs commuters about the type of ticket/ pass sold at each counter *(Novel)*.

c) Operational timings of each ticket window should also be displayed above each ticket window. Avoid handwritten signage *(Novel)*.

d) Handrails should be provided for the queue at each ticket window (Ministry Of Railways, Govt. Of India, 2023a) (Existing).

e) The identity markers of each ticket window, their operational timings and the type of ticket/ pass sold at each window can be provided in braille on the handrails for PVIs *(Novel)*.

f) If feasible, a separate ticket window with visual and non-visual identification should be dedicated to people with special needs, such as people with disabilities and senior citizens, etc., to help them save waiting time in long queues (Ministry Of Railways, Govt. Of India, 2023a) *(Existing)*.

g) Priority shall be given to people with disabilities in queues at each ticket window (Ministry Of Railways, Govt. Of India, 2023a) *(Existing)*.

h) In such a case, communicate special rules for People with Disabilities (PwDs) regarding travel concessions and queue-free ticket purchases through visual signage for those waiting in line to avoid fights between the general commuters and people with disabilities *(Novel)*.

6.5.2.6 Provide guidance to reach the ticket window and exit from the ticket hall.

a) For assisted wayfinding, a help desk should be deployed at each ticketing area to guide people with special needs, such as those with vision impairment, in purchasing tickets and exiting the ticket zone *(Novel)*.

b) For independent use, a tactile path should also be provided inside the ticket hall to guide commuters with vision impairments towards the ticket counters and ticketing zone exit (APTA, 2020) *(Existing)*.

6.5.2.7 Provide station orientation inside the ticketing area.

a) Implement the design and installation of station specific 'You are Here' visual and tactile maps strategically placed inside the ticketing zone. These station maps should offer a comprehensive overview of the station layout, including the following details for the convenience of commuters (Anuprayaas, 2019)*(Existing)*.

The following additions are proposed in the design of the visual and tactile map (Modified)

- Platforms with identities with corresponding train line codes and train type codes (Slow, semi-fast, fast trains)
- Foot-over bridges (FOB) or subways or skywalks marked with their identities and the availability of ramp/ staircase/ ramp cum staircase/ lift/ and escalator at each connecting point with cardinal directions. Connectivity with other station parts such as other platforms (of specific SG train line/ NSG trains/), other bridges/subways, other mass transit systems such as monorail and metro and station exit direction (east or west).
- Station entry-exit points marked with their identities.
- Deployment of station facilities such as canteens, bookstalls, drinking water, toilets, etc.
- Deployment of station services such as station manager office, police office, help desk, etc.

b) Ensure station maps should be designed for easy updating to reflect the current layout *(Novel)*.

c) To complement the online information provided by mobile apps, provide a real-time updated visual directory of upcoming trains inside the ticket hall, guiding people to different subways/ foot overbridges and different platforms *(Novel)*.

6.5.3 Foot Over Bridge, Subway & Skywalk

6.5.3.1 Enable identification of each foot over bridge, subway, skywalk.

a) Develop an identity system for each footbridge, subway, and subwalk to distinguish them from others. Integrate this identity into station maps, train indicators, braille and visual signages for better footbridge, subway and skywalk orientation *(Novel)*.

6.5.3.2 Enable selection and orientation of the desired foot over bridge, subway, skywalk.

a) All commuters independent of vision should be informed about the foot over bridge, subway, skywalk connectivity with different parts of the station, most importantly, platform, station building exit and way to non-suburban train line platforms, metro and monorail terminal. This information should be provided just before using the bridge/ subway/ skywalk and while on it *(Novel)*.

b) Further availability of lift/ escalator/ ramp/ staircase/ ramp cum staircase at each turn of the foot over bridge, subway and skywalk should also be communicated so that they can select the path on the station *(Novel)*.

c) This information should be provided through existing mobile applications such as M-indicator. The station map on the m-indicator app can be updated with this information *(Novel)*.

d) It is also proposed that braille stickers be placed on the top and bottom of the railing edges of the bridge, subway and skywalk, orienting people with visual impairment (APTA, 2020). Anuprayaas NGO, has initiated installing braille stickers with platform numbers on the handrails of the bridges of Mumbai local train stations in 2019.

The same intervention can be extended to guide PVIs at each decision regarding FOB, subway, and skywalk *(Modified)*.

6.5.3.3 Provide path guidance to reach foot over bridge, subway.

a) Provide a tactile path connecting the pathway on the platform to subways and the foot over bridges for wayfinding without deviation for people with vision impairments (APTA, 2020, Ministry Of Railways, Govt. Of India, 2023a) *(Existing)*.

6.5.3.4 Ensure the safety of commuters while using foot over bridge, subway and skywalk.

a) Design visual and tactile signs instructing people to stay on the right side when going up or down the bridge to reduce collision and improve pedestrian flow. The tactile sign can be placed on the handrail *(Novel)*.
b) Tactile warning titles should be installed at all different types of connectors, such as staircases/ ramps/ ramp cum staircases/ lifts/ escalators, of the foot over bridge/ subway, both at the beginning and the end (APTA, 2020); Ministry Of Railways, Govt. Of India, 2023a). Further, such indicators should also be provided during the ramp and staircase transition *(Existing)*.
c) Foot over bridge/ skywalk/ subway should have railings from the floor level on both sides. (APTA, 2020) *(Existing)*.

6.5.3.5 Lifts

a) Accessible lifts should be provided (Ministry Of Railways, Govt. Of India, 2023a; Raheja, 2021) to comfort commuters while entering the station building. Accessible lifts are proposed to save time and improve the convenience of people with disabilities *(Existing)*.

6.5.3.6 Ramps

a) Ramps are an ideal solution for vertical circulation. They require no mechanical devices, special knowledge, or language skills, making them intuitive and accommodating for many users. While ramps may impede rapid transit flow, they reduce the risk of accidents compared to stairs and escalators and can handle heavy traffic (APTA, 2020). Integrate ramps into the

central circulation path, providing continuous railings, even illumination, and extra resting space on landings. Ramps should have running slopes below regulatory maximums to accommodate diverse users and maintain consistent width and slope. Edge protection is also crucial for safety (Raheja, 2021; APTA, 2020) *(Existing)*.

b) Provide full ramps instead of ramp cum staircases on new station sites for improved accessibility *(Novel)*.

6.5.3.7 Staircase

a) Design stairs with the following provisions to enhance safety (Raheja, 2021; APTA, 2020) *(Existing)*:

- Make stairways wide enough for intermediate railings to accommodate opposing traffic.
- Ensure stairs have user-friendly riser heights and tread widths. Maintain consistent width for stairways.
- Stairs and steps should be designed with the leading edges, i.e. nosings with the contrast in colour and value with the riser and tread. Use yellow and reflective nosing strips at the edge of each step to avoid tripping for people with low vision (Raheja, 2016; National Institute of Building Science, 2015). Consider using photoluminescent stair nosing for visibility in low light or smoky conditions (APTA, 2020).
- Design the underside of the stairway to be free of overhanging hazards and include cane-detectable objects to prevent overhead obstructions.
- Ensure sufficient lighting along stairs to avoid dark areas.
- Design exterior stair treads and landings to prevent water accumulation.

6.5.3.8 Handrails

a) Compliance with building codes necessitates handrails on stairs and ramps. Handrails support horizontal surfaces and corridors, aiding individuals with walking or breathing impairments (APTA, 2020) *(Existing)*.

b) Concealed lighting can enhance handrails for wayfinding and safety (APTA, 2020) *(Existing)*.

c) Recommended best practices include crafting easily graspable grips, ensuring continuity on multi-sectional ramps and stairs, accommodating diverse user needs with varying heights, and enhancing accessibility for the visually impaired through textured designs conveying information (Raheja, 2021; APTA, 2020; National Institute of Building Sciences, 2020) (Figure 6.4) *(Existing)*.

d) Contrastingly colored railings in circulation areas aid individuals with low vision to locate them more easily (National Institute of Building Sciences, 2020) *(Existing)*.

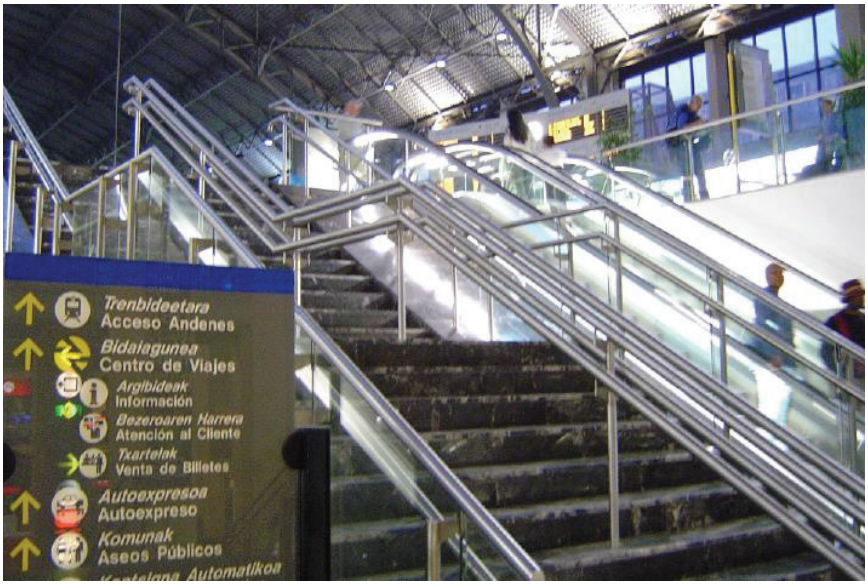


Figure 6.4 Handrails at varying heights to accommodate users, San Sebastian Central, Spain (APTA, 2020)

6.5.4 Platform Use

6.5.4.1 Enable identification and differentiation of one platform from another

a) Every platform should have a distinct numeric identity; overlap, such as platform numbers 1 and 1A, should be avoided *(Novel)*.

b) Enable platform identification through non-visual mediums for people with vision impairments (Anuprayaas, 2019) *(Existing)*.

c) Platform signage should be visible to the commuters landing on the platform using the foot over the bridge/ subway *(Existing)*.

d) Use the colour codes of different train lines on platform identity signages and other signages for easy identification (Standard Signages at Stations on Indian Railways, 2023) *(Existing)*.

6.5.4.2 Provide orientation about the positioning of station facilities on each platform

a) Install platform-specific overhead visual signs in line of sight of people ascending or descending from the bridge/ subway about the direction to avail station facilities such as food stalls, drinking water, toilets, help desks, etc. *(Existing)*.
b) Line drawing of the platform layout, as mentioned in the guidelines of Network Rail (2022), showing the order of positioning of station facilities should be displayed using braille on the poles or leaning handrails installed on the platform *(Modified)*.

6.5.4.3 Provide orientation about the train route of the upcoming trains on different platforms.

a) Install platform-specific overhead visual signs in line of sight of people ascending or descending from the bridge/ subway *about* the direction to avail station facilities such as food stalls, drinking water, toilets, help desks, etc. *(Existing)*.
b) Line drawing of the platform layout, as mentioned in the guidelines of Network Rail (2022), showing the order of positioning of station facilities should be displayed using braille on the poles or leaning handrails installed on the platform *(Modified)*.
c) Provide digitally updated train route maps of the upcoming trains (Auckland Transport, 2018) on crucial decision points such as station entry and ticket hall (Figure 6.5).
Modification: The digital sign should have multi-lingual language options



Figure 6.5 Digital train route map (Signage and Wayfinding Design Guide, Auckland Transport, 2018)

6.5.4.4 Provide orientation about the positioning of coaches on the platform.

a) Ensure consistency in the number of train coaches and coach orders for all suburban trains parking on the platform *(Novel)*.

b) If the coach composition is different for the trains parking on the specific platform, implement a real-time updated dynamic coach signage system on platforms where trains of more than one type of coach order park. Static coach signage may be provided on platforms where only trains of one coach order parks (Novel).

c) Ensure every coach waiting area should be earmarked on the platform with visual signage and non-visual design intervention. This allows people with vision impairments to choose the coach they want to board *(Novel)*.

d) As a current practice, sound beepers are installed on the platform to earmark the waiting area of the coach reserved for PwDs. Though they are very useful to people with no vision in detecting the waiting area on the platform, the sound beeper often does not work. In such cases, an additional social cue, such as a cobbler, can be deployed in front of the PwD coach waiting area to provide a distinctive sensory signal through polished smells and brush sounds for easy identification. Otherwise, ceiling fans can also be deployed at all waiting spots of PwD coaches on the platform. The air temperature change acts as a cue for the waiting area. Such objects and/or social cues should be consistently deployed at all waiting areas of all stations' platforms to offer consistency *(Novel)*.

e) Deploy a help desk at the intersection point between each foot over the bridge/subway and platform to guide people *(Novel)*.

f) If the coach composition is different for the trains parking on the specific platform, implement a real-time updated dynamic coach signage system on platforms where trains of more than one type of coach order park. Static coach signage may be provided on platforms where only trains of one coach order parks *(Novel)*.

g) Ensure every coach waiting area should be earmarked on the platform with visual signage and non-visual design intervention. This allows people with vision impairments to choose the coach they want to board *(Novel)*.

6.5.4.5 Ensure safe navigation on the platform.

a) Provide obstruction-free, directional tactile paths (Raheja, 2021; APTA, 2020) on all platforms at railway stations for people with vision impairments (Ministry Of Railways, Govt. Of India, 2023a). The path should be easily detectable with a cane. It should be designed to avoid obstacles like furniture, poles, girders and shops *(Existing)*.

b) All the existing and new upcoming platforms should be raised to a level of the train coach footboard for seamless transfer (APTA, 2020, Ministry Of Railways, Govt. Of India, 2023a) *(Existing)*.

c) Implement warning floor tiles to earmark platform edges for the safety of people with vision impairments (Ministry Of Railways, Govt. Of India, 2023a) *(Existing)*.

d) The platform edges may be painted with colour strips in high contrast to the floor colour to ensure safety for persons with low vision and others while boarding the train or otherwise (Ministry Of Railways, Govt. Of India, 2023a) *(Existing)*.

e) Paint structural elements of the foot over bridge underside, like girders, columns and poles, in contrasting colours for enhanced visual contrast to prevent could become a head-bumping hazard for commuters with no vision and low vision (National Institute of Building Sciences, 2015, Ministry Of Railways, Govt. Of India, 2023a) *(Existing)*.

f) Install anti-skid tiles on the platform surface to avoid slipping (Ministry Of Railways, Govt. Of India, 2023a) *(Existing)*.

6.5.4.6 Provide Leaning rails and Seating.

a) Leaning rails benefit space-constrained transit facilities, cater to standing individuals, and offer comfort for extended periods. They are not a complete seating replacement, but they are commonly used in stations with limited space. Best practices involve installing rails at waiting areas like platforms and ticketing areas and incorporating various heights for accessibility (APTA, 2020). These rails will also provide a reference and support to people with mobility requirements, including people with vision impairment, who need to walk on highly crowded platforms (Figure 6.6) *(Existing)*.

b) Seating materials must be non-absorbent, contamination-resistant, easily cleaned, smooth but not slick, and vandalism-resistant. Best practices include accommodating diverse body sizes, sturdiness against vandalism, and intermittent placement along circulation paths on the platform (APTA, 2020) *(Existing)*.

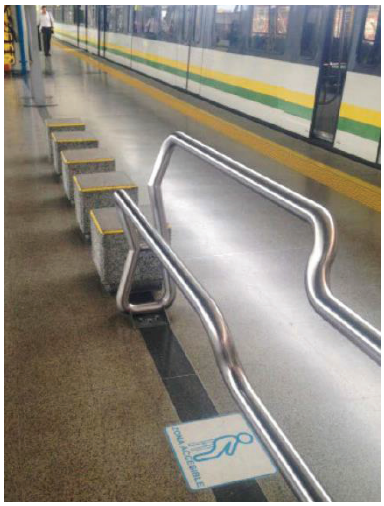


Figure 6.6 Leaning rails with multiple heights, Medellin Metro, Colombia (APTA, 2020)

6.5.5 Station Facilities and Services

6.5.5.1 Create awareness about the station facilities and services.

a) Share detailed station-specific updated information on facilities and services available at each railway station and suburban train station through the Mumbai Suburban Railways website and digital applications such as Rail *Madad* (Help), M-indicator, and Rail *Yatri* (Passenger) or through a dedicated mobile app containing information for all amenities for people with disabilities (Ministry Of Railways, Govt. Of India, 2023a). The web page should verbally describe station and train features with special provisions for people with special needs (APTA, 2020) *(Existing)*.
b) Represent their deployment through symbolic representation on visual and tactile maps and signages on stations (Ministry Of Railways, Govt. Of India, 2023b) *(Existing)*.
c) All the doors of the station services, such as the Railway Police Office, Station Master Office, Ticket vendor's office, and toilet stall, shall be identifiable by commuters with low vision using high contrast with the surrounding walls in material, colour, and value to make them more easily identifiable. Place well-lit room numbers and graphics for easy readability. If a door has the same finish on both sides, add a contrasting color on the leading edge to help individuals with low vision identify if the door is open, preventing collisions (National Institute of Building Science, 2015) *(Existing)*.

d) *Sahayaks* at the Help Desk should be trained to address queries related to station services, facilities and trains *(Novel)*.

6.5.5.2 Toilets

i. Provide consistent deployment of toilets for different commuter types.

a) To ensure predictability, each station should have a standardized deployment of toilet stalls inside the railway station building (APTA, 2020) *(Existing)*.

b) There should be a minimum of two toilet stalls for males and females at both ends of all platforms. People with disabilities should be allowed to use the platform's general male and female toilets *(Novel)*.

c) A tactile guiding path (Raheja, 2021; APTA, 2020) is proposed for toilet blocks on all platforms *(Existing)*.

d) Additionally, a toilet dedicated to Persons with Disabilities (PwDs) with step-free access (Ministry Of Railways, Govt. Of India, 2023a) should be located near one prominent station entry and exit point on both the east and west side of the station building. A tactile guiding path (APTA, 2020) is also proposed for reaching these facilities *(Existing)*.

ii. Provide path guidance to locate toilets.

a) Commuters should be directed towards the toilets with the help of visual and non-visual directory signage on station facilities deployed on each platform *(Novel)*.

iii. Ensure identification of toilet stalls

a) Provide standardized audible signage to differentiate toilet stalls based on gender and disability. People with disabilities should be allowed to use the general male and female toilets along with special toilets dedicated especially for them *(Novel)*.
b) Provide a caretaker for toilet management throughout working hours. The caretaker should be trained to guide disabled people to the preferred toilet stall. Caretakers for male and female toilets should be gender specific. A lady caretaker should be deployed to manage female toilets and assist female commuters *(Novel)*.

6.5.5.3 Drinking Water Facility

i. Enable location and identification of drinking water facilities.

a) Provide drinking water on each platform near the waiting area of the PwD coach for easy access to people with disabilities. Additionally, the drinking water facility may act as an object marker to locate the PwD coach *(Novel)*.

b) Drinking water points should be made accessible to people with vision impairments (Ministry Of Railways, Govt. Of India, 2023a) *(Existing)*.

c) Install a sensor with the sound of the water on the drinking water facility to make it detectable by commuters with vision impairment *(Existing)*.

d) The contrast value for its drinking water basin and waterspouts can be improved by using highly reflective paints for visibility by people with low vision *(Existing)*.

e) The drinking water facility should be earmarked with a visual identification (Ministry Of Railways, Govt. Of India, 2023a) and directional sign on each platform for recognition by sighted commuters *(Existing)*.

6.5.5.4 Dustbins

i. Identification of Dustbins

a) Dustbins should be visible in form, colour, and value contrast with the surroundings and adjacent glazed areas at a height of not less than 1 m (National Institute of Building Sciences, 2015) and be placed offset from the tactile path on the platform to prevent a collision or falls *(Existing)*.

b) Dustbins should be detectable by commuters with visual impairments *(Novel)*.

6.5.5.5 Help Desks

i. Create awareness about the purpose of the help desk.

a) Provide information about the purpose and role of the helpdesk through existing digital platforms like the Rail *Madad* mobile app *(Novel)*.

ii. Guide people to the help desk

a) The location of the Help Booth shall be near the entry/exit of the railway station and prominently identifiable by signage for ease of assistance to persons with disabilities and others (Ministry of Railways, Govt. Of India, 2023a).

Modification: At each railway station, a help desk should be deployed at key decision points such as each platform, bridge/subway intersection, station entry/exit, and inside each ticket hall. Their deployment should be standardized for all suburban stations for easy prediction by all people, especially those without vision.

b) The visual identity of the help desk should be designed and tested to ensure that it is understandable for its purpose and accessible by commuters independent of familiarity, vision and literacy level *(Novel)*.

c) Install a sound sensor to make the help desk detectable by people with no vision *(Novel)*.

d) The *Sahayaks* should be uniform, distinguishing them from other rail staff and general commuters *(Novel)*.

iii. Increase the usefulness of the helpdesk service.

a) Ensure two *Sahayaks*, one male and one female, are deployed at each desk to ensure that female commuters are comforted while asking for help *(Novel)*.

b) Manning of the help booths is to be done by any NGO working in the field of disability-free of cost. The said manpower should be given basic training on railway systems like ticketing rules, facilities for people with disabilities etc., by the Railways who will guide and assist PwDs. If no NGO is forthcoming for providing free manpower to be deployed in the Help Booths, then the possibility to be explored for outsourcing manpower for manning of Help Booths. The provision of assistance at Help Booths in such cases on a to-be-chargeable basis (Ministry Of Railways, Govt. Of India, 2023a)

Modification: A person with vision impairment should be employed as a Rail *Sahayak* to escort commuters with vision impairments as a Railway staff. Training should be provided to Help Desk *Sahayaks*, both sighted and those with VI, on communicating in the following languages: Hindi, English, Marathi, and sign language. They should be trained to give verbal directions to people

with vision impairment. Further, they should be taught station infrastructure, amenities, layout, travel rules, and regulations.

c) Provide a printed and braille-embossed portable map to the *Sahayaks* to guide people using a map (Ministry Of Railways, Govt. Of India, 2023b) *(Existing)*.

d) Ensure that the Help Desk Sahayaks are available throughout the operational hours of local trains on a rotation basis *(Novel)*.

6.5.5.6 Introduce the service of Personal Rail *Sahayak Service*

a) Like porter services available in NSG stations to carry passengers' luggage from station entry to train and vice versa, both NSG and SG train stations should launch a new service called '*Personal Rail Sahayaks'*. The role of such a person is to provide physical assistance to commuters in need *(Novel)*.
   - Provision of such personal assistance will be on a chargeable basis fixed by Railways.
   - A male and a female person with and without vision impairment should be employed as a Personal *Sahayak*.
   - Ensure such *Sahayaks* are available in shifts throughout the working hours of the train service.
   - Unlike help desk *Sahayaks,* as recommended *in the guidelines of Indian Railways, 2023*, personal *Sahayaks* should be equipped with mobility aids such as canes, wheelchairs, and crutches to assist people with mobility requirements. They require training to help commuters, such as pregnant women, individuals with babies, those with vision or mobility impairments, and senior citizens. This assistance involves guiding commuters from one point to another within the station, helping them board taxis or autos, assisting with ticket purchases, facilitating train boarding and disembarking, etc. *(Modified)*
   - Training should be provided to *Sahayaks* to communicate in the following languages: Hindi, English, Marathi, and sign language.
   - They should be in a specific uniform so that they are recognisable and distinguished from other rail staff and general commuters.
   - Commuters in need can book a *Sahayak* based on gender and vision through the 'Rail Madad' app.

- Once the service is launched, awareness needs to be created amongst the commuters about the service using various onsite and online modes of information dissemination such as the *Rail Madad* App, advertisements, social media platforms, etc.

6.5.6 Train Boarding & Disembarking

6.5.6.1 Provide real-time updated information on the upcoming trains.

a. Implement "real-time" visual message systems and public address announcements at station entries to notify users of delays or interruptions, providing timely information before fare gates and boarding platforms (APTA, 2020). Train- indicators display real-time visual information about the upcoming trains on the platform. Public Announcements provide the information in audio format *(Existing)*.

6.5.6.2 Train Indicators

a. Train indicator design should be designed to be comprehensible by unfamiliar-sighted commuters and for readability by people with vision. It should display the following information about the upcoming trains: Arrival time, slow/ fast/semi-fast train, platform number, and full name of first and last station stop. The display can be colour-coded as per the upcoming train line colour. The use of abbreviations is proposed to be kept to a minimum. Further abbreviations should be easily understandable. These indicators should be installed at each decision point, such as platforms, Foot over bridges/ subways, ticketing zones, and station entry points (Ministry Of Railways, Govt. Of India, 2023b) *(Existing)*.

6.5.6.3 Public Announcements

a. Public announcements should provide updated information about upcoming train platform numbers, timing and train type. If there is any delay in the expected arrival time of the upcoming train, that information should be broadcast both on the affected platform and the train *(Novel)*.

b. Communicate delays and platform changes on affected platforms and trains, preferably using a female voice over a male voice *(Novel)*.

c. Install speakers strategically at platform ends for widespread public announcement coverage in the station *(Novel)*.

d. Optimal public address system design includes clear and pleasant voices, whether digital or live, compensating for noise by using closely spaced speakers instead of increasing volume with fewer speakers (APTA, 2020) *(Existing)*.

6.5.6.3 Enable identification of train coaches

a. Each coach should assign a unique identity as part of the identity system. The identity of each type of coach of suburban trains should be tested for comprehension, visibility, and readability by commuters with literacy, vision and familiarity levels *(Novel)*.

b. Install braille signage on the grab bars at the entry of each train coach to enable recognition by people with vision impairments (Ministry Of Railways, Govt. Of India, 2023a) *(Existing)*.

c. Ensure consistency in the visual language of the coach between the signs on train coaches and platforms' coach signs to prevent confusion *(Novel)*.

d. Disseminate updated information about Mumbai's local train coach typologies, boarding criteria, and nomenclature system for the knowledge of novice commuters with and without vision impairments through mobile applications, websites, and onsite information sign systems *(Novel)*.

6.5.6.4 Provide a safe boarding experience for all commuters.

a. Every local train in future should have an automated door-closing feature for all train coaches for the safety of all commuters *(Novel)*.

b. A tactile pathway should be created to guide people with vision impairments towards the door of each train coach. The width of the pathway should be the same as the width of the coach entry *(Novel)*.

c. Ensure high accuracy in the train parking position so that the coach entry aligns with the platform's tactile pathways (APTA, 2020) *(Existing)*.

d. Install audio and a visual timer on the coach's exterior and interior interface to inform boarding and disembarking commuters of the time left for the train to depart *(Novel)*.

e. Minimize, to the greatest extent possible, the horizontal gap between the transit vehicles and the boarding platform, particularly rail vehicles, to increase ease of access for all users, especially people with vision impairments, wheelchair users, walking aid users, and those with luggage (APTA, 2020) *(Existing)*.

f. Provide barricades on the platform to safeguard people with vision impairments and others who fall in the gap between the coaches *(Novel)*.

g. Provide a Railway Staff at the platform to ensure safe boarding of eligible commuters in the coach for PwDs and restrict boarding of general commuters in the coach other than escorts travelling with a person with a disability (Ministry Of Railways, Govt. Of India, 2023a) *(Existing)*.

6.5.6.5 Provide a comfortable and safe train commuting experience.

a. Provide information through public announcements to alert commuters in emergencies like accidents, natural calamities, unusual delays, etc., both on the station and inside the train *(Novel)*.

b. Safety protocols inside the train coaches should be accessible to all commuters. Such information signages should be tested for their reliability and comprehensibility. The safety protocols for train commuting should also be uploaded on the Mumbai Suburban train mobile applications *(Novel)*.

6.5.6.6 Provide a safe train disembarking experience.

a. The public announcement system inside the trains should inform passengers in each train coach about the upcoming station names, platform numbers, and disembark directions before arrival *(Novel)*.

b. The digital train route map should be deployed inside each coach to inform the real-time position of the train and upcoming stations *(Novel)*.

c. Offer real-time updates via public announcements regarding the train's current location—whether at a platform or a signal. This ensures that visually impaired commuters know when to disembark *(Novel)*.

d. Station names may be displayed at the platform's start and end, perpendicular to the tracks, for visibility to arriving travelers and those on the platforms. (International Railway Solution, 2021; Network Rail, 2022; Ministry Of Railways, Govt. Of India, 2023b) *(Existing)*.

e. Provide a real-time station display depicting the correlation of train coach position and platform circulation system (Figure 6.7) (APTA, 2020) *(Existing)*.

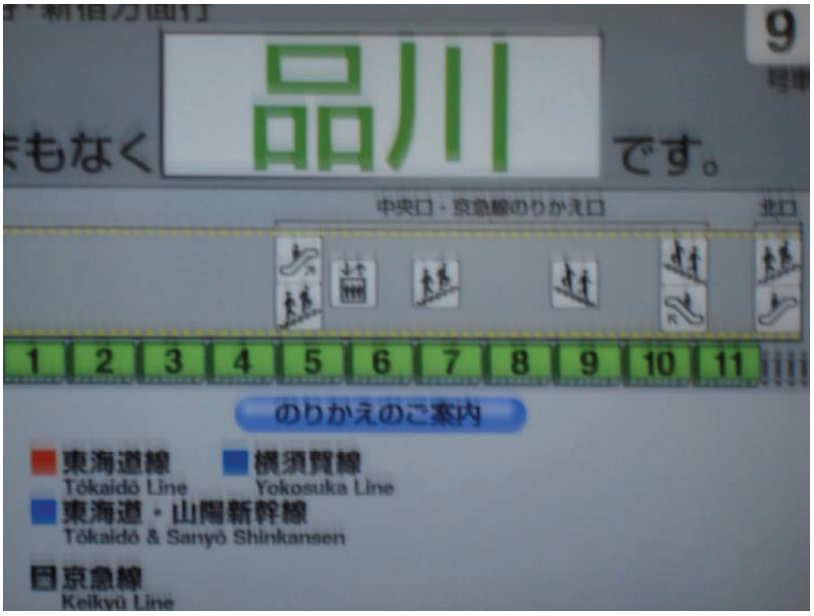


Figure 6.7 A real-time station display on the train depicting the correlation of train position and platform circulation points at Tokyo Metro Station, Japan (APTA, 2020)

Non-Stage Specific

This stage provides guidelines for more than one wayfinding stage related to station and train use and beyond.

6.5.7.1 Provide information about Station rules – behavioural

a) Provide information about station rules through physical signs, outlining expected behavior with the use of 'do not' messages for enhanced effectiveness and a sense of safety (Auckland Transport, 2018, Ministry Of Railways, Govt. Of India; 2023b). They can be typically implemented inside the station building. The same rules can be updated on the existing Mumbai Suburban Rail applications, such as the MRVC website and mobile apps, such as UTS, M-indicator, Rail *Madad*, and M-indicator *(Existing)*.

b) Commuters should be directed to a different route when any station site location is undergoing construction with the help of signage such as No-Entry, Do not Cross, Caution, No Access Beyond this point, Authorized personnel only beyond this point (Auckland Transport, 2018).

Additionally: The help desk should be stationed at such sites to direct people to a new path. Such signs should also control rail track trespassing behavior *(Modified)*.

6.5.7.2 Design opportunities for people with vision impairments to learn the train commuting system offsite.

a) Inculcate the ability to wayfind in Mumbai Suburban Railways among children and or adults with vision impairments who have lost eyesight since birth or are losing eyesight at a later age through tactile educational or play aids. Aids can educate children and/or adults who lose eyesight later about the general station layout, train coach composition, eligibility coach orders, etc., before using the commuting system *(Novel)*.

6.5.7.3 Create awareness among various stakeholders on how to guide PVIs in their wayfinding.

a) There is a need to sensitize various stakeholders on verbally and physically assisting individuals with visual impairment in Mumbai's suburban stations *(Novel)*.
   - Rail *Sahayaks* deployed at the help desk and as personal escorts.
   - Front-line station staff who directly interface with the commuters, such as toilet caretakers, water facility service providers, Railway Policy staff, etc.
   - Shopkeepers, cobblers, and vendors should also be sensitized to verbally assist commuters with vision impairment.
   - General sighted commuters

The training and sensitization through workshops, social media, etc., is a must for Rail *Sahayaks*, front-line staff, followed by other service providers such as shopkeepers, cobblers, vendors, etc, and train commuters.

6.5.7.4 Create identity markers for PVIs to increase their visibility in the crowd.

a) Create an identifying marker for people with vision impairments to make them recognizable. The design can be extended to vulnerable commuters weak in mobility, such as those with mobility impairments, senior citizens, and pregnant women *(Novel)*.

The purpose of these markers is:

- To attract Rail *Sahayaks* among commuters for help when needed, especially in case of emergency.
- To alert sighted commuters to be mindful of their rushed body language and avoid collision with such commuters.

6.5.7.5 Ensure Safe Navigation

a) Restrict vendors from setting up their stalls in busy areas inside the station building, such as footbridge, subways, ticket halls, and station entry points, to avoid slowing down traffic, especially during peak hours *(Novel)*.

i. Flooring

a) Avoid building steps for floor transition at the station entrance, ticketing, and platform area. Use reflective paint with handrails to build curbs with contrasting colours and value (Raheja, 2021; Ministry Of Railways, Govt. Of India, 2023a; National Institute of Building Sciences, 2015) *(Existing)*.

b) Ensure all floor level changes inside the railway station, such as ramps (Raheja, 2021, Ministry Of Railways, Govt. Of India, 2023a), staircase, ramp cum staircase, lift, and escalator, should be marked with tactile floor indicators both at the beginning and end to warn visually impaired commuters and prevent tripping incidents. A tactile path facilitates navigation for vision-impaired users using canes on surfaces with textures, raised elements, and audible features. It may include colour contrast for low-vision users. Differentiated from warning surfaces, tactile paths can pose challenges for wheelchair users, people with mobility devices, stability issues, high-heeled shoes, and wheeled luggage. Hence, they should be narrowly defined with clear reconnection points. Discontinuities should be avoided. Consistency in material, width, colour, beginnings, endings, and decision points is key. Awareness and training on the purpose and placement of tactile paths within a station layout are essential for novice commuters with no vision. Priority should be given to

implementing tactile paths that lead to station entry to the ticketing area and foot over the bridge/ subway to platforms. Encouraging the development of state or national standards for tactile paths, involving the disabled community, and rigorous testing is crucial (APTA, 2020) *(Existing)*.

c) All walking surfaces in various station areas, such as the ticket hall, foot over bridge/subway, path to station entry and exit and platforms, should provide glare-free and non-slip surfaces, avoiding surfaces like gravel, sand, stone, brick, concrete blocks, and grates, free from the presence of any potholes, open manholes, protrusions and floor damage (Raheja, 2021; APTA, 2020; National Institute of Building Sciences, 2015). It is recommended that paving is of medium-dark colour value and not glaringly reflective (National Institute of Building Sciences, 2015), especially on platforms where reflections of sunlight into the building could add to glare for commuters with low vision *(Existing)*.

d) Ensure that the station interior environment remains as dry as possible during the monsoon season by providing drainage in different station parts and extended roof protection *(Novel)*.

ii. Lighting

a) The lighting in office rooms, passages, stairs, open areas, etc., shall be provided as per established norms and appropriately positioned (Raheja, 2021, Ministry Of Railways, Govt. Of India, 2023b). Ensure adequate lighting at station entry/exit points, ticket halls, foot over bridges, subways, skywalks, throughout the platforms and train coaches after sunset for enhanced safety and security of commuters, eliminating strong shadows. Illumination inside the station building should generally be consistent day and night for a consistent visual experience. Older adults and those with low vision have longer adaptation times when moving from bright to dim lighting areas and vice versa. Therefore, a smooth transition should be ensured from the bright light of an outdoor space to an indoor space (APTA, 2020). Avoid lighting placement that shines directly into commuters' eyes (National Institute Of Building Sciences, 2015) *(Existing)*.

b) Distinct value contrasts in environments are crucial for safely navigating spaces. This is particularly important in circulation areas, where it helps define changes in level, surfaces, and objects from their background. Designing for individuals with low vision should consider surface characteristics such as value, sheen, texture, and pattern (National Institute Of Building Sciences, 2015) *(Existing)*.

6.5.7.6 Improve the existing visual signage system.

a) Digital signage is increasingly employed for station wayfinding and should be gradually integrated with other wayfinding elements. The benefits of digital wayfinding include flexible messaging, seamless integration of customer information, and easy connection to the commuter information database. As digital information becomes more common, consider screens to be made inclusive to be used by people with different heights, language backgrounds, quality of vision, etc. (Network Rail, 2022; Ministry Of Railways, Govt. Of India, 2023b) *(Existing)*.

b) It is crucial to separate digital advertising from wayfinding information visually. To ensure clear wayfinding, a balance is needed between maintaining the legibility of station and train signage and incorporating advertisements for retail, promotions, and publicity. Wayfinding signage must prioritise visuals over advertisements (APTA, 2020). Wayfinding and advertising should not be combined on the same sign, and ads should not obstruct, obscure, or distract from station wayfinding or signage (International Railway Solutions, 2021). Dedicated spaces inside the station building and the train should be allocated for the visual ads, ensuring no visual clutter. Further, the colours chosen for commercial boards shall not interfere with the wayfinding signages. (Network Rail, 2022; Ministry Of Railways, Govt. Of India, 2023b).

   Addition: Avoid placing advertisements on the train interface to increase the coach signage's visibility. The interface of the ticket windows should be free from the visual clutter of excessive information advertisements and commercial hoardings/ boards *(Modified)*.

a) Update and maintain the visual sign system to match the changes made to the station layout, train compositions, or coach order. Remove outdated signs to prevent confusion and errors *(Novel)*.

b) The visual sign system design should be tested for comprehension and readability by people with low vision. Other vision impairments, such as colour blindness, should also test the sign system. Further, people with lower literacy levels should also test the visual sign system *(Novel)*.

c) Ensure signage accommodates varying user heights by using large overhead signs for distant visibility. Place both overhead and eye-level signs at boarding platform entrances with prominent type to confirm correct vehicle boarding. Integrate wayfinding into

architecture and site design as a core element, avoiding it as an afterthought. Utilize floor signs or graphics for enhanced wayfinding, which is particularly beneficial for shorter individuals (APTA, 2020) *(Existing)*.

d) Maintain uniform graphics and formatting across the transit system to establish a distinct regional identity. Specify consistent characteristics for signs, including size, shape, colour, content, format, information hierarchy, installation method and location, and construction materials (APTA, 2020) *(Existing)*.
e) Employ succinct text and universally understood symbols for effective communication across language barriers (APTA, 2020) *(Existing)*.
f) Reiterate wayfinding signs along the route, especially at decision points (APTA, 2020) *(Existing)*.
g) Enhance signage with multilingual brochures, audio, and videos for comprehensive guidance (APTA, 2020) *(Existing)*.
h) Ensure regular audit of the working of all digital, electric or electronic devices and signages *(Novel)*.

6.5.7.7 Special Consideration of Signage for People with Vision Impairment.

a) There is a need to sensitize people with vision impairments towards braille and audio signages installed in different station parts through mobile applications and other non-tech ways *(Novel)*.
b) Signs are more legible for people with low vision when characters contrast 70% with their background with a Light Reflectance Value (LRV). Lettering and other graphics should be monochromatic white information in the black fields because many persons with low vision have some degree of colour blindness and difficulty with low contrast (National Institute Of Building Sciences, 2015) *(Existing)*.
c) Raised or incised lettering that does not contrast in colour or value with the surrounding field is not recommended for use by persons with low vision. Shadows may confuse rather than enhance visibility (National Institute Of Building Sciences, 2015) (Existing).
d) Sign surfaces should be shielded from the light source to avoid reflected glare. Internally illuminated or backlit signs may be difficult for persons with low vision due to glare (National Institute Of Building Sciences, 2015) *(Existing)*.

e) Do not use multiple colours or flashing messages (National Institute Of Building Sciences, 2015) *(Existing)*.

6.5.7.8 Provide an interactive voice-response system to address queries of commuters.

a) Create a provision for the interactive voice-response system to address the queries of commuters, such as those with basic phones. This service should be crucial in assisting commuters in preparing and planning for the journey, especially for those with vision impairments. Pre-visit information should advise commuters, including those with vision impairments, on issues such as intermodal transport connectivity from each station site, preferred entry into the site, different ways local train tickets can be purchased, availability of services and facilities at the station, etc. The integrated railway helpline (139) and Rail *Madad* mobile app services should be extended to provide wayfinding information related to different stations and trains *(Novel)*.

6.5.7.9 Design an Online and offline feedback mechanism.

a) Online and offline feedback should be designed so that people with vision impairments can provide feedback or lodge complaints. The online mechanism is already integrated into the MRVC website, and apps like Rail *Madad* and Railway Helpline no. 139 are designed for all suburban stations. Offline feedback mechanisms can be regulated at the help desk or the Station Manager's Office (Ministry Of Railways, Govt. Of India, 2023a) *(Existing)*.
b) All complaints are to be directed to the designated officials of the concerned Railway for their appropriate redressal (Ministry Of Railways, Govt. Of India, 2023a). The complainant should be informed once the action is taken on the complaint *(Existing)*.

6.5.7.10 Increase the legibility of the station building using sensorial cues .

The legibility of the station building can be increased by systematically integrating sensory cues, such as tactile, auditory, olfactory, and air, that serve as route landmarks within the station building (National Institute of Building Sciences, 2015; Network Rail, 2022).

a) Smell-emitting plant creepers should be encouraged to recognise spatial zones and essential junctions such as foot over bridges, skywalks, station entry, and poles at the platform to

make such spatial zones easily identifiable by olfactory cues by people with vision impairments *(Novel)*.

b) Tactile murals on foot over the bridge and walls of the end platforms or any other accessible surface can be used to provide information about station use and empowering messages. Such murals can contribute to the aesthetics and legibility of the station zones for people with and without vision impairments *(Novel)*.

c) Sound-based installation may also help identify specific decision points for people with vision impairments. The sound can be regulated to ensure that it does not mask the audibility of the public announcements. Such installations can contribute to the overall aesthetic of the station building *(Novel)*.

6.5.7.11 Provide consistency in station building layouts and deployment of facilities and services.

a) Wherever possible, especially on new construction sites, consistency in station layouts should be provided (APTA, 2020).

   Modification: This includes the layout of the spatial zones and deployment of escalators, lifts, ramps and stairs, station facilities and services. This will help to reduce the cognitive load of remembering pathways in each station building.

6.6 Discussion

The above-stated guidelines were proposed after reviewing the Indian and International guidelines developed for the Rail transit system. As detailed below, a few similarities and differences are observed between the proposed and the existing guidelines.

The manual on Standard Signages at Stations on Indian Railways, Ministry Of Railways, Govt. Of India, 2023b mainly proposed guidelines on visual signage design. The design guidelines are chiefly designed for visual wayfinding by sighted commuters. Further, generic guidelines are proposed for integrating non-visual signages for people with vision impairments. The manual proposes guidelines for only colour considerations for low vision in the signage design. The guidelines mention the installation of tactile maps or models and braille signage. However, execution details regarding approach, content and deployment are not included in the guidelines proposed in the manual (Figure. 6.8).

1.1.3 Universal Accessibility:

- Contrasting colours should be used to differentiate the pictogram from the background. The commonly employed colours are white for the pictogram and blue for the background.
- The wheelchair figure should always be seen from drawn facing right.
- A tactile map or model is a useful way of providing information to visually impaired people and people with hearing impairments who wish to navigate around a building.
- Braille signage may also be provided along with all other signages. Audio/ visual Braille map is another important thing that can be provided at the main premises from where onwards, it shall guide the user to its intended location/facility.
- A tactile map shall be provided to the intended user at the Information counter which shall be helpful in providing information to visually impaired people and people with hearing impairments who wish to navigate around a building.
- Braille signage may also be provided along with all other signages at the stations. Audio/ visual Braille map shall also be provided at the station main concourse area at Information/Service counter and Help booths duly integrated with the tactile flooring as illustrated in the Guidelines for Divyangjan. Efforts shall be made to get frontline service staff trained in sign language in a phased manner.

Figure 6.8 Guidelines proposed in Standard Signages at Stations on Indian Railways, Ministry of Railways, Govt. Of India, 2023 for people with vision impairments.

The guidelines proposed in the manual on Standard Signages At Stations On Indian Railways, 2023, are limited to wayfinding in the station environment of Non-Suburban (NSG) train stations. They need to address the information needed to make the right decisions for stages like ticketing and foot-over bridge use, train boarding and disembarking of passengers.

The guidelines proposed in this thesis are highly detailed, exhaustive, and holistic, guiding the design of sign system content and deployment plans for people with visual impairment and sight for each wayfinding stage at railway stations and local train travel.

The proposed guidelines address the unique wayfinding challenges specific to Suburban (SG) Trains and stations, which are not stated in the guidelines on Standard Signages At Stations On Indian Railways, 2023 manual. For example, we proposed designing distinct identities for non-suburban and Mumbai local trains to distinguish ticketing zones where ticket zones sell tickets for both or any train ticket. Further, we have proposed designing an identification system for all the station entry-exit points. The identification system should include the station's cardinal directions- the eastern or western side as a social behaviour. All commuters differentiate station entry-exit points by cardinal directions.

Many guidelines proposed for NSG train commuting systems in the Standard Signages At Stations On Indian Railways, 2023 manual may not be suitable for suburban train commuting systems. For example, the manual on ‘Standard Signages At Stations On Indian Railways, 2023, proposed the installation of ‘You are here map’ on the platform, foot over the bridge and concourse, whereas our guidelines proposed their deployment in the ticketing area as the traffic is less and moves at a slow speed compared to foot over bridge. Hence, people will have the opportunity to wait and read the map.

In addition to the guidelines proposed on ticketing in the manual ‘Guidelines on the accessibility of Indian railway stations and station facilities for PwDs and passengers with reduced mobility, Ministry Of Railways, Govt. Of India, 2023, our guidelines stated the need for providing information support in braille on handrails of the ticket queue and through help desk deployed in the ticketing area on aspects like identification of ticket window, their operational timings and type of ticket/pass sold on each ticket window. Further, just giving priority to the disabled commuters in the general ticket queue is not enough as general-sighted people, due to lack of unawareness of special provisions for PWDs, quarrel with them for taking such benefits. Hence, our guidelines additionally propose the need for clear communication for special rules for People with Disabilities (PwDs) regarding travel concessions and queue-free ticket purchases through visual signage and the Unreserved Ticket System (UTS) app. Further, ticket vendors should be trained to attend to people with disabilities. Though we agree with the Ministry of Railways, Govt. of India (2023a) to induct PwDs ties respectfully, maintain harmony and avoid disputes in the queue. Like economically developed countries, India is

slowly progressing towards the automatic fare collection system (AFC) to minimise people's waiting time in long queues. However, a manual paper ticket purchase system from the ticket window is still prevalent in all suburban stations in India. Hence, distinct and unique guidelines are proposed to make the experience of buying a ticket from the ticket window accessible with the provision of desired information both for sighted and PVIs.

Unlike the 2023 Ministry of Railways Guidelines on accessibility for disabled individuals and passengers with reduced mobility at Indian railway stations, we emphasize the importance of orienting PVIs (Persons with Visual Impairments) regarding foot overbridge/subway connectivity to prevent wayfinding errors with the help of braille stickers on the handrails.

To improve wayfinding for PVIs on platforms, we have suggested specific guidelines, including a platform-specific tactile map indicating the arrangement of station facilities, services, and train coaches. Additionally, we have proposed deploying cobblers or ceiling fans in the waiting zone of the PwDs coach to offer a distinct sensory signal for identifying the coach's waiting area as an additional sensory cue to the sound beeper as many times they need maintenance.

Unlike the guideline on braille signs for toilet identification as stated in the 2023 Ministry of Railways Guidelines on accessibility for disabled individuals and passengers with reduced mobility at Indian railway stations, we have proposed an audible sign system for identification of toilet stalls based on gender and disability. Audible signs will allow detection of toilet stalls from a certain distance; our empirical research states that PVIs may not attempt to find Braille signs in areas like toilets, as their hands become dirty exploring and finding the sign locations, as also confirmed by the guidelines stated in APTA, 2020. In addition, our proposed guidelines are sensitive to the challenges women with and without vision impairment face while seeking help for directions to locate toilets. Our guidelines suggest the deployment of male and female toilet stalls on both sides of the platform for easy access. We also propose a toilet for people with disabilities and a unisex toilet near any station entrance on the eastern and western sides of the station. Furthermore, to assist people with disabilities, we have proposed a provision of toilet caretakers. For women's toilets, the presence of female caretakers is recommended.

In contrast to the Ministry of Railways, Govt. of India, 2023 guidelines for accessibility in railway stations, our guidelines emphasize raising awareness about help desk functionality

through digital mobile apps like Rail *Madad*. We advocate for standardized placement of help desks at all suburban train stations, making them predictable to locate by all commuters. In addition to visual cues, we propose non-visual indicators to enable identification by PVIs. Diverging from the Ministry's guidelines, ours recommend a diverse gender representation among help desk staff, offering commuters the option to seek assistance from staff they feel comfortable with.

Though we agree with the Ministry of Railways, Govt. of India (2023a) to induct PwDs as Rail *Sahayaks* from the NGOs working, we disagree with the Ministry that such services should be offered by individuals with disability free of cost. We think this is unsustainable in the long run as it will not have any accountability and may get discontinued due to a lack of motivation among individuals with disabilities towards such an offering. Voluntary services are offered by choice and should not be demanded. Hence, we suggest the induction of PwDs as Rail *Sahayaks,* outsourced from the NGOs (private bodies), where the Ministry of Railways and the Govt. of India (public body) invest public funds to outsource them on a contractual basis. The Ministry could develop the training programme in collaboration with the NGOs. The execution of the training may be the responsibility of the NGO. Local station authorities should ensure the accountability of the performance of the *Sahayaks.* Through such an approach, *we* emphasize creating work opportunities for individuals with disability rather than having them outsourced free of cost from the NGOs working in the field of disability as stated in the guidelines of the Ministry of Railways, Govt. of India.

Further, our guidelines emphasize improving the usefulness of help desk service by increasing the availability of help desk staff throughout operational timings of the trains, providing printed and embossed tactile maps with the Help Desk *Sahayaks* as a guiding tool, and distinctive uniforms for easy identification and differentiation with the Railway Police force and other station staff.

American Public Transit Association 2020 (Figure 6.9) & Signage and Wayfinding Design Guide, Auckland Transport, 2018 (Figure 6.10) guidelines specify the deployment of station agent courtesy phones. The service enables the passengers to communicate with the station agent using the phone service deployed throughout the station, such as ticket vending areas, elevator lobbies and platforms.

Such services may not be effective in extremely crowded and noisy environments, especially during peak hours. At railway stations in India, face-to-face help provided through

help booths or help desks is already available where Helpers *(Sahayaks)* are deployed to address passengers' and/or commuters' travel-related queries. Face-to-face address of an inquiry gives an added benefit of confirmation through verbal communication, facial gestures, and body language. However, such a service in its current state needs improvement. Our guidelines have proposed several directions to make the help desk service more effective.



Figure 6.9 Hands-free audio and visual intercom with kick panel activation, Los Angeles Metro, USA (APTA, 2020)

We have taken a step forward to strengthen human assistance by stating a need to introduce Personal Rail *Sahayak* Service at stations to physically assist people in need, such as PVIs, senior citizens, people with health conditions, etc. Unlike the latter, who assist commuters from a fixed station location, Personal Rail *Sahayaks* are paid escorts that offer physical assistance to commuters, including those with disabilities, from one point to another inside the station building. Both male and female sighted and non-sighted individuals can be hired for this service. The Ministry of Railways recommends that help desk *Sahayaks* be equipped with mobility aids, such as canes, wheelchairs, and crutches, for commuters inside the station building. However, our guideline suggests that Personal *Sahayaks* should provide such assistive

aids. If needed, they should help the person with a mobility aid, ensuring better accountability and proper use. Commuters may be charged extra for the use of assistive aids of Railways.

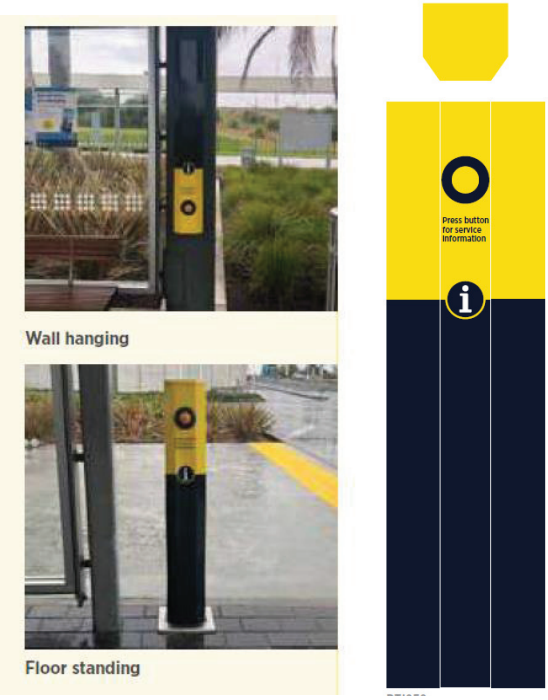


Figure 6.10 Audio Information Points (Signage and Wayfinding Design Guide, Auckland Transport, 2018)

Unlike the Ministry of Railways guidelines 2023, our guidelines emphasize disseminating updated information about Mumbai's local train coach typologies, boarding criteria, and nomenclature system inside the station building for novice commuters. Our guideline expands upon the Ministry of Railways guidelines, specifying that the Coach Position Display system must indicate the coach's position dedicated to PwDs at stations. We emphasize the requirement to recognize each coach of the Mumbai Local train, with information displayed on the platform and during boarding in visual and non-visual formats. This provision facilitates individuals with disabilities, including PVIs, to board their preferred coach, which may not be just the coach reserved for them. This proposed guideline emerged from our empirical research

where the participants with VI expressed the need to exercise choice to board the preferred coach beyond the coach reserved for PwDs. Instead of using the approach of public announcements only for the position of coach reserved for PwDs, as stated in the Ministry's guidelines, 2023, we propose using sound and/or tactile cues as a subtler approach for such an indication.

Our guidelines provide detailed recommendations for enhancing commuter safety during the entire train journey, addressing challenges PVIs face. Suggestions include installing audio and visual timers on the train's exterior and interior to inform passengers about the departure time, minimizing accidents. We also advocate for real-time updates through public announcements, informing visually impaired commuters about the train's location and when to disembark, significantly when the local train halts on tracks between two stations.

Our guidelines provide some distinct and unique approaches to wayfinding, such as the need to create design opportunities for PVIs (novice commuters) to learn to wayfind offsite using tactile aids. This approach will increase their awareness and develop their mental model and preparedness to use the commuting system. Tactile aids may focus on developing an exocentric view of SG train coach composition, eligibility criteria, coach order and railway station layout.

Unlike passengers' preference for independent travelling in economically developed countries, our study from India shows a considerable dependence of commuters on social wayfinding. Social wayfinding is an effective way to provide instant verbal help and physical assistance to people in need. In India, unlike other countries, people prefer to ask and give verbal help as well as physical assistance. Hence, this culture can be strengthened and made more effective by introducing design strategies to sensitize front-line railway staff such as help desk *Sahayaks*, toilet caretakers and ticket vendors, other service providers (cobblers, vendors, shopkeepers, etc.) and commuters on using appropriate verbal instructions and body language to guide sighted and PVIs. Such initiatives can later be extended to sensitize sighted people towards guiding commuters with hearing impairments.

Considering the challenges people with vision impairment encounter while navigating in highly crowded environments during peak hours, we also propose designing identity markers to increase the visibility of PVIs in the crowd. These markers aim to attract Rail *Sahayaks* among commuters for help, especially in emergencies, and to alert sighted commuters to be

mindful of their rushed body language and avoid collision with such commuters. Such design initiatives can later be extended to people with permanent or temporary mobility challenges.

We proposed several unique guidelines to make the first-time experience of the train commuters comfortable, such as proposing a need to design a system of identification for differentiating station entry-exit points. For new commuters with VI, we proposed a seamless non-visual orientation system through braille stickers on the foot handrails over the bridge/ subway. The proposal to strengthen the help desk and Personal Rail *Sahayak* service should play an instrumental role in the wayfinding of novice commuters, both with and without visual impairments.

Unlike the Ministry of Railways guidelines, 2023, we proposed several approaches to increase the legibility of the station building using sensorial cues using smell emitting plants and creepers, sound and tactile installations and public art.

The proposed guidelines will also help improve the wayfinding of other suburban commuting systems, non-suburban train commuting systems, metro and monorail. They are developed to offer choices to people for assisted and independent wayfinding depending on their ability, experience of use and psychological comfort. Hence, we have proposed measures to strengthen the wayfinding support system from multiple perspectives, such as visual and non-visual signage systems, minimal architectural modifications in the existing train and station infrastructure and the existing digital interfaces of websites and mobile applications and strengthening human assistance and related services. The proposed guidelines highlight the necessity for creating efficient visual, non-visual, and digital aids to convey spatial information.

The following section reviews the areas of design interventions for guidance and navigation for PVIs in India and the International context to map their appropriateness in the Indian context.

6.7.1 Review of Wayfinding Technologies

Technologies support a blend of the virtual and the physical interactions with the traveller for the cognitive and bodily aspects of wayfinding (Parker et al., 2021). Wayfinding design interventions are classified into three broad categories: personal travel aids, environmental aids and both personal cum environmental aids. Personal aids are portable, and environmental aids are installed inside the built environment. Different environmental aids for

wayfinding are used for indoor and outdoor environments. There are travel aids designed with hybrid portable technology that works with the technology embedded in the environment.

Personal aids are designed both for mobility and orientation. The most common devices are used as mobility aids and obstacle detectors. Such aids are generally limited to providing information about the nearby environment (Giudice & Legge, 2008). Environmental aids help one become acquainted with a geographical area or routes and find one's way from location A to location B (National Research Council, 1986; Tjan et al., 2005). There has been much technological development in both personal and environmental aids designed for mobility and orientation for people with vision impairments in outdoor and indoor environments. From passive, non-interactive technologies to dynamic technologies with interactive features (Crawford, 2013).

6.7.1.1 Personal aids

Personal assistive aids for individuals with visual impairments (PVIs) aim to enhance mobility (Senjam & Prasad, 2019). The white cane, introduced by Richard Hoover after World War II, is a widely used mechanical aid in India, detecting obstacles within a 3-foot range and serving as a symbolic indicator of blindness (National Research Council, 1986). While affordable, it has limitations, such as detecting obstacles only up to knee level and providing minimal time for preventive actions (Singh et al., 2010). Innovations, like the 'Smart cane' developed by the Indian Institute Of Technology Delhi in 2007, address these limitations using ultrasonic range, vibratory patterns, and improved obstacle detection (Singh et al., 2010). However, the 'Smart cane' lacks spatial orientation features, and the selling price is crucial for penetration in India due to the interlink between poverty and disability (Rao, 2009). In contrast to countries like the United States, where guide dogs are widely used, their adoption is limited in India due to social acceptance issues and restrictions to flights and trains (National Federation of the Blind, 2019). Considering the economic background of PVIs in India, mechanical white canes remain the most popular and affordable assistive aid for PVIs.

6.7.1.2 Electronic Travel Aids (ETA)

Over the past 70 years, researchers have developed electronic travel aids (ETAs) for people with vision impairments, spurred by advancements in radar and sonar during World War

II (Real & Araujo, 2019). ETAs serve as mobility and wayfinding aids, helping users detect obstacles and navigate from one point to another. The National Research Council, 1986, outlined key ETA requirements, including obstacle detection, travel surface information, and landmarks for wayfinding.

Despite ongoing efforts to improve ETAs, none fully meet users' expectations (Cardillo & Caddemi, 2019). Early models faced limited public acceptance, with around 3000-3500 units sold by 1985 (National Research Council, 1986). Initial designs focused on obstacle avoidance, leading to subsequent enhancements in weight, cost, and reliability. Sensory substitution devices using acoustics or haptics faced challenges due to cognitive load limitations.

Researchers developed navigation systems adapted for vision-impaired individuals in the 1970s and 1980s to address limitations. These systems integrated computer-modeled maps, sensors, and landmarks to guide users while avoiding obstacles. The advent of global navigation satellite systems, particularly GPS, in 1995 revolutionized navigation solutions for people with vision impairments, offering portability and independence without needing continuous floor contact.

6.7.1.3 Outdoor Navigation System

GPS-based devices have gained popularity in addressing the unmet needs of blind navigators for effective wayfinding. Several outdoor GPS mobile apps like Ariadane GPS, Blindsquare, Get There, Nearby Explorer, Sendero GPS Look Around, and WalkyTalky inform users about their location and guide them to their destination. However, GPS has limitations, with signals disrupted under dense foliage or between tall buildings, rendering it unreliable indoors (Giudice & Legge, 2008; Woodwill, 2016;).

Lechal, the world's first haptic footwear developed by Ducere Technologies in India, aids visually impaired individuals in navigation. The footwear connects to a smartphone app using Bluetooth and GPS technology, providing directional guidance through gentle vibratory responses. The shoes can be worn by individuals with vision, with prices ranging from Rs 6000 to Rs 10000.

While mobility aids and vision substitution systems extend the perceptual reach of blind navigators, there is uncertainty about the desire for additional electronic devices. Critics cite cost-effectiveness, the masking of natural echolocation cues, and the need for training for more

complex aids as challenges (National Research Council, 1986; Giudice & Legge, 2008). Despite the innovation driven by GPS technology for outdoor navigation, there is limited knowledge about tracking position and orientation indoors (Giudice & Legge, 2008).

6.7.1.4 Indoor Navigation Systems

Most of the proposed wayfinding systems for the visually impaired are outdoor systems that mainly use GPS for localization (Ross & Blasch, 2002). Indoor systems cannot use GPS signals, as buildings block them. As a result, first, many passive (non-interactive) environmental aids were developed to support the wayfinding of people with vision impairments in indoor environments. Braille signs, tactile maps, and tactile ground surface indicators (Crawford, 2011) are some of the most popular environmental passive aids implemented in indoor public buildings, especially in India. Later, many of these passive technologies were developed into dynamic ones with technology integration. However, crowds can significantly affect the performance of localization techniques, and again, this issue has not been studied much worldwide (Upadhyay & Balakrishnan, 2019).

(i) **Braille Signs**: Braille signs, prevalent in public buildings like railway stations, are often ineffective for blind users due to difficulties in locating them, especially in unfamiliar environments. Moreover, Braille literacy is less than 1% in countries like India, impacting the usability of these signs for visually impaired individuals (Yuki, 2020). A survey conducted by Vashist et al., (2022), revealed that 57.6% of the population of adults (aged 50-80 years) are illiterate. Even among those who read Braille, difficulties persist in finding signs (Tjan et al., 2005; APTA, 2020), particularly in areas like toilets. To address this, a Bengaluru-based social enterprise, Anuprayaas, collaborated with Indian Railways to provide customized passive design solutions, including braille signs on handrails of foot over bridge (Figure 6.11), tactile maps, and embossed signs in lifts (Anuprayaas, 2019, 2020). While the current implementation focuses on braille signs having only platform numbers (Figure 6.12), the initiative can be expanded to include more information content proposed in our guidelines for various station locations such as ticketing, station entrance, platform and foot over bridge/ subway. Additionally, it is suggested that the government of India should promote mandatory Braille literacy initiatives, especially targeting senior citizens and those acquiring vision impairment later in life.

(ii) Tactile Maps

Tactile maps, designed for individuals with varying vision abilities, offer insight into floor plans. They are available in permanent and portable formats (Figure 6.13), aiding navigation for visually impaired individuals. Research on the effectiveness of tactile maps has shown that visually impaired people can use them effectively to learn routes through a new location as they help mental mapping develop an exocentric view of space (Siekierska et al., 2003).



Figure 6.11 A person with vision impairment using a braille sign on the handrail of the staircase of the Borivali Station of Mumbai Suburban Railways (Anuprayaas, 2019)



Figure 6.12 Braille sign on the handrail of the staircase having platform number in the Borivali Station of Mumbai Suburban Railways by Anuprayaas (Source: Urban Update, 2018)



Figure 6.13 Figure 6.13 Portable maps (3D print.com)

However, tactile maps have limitations, such as displaying limited information per map (Brock & Jouffrais, 2015), making them time-consuming to produce and expensive (Štampach & Mulíčková, 2016). Additionally, they are inaccessible to those without braille literacy. In India, permanent braille maps have recently been installed in NSG-1 railway station buildings in several cities (Figure 6.14). However, they are still inaccessible as PVI cannot locate them in large-scale, unfamiliar buildings. Hence, there is a need for additional sound cues to make the tactile maps detectable by PVI from a certain distance.



Figure 6.14 Anuprayaas, in Collaboration with Southwestern Railways, provided tactile maps in braille for the visually impaired at Coimbatore railway station, Bangalore (Anuprayaas, 2017)

Recent technological advancements have led to the development of interactive maps, addressing these limitations. These maps, diverse in content, devices, and interaction techniques, have the potential to provide spatial knowledge for all, regardless of age or impairment (Brock & Jouffrais, 2015). While most prototypes rely on touch input, some incorporate audio cues. Although not yet implemented in India, there is potential for future adoption with increased digital literacy among PVIs.

(iii) Tactile ground surface indicators (TGSI)

Tactile ground surface indicators (TGSI) are used in most countries to indicate direction and alert the visually impaired in the built environment. TGSI are passive environmental aids (Crawford, 2011) installed into the ground. Installing these blocks is mandatory in most countries worldwide to create a barrier-free environment for the visually impaired (Prabhu & Thilagam, 2019). TGSI offers specific textures that are different from the rest of the flooring and are felt by the feet. Further, they are aided with colour contrast, mainly yellow, to be visually perceived by those with residual vision. The common types of TGSI blocks in many countries, including India, are direction blocks (Figure 6.15) and warning blocks (Figure 6.16). The directional Block surface has ribs that indicate the direction for the visually impaired. TGSI is placed at appropriate locations in the street or inside a building to enable them to find

directions towards their travel destination. TGSI is used at cross junctions to orient the visually impaired (Prabhu & Thilagam, 2019). TGSI help to identify public access facilities such as intersection kerb ramps, pedestrian crossings, stairs, lifts, ramps, building entry-exit doors, escalators, etc. (Mobility Research Centre). The warning block's surface has dots or truncated domes. The blocks are placed to warn the visually impaired about the approaching hazards in their path. The use of warning blocks is important at pathway endings, platform edges, stairs, doorways and places of obstacles. In India, they are primarily implemented in transit buildings such as railway stations, airports and metro stations. However, their design and installation lack standardization in Indian conditions.

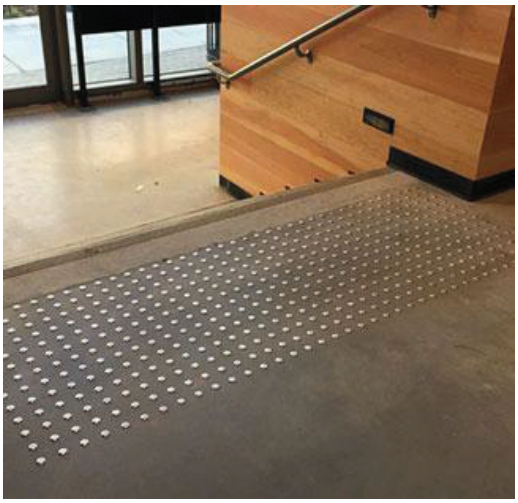


Figure 6.15 Warning floor tiles (Urban Access Solutions)



Figure 6.16 Directional floor tiles (Tacpro.com)

(iv) Talking Signs

Braille signs evolved into Talking Signs, specifically the "Talking Signs" system (Loughborough, 1979), developed at Smith-Kettlewell. It utilizes low-cost infrared transmitters on navigational signs, transmitting voice messages to a handheld receiver. The Smith-Kettlewell Eye Research Institute pioneered RIAS technology, an infrared audible signage system with a $250 handheld receiver and $2000 transmitter cost. Talking Signs have a limitation as they require a permanent power source, necessitating costly retrofits.

In contrast, radiofrequency (RF)--based systems are omnidirectional and accessible without environmental scanning. RFID tags in the environment connect to an assistive aid, conveying location information verbally. Disadvantages include the need for widespread RFID tags, time-consuming data access, server storage requirements, and limited directional information.

Awasthy et al. (2015) developed an RF-based talking signage system for visually challenged individuals in a study in Kollam, India. Implemented through a mobile phone app and a waist belt with motes, it claims cost-effectiveness. However, this technology is yet to be adopted in Indian public spaces.

Streamline the creation and deployment of information-disseminating devices to improve accessibility for visually impaired users, ensuring equal opportunities and full utilization of public infrastructure. Thoughtful design of the audio assistance system, considering speech quality, message length, and clarity, along with coordination with other audible systems, is essential to prevent confusion (National Institute of Building Sciences, 2015). Further, multilingual features are another vital aspect when designing audible signs. The deployment of information-disseminating devices needs to be carefully planned in spatial zones where the crowd is slow, such as the ticketing area, or else the signs will nearly remain unused in peak hours due to the unimaginable jam-packed crowd, leaving no space to wait and listen to the message. This technology has the potential to facilitate efficient wayfinding in extensive and complex transit environments.

(v) Auditory Cues

Auditory cues, essential for supporting the mobility of visually impaired individuals, are primarily implemented in public passenger facilities like railway stations, as outlined by the

Ministry of Land, Infrastructure, Transport and Tourism (MLIT) of Japan, Guidelines for Facilitating the Movement of Passengers in Public Transport Facilities, 2007. These cues have become a vital means of conveying information in public spaces where traditional visual signs are challenging for the visually impaired. Many countries, including Japan, have adopted sound guidance systems in public transport locations, such as train stations, to enhance independent use for individuals with visual impairments (Salih et al., 2007). In Japan, audio-guidance systems are prevalent, emitting distinctive sounds like two-pitch tones for entrances or ticket areas and birds chirping sounds for indicating stair locations, as noted by Iwamiya et al. 2004, distinguishing sound for upward and downward escalators. Further, the need for auditory cues is emphasized in toilets, ticket offices, exits, and elevators (Kurakata et al., 2011). In envisioning future assistive technology for the visually impaired in developed nations like Japan, there is a consensus for devices offering on-demand minimal auditory feedback and conveying more information than traditional white canes.

Unlike Japan, in India, the integration of auditory cues is minimal in railway station wayfinding implementation. Only the waiting area of the coach reserved for PwDs is earmarked with a sound cue on the platforms of SG railway stations of Mumbai Locals. Hence, as shown in our research, individuals use existing natural sounds to recognize their surroundings, identify objects, maintain direction, walk straight, and avoid hazards. This aligns with findings from prior studies (Quinones et al. 2011; Papadopoulos et al. 2012). Our empirical research further highlights another critical issue: the masking of sound, a situation generated through overlapping various sounds. The sound emitted from fast-moving crowds in different directions and trains, mixed with other noises, masks necessary signals or the sounds that a visually impaired person is trying to keep track of, as also reported by Seki, 2009. Yet, there is a huge potential for installing distinctive sound cues easily discernible amidst other noises for various purposes as proposed in our guidelines, such as identification of help desk, etc.

(vi) Sensors and Portable Technologies Integrated with Smart Phone Apps

Researchers from developed countries have designed apps to assist visually impaired travelers in wayfinding tasks. Smartphone apps, like Aira, Navilens, Infsoft Indoor Navigation, and Wayfindr (Figure 6.17) (implemented in metro stations of Los Angeles), offer diverse wayfinding assistance, connecting users to real-time help, aiding in object recognition,

facilitating station navigation, and providing voice-guided navigation in transit stations, respectively (APTA, 2020). Sensor-based wayfinding supports, such as RFID tags, QR codes, Bluetooth beacons and Augmented Reality interfaces, have been employed (Yoon et al., 2019; Zhao et al., 2020).



Figure 6.17 A passenger using an indoor navigation application, Wayfindr, using a metro station in Los Angeles, USA. (Wayfindr, 2019)

Beacon technology, introduced by Apple in 2013 (World Stream, 2020), is a cutting-edge development in location technology and proximity marketing. Like lighthouses, beacons are small, low-energy Bluetooth Radio Emitters that transmit signals detectable by Bluetooth-equipped devices like smartphones. Unlike GPS or WiFi modules, these signals contain unique, location-specific data, allowing for precise indoor navigation. Beacons, with a lifespan of a few years, offer a cost-effective solution, though they are vulnerable to physical tampering (Koskiola, 2016). In applications for the visually impaired, beacons enable wireless interaction with control boxes, tracking the user's position and providing verbal instructions (Spinks, 2014). Companies like indoo.rs have implemented real-time indoor positioning systems at locations such as San Francisco International Airport, offering voice-based directions via smartphones (indoo.rs, 2014). However, this technology has a scope for future implementation in India.

Our study established the wayfinding information PVIs need for detailed planning of the journey they plan to make using local trains. Research conducted in developed nations addresses a similar concern about PVIs. According to research conducted by Sato et al. (2019) and Giudice et al. (2020), PVIs express a preference for virtual previews when faced with the complexities of navigating dynamic environments before undertaking travel tasks. Wayfinding devices are highly regarded by PVIs, providing them with advanced functional knowledge of spaces and, in some cases, enabling unassisted navigation through short routes. Some individuals also find value in preparing by reading instructions in advance (Abu Doush et al., 2016) or receiving a comprehensive narrated route description (Cheraghi et al., 2017). These approaches contribute to improved environmental literacy for travelers, as highlighted in the work of Parker et al. (2021).

Portable wayfinding technologies, mainly on smartphones, have improved travel planning for individuals with visual impairments. However, challenges such as functionality issues, integration problems, sustainability concerns, and reliance on multiple apps per trip hinder widespread adoption (Swobodzinski & Parker, 2010). Research often lacks direct evaluation from visually impaired participants (Parker et al., 2021), with a notable gap in studies from India.

In economically developing countries like India, where visual impairment is linked with illiteracy and poverty, reliance on non-tech solutions such as braille signs and social communication strategies is crucial initially. As digital literacy among visually impaired individuals increases, there is potential for developing indoor navigation apps based on proposed guidelines for each task.

Training for technology users varies widely, and participants in our research express a preference for hands-free options during dynamic tasks. Wearable technology compatibility with the body in motion, particularly for those using long canes, is crucial. Additionally, studies highlight the importance of auditory cues in wayfinding decisions, emphasizing the need to ensure that technology does not mask the ability of visually impaired individuals to sense environmental information. In crowded environments, such as Mumbai Suburban Railways, the efficacy of indoor navigation apps for visually impaired individuals needs design and further testing.

6.8 Conclusion

This chapter builds on the limitations of the existing guidelines of Indian Railways. Historically, Indian guidelines prioritized accessibility over wayfinding, with a shift towards wayfinding only in 2021. However, these guidelines are generalized for suburban and non-suburban systems, neglecting crucial differences. The 2023 guidelines primarily address wayfinding within station buildings, overlooking train route information and safety in suburban rail systems. Representation of wayfinding needs for sighted and visually impaired individuals started in 2021, resulting in separate manuals for each group. Our research identified common wayfinding challenges for both groups, suggesting potential holistic approaches to designing wayfinding solutions for implementing the proposed guidelines. Further, the Indian Railways' guideline development methods, relying on audits, do not account for behavioral and social dimensions in people's interactions with the system. From the review of existing international wayfinding guidelines for sighted and PVIs for rail transit systems of developed nations, we understood that there was an emphasis on designing wayfinding solutions for independent wayfinding. On the contrary, our empirical research suggests strengthening both assisted and independent wayfinding.

The proposed guidelines address these notable research gaps and offer a comprehensive framework for improving suburban rail commuting wayfinding based on empirical research involving over fifty participants in a real-life environment. Addressing the needs of individuals with and without vision impairments, the guidelines cover various aspects such as station entry-exit points, ticketing zones, station facilities and services, bridges, platforms, and local trains. Unlike existing guidelines, these detailed and exhaustive recommendations focus on each wayfinding stage, considering other factors like familiarity, gender, and literacy. The guidelines aim to enhance the wayfinding experience through visual and non-visual signage, minimal architectural modifications, updated digital interfaces, and strengthened human assistance. Intended for rail operators, station managers, architects, designers, disability advocates and NGOs involved in passenger wayfinding signage for Mumbai Suburban Railways, the guidelines can also benefit other commuting systems like non-suburban trains, metro, and monorail.

A comprehensive review of wayfinding technologies was conducted to assess their suitability for implementing wayfinding guidelines. The advancements in wayfinding

guidelines and technologies in economically developed nations aim to empower people to travel independently in transit environments, bridging the gap between the sighted and the non-sighted world. Dependency on other human beings for help is not socially acceptable in developed nations and is considered a sign of weakness.

Economically developing nations like India are slowly progressing towards technological interventions to improve the wayfinding experiences due to factors like people having high braille and digital literacy and better financial status, there is a relatively high penetration of advanced technological solutions in the society of the developed nations. However, little is known about how the wayfinding technologies, mainly on smartphones, have improved travel planning for individuals with visual impairments in complex, incredibly fast-moving, crowded and noisy environments, as the existing research often lacks direct evaluation from visually impaired participants (Parker et al., 2021), with a notable gap in studies from India as well.

In economically developing nations like India, attention to wayfinding has grown with the introduction of new transit systems such as Metro and Monorails. The proposed guidelines are crucial for retrofitting and enhancing older commuting systems and guide designing wayfinding in newer systems.

In India, social interdependence is prominent for wayfinding due to low literacy, especially in braille and digital mediums, among people with disabilities, including those with vision impairments. With its crowded and dynamic environment, Mumbai Suburban Railway commuters, both with and without vision impairment, rely on social cues and support for effective wayfinding. However, we cannot ignore that India has experienced a significant technological revolution in recent years. Rapid advancements in information technology, telecommunications, and digital services characterize this transformation. The widespread adoption of smartphones, increased internet penetration, and the government's emphasis on digital initiatives, such as Digital India, have played pivotal roles. The push for smart cities, increased connectivity, and the expansion of 4G and 5G networks have further propelled the technological landscape. Overall, the technological revolution in India has not only reshaped how people live and work but has also positioned the country as a global player in the tech industry. Considering India's present and future scenario, we propose an incremental strategy, combining non-tech environmental solutions, upgrades to digital platforms, and reinforcement of human-driven services and social wayfinding for both assisted and independent wayfinding.

The interconnections between the person, the technology, the environment, and the systemic support deserve additional attention as part of the future scope of wo

Chapter 7 Conclusion

7.1 Summary

The thesis explores how changes in vision levels impact wayfinding abilities. It aims to contribute new insights into the navigation experiences of commuters with vision impairments within the bustling Mumbai Suburban Railways, one of the world's busiest rail systems. This doctoral research identifies the Mumbai Suburban Railways as an ideal environment for studying wayfinding challenges due to its intricate nature, ageing infrastructure, dense population, hurried commuter behaviour, diverse station architectures, and safety concerns. Despite these challenges, there is a significant reliance on this commuting system for daily livelihood, attributed to its extensive connectivity to various parts of the city and affordability.

The research attempts to find answers to four research questions:

RQ1. How does the existing scenario of the commuting system affect the wayfinding *experiences* of people with different levels of vision?

RQ2. How does the existing scenario of the commuting system affect the wayfinding *performance* of people with different levels of vision?

RQ3. What is the *order of priority* of wayfinding problems faced by people with different levels of vision?

RQ4. What design support may improve the wayfinding experience and performance of people with different levels of vision?

The thesis comprises two essential parts. Part A delves into research questions 1, 2, and 3, forming an empirical foundation for understanding wayfinding scenarios among individuals with and without vision impairments. Part B, on the other hand, focuses on addressing question 4, offering design support by developing comprehensive wayfinding guidelines for effective design interventions.

The research unfolded in four distinct phases to address critical inquiries. Firstly, semi-structured interviews (Study 1) were conducted, engaging 30 participants to delve into their wayfinding experiences within Mumbai's local train commuting system. These discussions covered various topics, including challenges encountered, strategies employed, and design preferences, encompassing individuals with and without vision impairment.

Subsequently, the study advanced to the second stage, where an empirical walkthrough (Study 2) was executed within one of Mumbai's medium-sized railway stations. This stage involved 22 out of 30 participants who participated in the previous study, undertaking a series of sequential tasks to evaluate how the existing environment influenced wayfinding performance across varying levels of vision. Performance measures were employed to discern specific aspects of the commuting system that posed challenges to participants.

In the third stage (Study 3), the research focused on categorizing the seventy identified wayfinding issues from the initial two stages into a wayfinding problem severity matrix. This matrix classified problems as minor, moderate, or critical based on their impact on wayfinding from the commuter's perspective. This classification aimed to prioritize addressing these issues by Indian Railways, involving 30 new participants representing three levels of vision.

Research conducted at stages 1, 2, and 3 described the current wayfinding situation in Mumbai Suburban Railways.

Lastly, the fourth stage entailed the formulation of inclusive wayfinding guidelines targeting all stages of station and train use. These guidelines were developed to cater to the diverse needs, behaviours, and challenges identified in the preceding stages, spanning individuals with no vision, low vision, and sighted. They aimed to bolster architectural and interior aspects, information dissemination, and social dynamics of wayfinding within the

commuting system. Wayfinding guidelines served as ‘design support’ for designing wayfinding interventions in future.

7.2 Answers to Research Questions

RQ 1. How does the existing scenario of the commuting system affect the wayfinding *experiences* of people with different levels of vision?

RQ 2. How does the existing scenario of the commuting system affect the wayfinding *performance* of people with different levels of vision?

The insights from the studies responding to RQ1 and RQ2 are reported jointly below.

A detailed and elaborate description of the participants' wayfinding experiences of travelling in local trains was reported in Study 1 to address RQ1. Both positive and negative experiences were highlighted in the study, as advocated by McIntyre (2011). The experiences shared by the participants were categorized into wayfinding challenges, strategies, and design suggestions.

Six sub-themes were identified to discuss the wayfinding challenges faced by participants of the study: (i) Limited signs to identify spatial zones, facilities, and trains, (ii) Limited direction signs to reach from one place to another, (iii) Poor orientation in the entire station and train route (iv) Lack of updated information to enable the use of facilities, station infrastructure & trains (v) Poor sense of safety and security (vi) Difficulty in receiving, comprehending & trusting public help. Both station and train-related concerns are discussed under each sub-theme.

Four wayfinding strategies that aid in wayfinding were explained: (i) Travel with an escort, (ii) Use of cane, (iii) Use of sensory cues and (iv) Use of social support. The chapter also lists the wayfinding design improvements suggested by the participants from each user group for each journey stage.

The study identified shared and unique wayfinding challenges among participants with different levels of vision and familiarity and gender and literacy differences.

The study contributed to a deeper understanding of participants' perceptions and experiences regarding wayfinding within the Mumbai Suburban Railway system.

To answer the RQ2 question, a step forward was taken. A study was designed to examine the actual scenario of wayfinding by participants in a railway station. For this, a walkthrough study was designed to assess participants' performance, thereby understanding what factors affect their performance and how. We have the following conclusions for all performance measures, which are based on empirical evidence.

The findings indicate that while all participants, including those with sight, experienced difficulties in wayfinding, individuals with vision impairments faced more pronounced challenges, as anticipated based on Study 1. Notably, participants with low vision made more errors and halts on average compared to those without vision impairments. This difference is attributed to the low-vision group's greater self-reliance and reduced reliance on assistance from other commuters. In contrast, participants with no vision relied more on human assistance, mainly escorting, as observed in Study 1, resulting in fewer wayfinding errors, halts, and overall time spent navigating. However, individuals with no vision still encountered unresolved challenges by employing personal strategies, i.e., asking for and receiving assistance and using multisensory cues.

Those with no vision demonstrated poorer performance across various metrics, including deviations, encountered obstacles, and time spent than sighted participants. However, being fully familiar with the layout of the station building compensated for the absence of vision. Partial familiarity with the station did not significantly account for the differences in wayfinding performance measures. Having partial vision contributed to greater self-reliant wayfinding than the no-vision group. This study highlighted how the performance of individuals with varying levels of vision, familiarity and gender was affected by the external factors of the commuting system.

A comprehensive assessment of observed wayfinding performance in study 2 and the self-reported wayfinding experience in both studies 1 and 2 highlighted the several limitations of the existing wayfinding support offered by Mumbai Suburban Railways. These limitations are discussed in relation to consolidated external factors like the built environment, signage design, rail services, and overcrowding. Further use of personal strategies of social wayfinding, sensory cues, use of personal mobility aids and personal escorts significantly influenced the

participants' wayfinding experience and performance. The findings from both studies are summarized for all these factors below:

a) ***Built environment*:** Diverse architectural layouts among station buildings present significant hurdles in wayfinding tasks, including locating ticket halls, restrooms, footbridges to desired platforms, and entry/exit points (as highlighted in study 1). Memorizing one station's layout does not facilitate wayfinding in another, particularly for individuals with no vision (as highlighted in Studies 1 and 2). Factors such as the number of decision points, especially on the foot overbridge and subway use, floor level changes, and perceptual inaccessibility of distant locations add to the wayfinding complexity (as highlighted in studies 1 and 2). Environmental factors, like the absence of safe edges on open-ended paths, increase risks for vision-impaired commuters, resulting in high deviations and potential falls onto rail tracks, especially on middle platforms (as pointed out in studies 1 and 2). Furthermore, the lack of warning signs at floor transitions and poorly maintained flooring contribute to deviations and injuries (as identified in studies 1 and 2). The absence of safety measures to prevent collisions with poles and girders on the platforms further compounds these challenges (as pointed out in Studies 1 and 2).

b) ***Signage Design:*** The existing signage is limited to identifying platforms, station services, and facilities, and it overlooks information, direction, orientation, and safety alerts even for sighted commuters (as highlighted in studies 1 and 2). The signage system, being visual-centric, overlooks other sensory modalities for wayfinding communication, creating barriers, especially for commuters with vision impairments (as highlighted in studies 1 and 2). Visual signage design, with the exception of platform number boards and PwDs coach identity, does not consider commuters with low vision as their potential viewers. Existing signage is sparse, fragmented, difficult to interpret, and falls short of meeting the wayfinding requirements of sighted beginners (also observed in Studies 1 and 2). Consequently, sighted people even experienced errors, deviations, and halts (Study 2). However, they performed better than the visually impaired group due to their visual advantage (as pointed out in Study 2). The signage system primarily caters to developing a very limited understanding of the station for even sighted individuals while offering minimal, disjointed support for people with vision impairment. (as highlighted in studies 1 and 2).

c) ***Rail Services:*** Railway helpers, known as *Sahayaks*, stationed at help desks to assist commuters, have a limited impact on enhancing the wayfinding experience of unfamiliar commuters. Inexperienced commuters often possess a limited understanding of their role, occasionally mistaking them for Railway Police, as noted in Study 2, likely due to their similar appearance. This confusion sometimes deters them from seeking assistance when needed. The help desk is sometimes mistaken for furniture and occupied by general commuters when *Sahayaks* are unavailable (as highlighted in Study 2). Without non-visual cues*, Sahayaks* and the help desk are not easily identifiable by individuals without vision (as highlighted in Study 2). Moreover, predicting the desk locations at each station proves challenging due to their movable nature, resulting in frequent changes in their positions (as highlighted in studies 1 and 2). This issue mirrors the findings of Raheja and Tyagi (2016) in their study on the New Delhi Railway station. Moreover, *Sahayaks* lack adequate training to assist even sighted individuals due to language differences (as identified in Study 2). Verbal directions they offer, much like those given by fellow commuters, often prove challenging for individuals without vision to fully comprehend. Inexperienced commuters without sight prefer escorting over verbal directions, particularly when manoeuvring inside the station and boarding the train. However, the role of escorting is not currently within the scope of *Sahayaks.*

d) ***Overcrowding***: Study 1 emphasizes that overcrowding creates a hostile environment, posing safety risks for navigation inside railway stations and trains, especially during peak hours. For sighted commuters, navigating crowded platforms and trains leads to missed stations and train boarding opportunities. Conversely, commuters with no vision face increased risks of falls on railway tracks at boarding points and struggle to detect platform transitions amidst congestion.

Collisions among commuters and their belongings emerge as significant wayfinding challenges, particularly for those without vision (as highlighted in Study 1). Reduced visibility and increased crowd mobility heighten the risk of injury, especially in areas like the platform-train interface and foot overbridges. Despite using identifying markers like white canes and black glasses, PVIs find it challenging to remain visible amidst congestion, hindering wayfinding and cane navigation, as pointed out in a study on Bangalore Metropolitan by Nagraj et al. (2021).

The overcrowded environment also takes a toll on individuals' psychological well-being, particularly for those with no vision, fostering negative perceptions and diminishing confidence. This is exemplified by derogatory remarks and discriminatory behaviour towards individuals with VI and Railway staff (as highlighted in studies 1 and 2).

Local train's crowded and noisy environment obscures visual and auditory signage, necessitating reliance on assistance from other commuters as a more effective wayfinding strategy. Overcrowding disrupts directional navigation and exacerbates challenges for those with low or no vision, inhibiting the ability to seek out wayfinding information and increasing the likelihood of errors, especially among inexperienced, unfamiliar commuters across all three levels of vision with the system. Overcrowding in peak hours influenced the probability of receiving public assistance in different station zones. The probability of receiving assistance or verbal help is higher from commuters waiting in ticket queues or on platforms during non-peak hours than rush hours. This point highlights the limitations of social wayfinding in peak hours when help, especially escorting, is desired by those with no vision and unfamiliarity (as pointed out in Study 2).

Overall, the overcrowded environment significantly impacts wayfinding experiences, leaving individuals with vision impairments feeling more vulnerable and unsafe than sighted commuters.

Next, we discuss four critical wayfinding strategies that, to some extent, aid in mitigating the wayfinding challenges, however, with their limitations.

e) ***Social Wayfinding:*** In the Mumbai Suburban Railways, passengers heavily rely on social help from other commuters for navigation due to architectural inconsistencies, insufficient signage, inadequate staff assistance, and the convenience of seeking guidance from fellow commuters, as highlighted in Studies 1 and 2. Social interactions, particularly the act of seeking assistance from fellow commuters, have been identified as vital for individuals with limited knowledge of the stations and the commuting system, regardless of their visual impairment status, as observed in Study 2. Among various navigation needs, visually impaired individuals predominantly seek public assistance to confirm places, with directional guidance being the most requested aid, followed by informational support and orientation assistance (as noted in Studies 1 and 2). Additionally, sighted commuters at

stations voluntarily help those without vision, mainly to prevent accidents such as falls or collisions with architectural elements.

Contradicting findings from studies in economically developed countries by McIntyre (2011), Mckeen (2011); Afrooz et al. (2012), and Balata et al. (2014), where visually impaired participants were reported to be hesitant and awkward in seeking help from strangers for wayfinding, our study found a high reliance on social wayfinding among individuals regardless of their level of vision, gender, or age, due to lack of wayfinding aids. Social wayfinding significantly alleviates challenges for participants in all user groups, particularly commuters without vision, who heavily rely on escorting strangers in unfamiliar places (as noted in Studies 1 and 2). Sighted commuters experience minimal dependence on human help, even in less familiar stations, reducing time spent on wayfinding (as noted in Study 2). However, during peak hours when stations and trains are crowded, getting physical and verbal help is problematic (as noted in the Study. Additionally, individuals with visual impairments may struggle to understand help from sighted individuals due to a lack of awareness about communication methods (as noted in Studies 2). Poor information comprehension can lead to unintentional misguidance and wayfinding errors (as noted in Study 2) as also pointed out by McIntyre in her research on people with vision impairments (2011). Validation of help through signage and confirmation from multiple individuals is common among sighted commuters to prevent misguidance, as also highlighted by Ahmed (2015) and Nagraj et al. (2021) (as noted in Studies 1 & 2).

To avoid misguidance, those with higher visual abilities select trusted individuals for assistance based on criteria like physical appearance and gender, occupation, and demeanor (as noted in Studies 1, 2), as also pointed out by Ahmed (2015), Mckeen (2011), and Lawton & Kallai (2002). However, individuals with no vision face challenges in selecting trustworthy commuters for help. Female commuters, independent of the level of vision, prefer to seek help from the same sex for personal security. However, identifying them in the bustling crowds is challenging for female commuters with lower levels of visual acuity (as noted in Studies 1, 2).

f) ***Personal outdoor mobility aid:*** Unlike economically developed nations, where people with vision impairments use technology-intensive expensive personal aids and smartphone applications for wayfinding, our study found that all participants with VI rely solely on

white mechanical cane for outdoor mobility due to modest economic and literacy background. Only recently have several mobile applications been made to provide real-time updated information about trains (M-indicator app), give feedback (Rail-Yatri), and book online train tickets (UTS app).

Using a cane is reported to be much more significant among those with no vision. It is primarily used for two purposes: 1) Identification of spatial zones, facilities and services and 2) Safe navigation (as noted in Studies 1 and 2). Using a cane helps gather spatial, social, and object cues from PVIs. For participants with higher visual acuity, cane use is less significant for outdoor mobility. However, it signals their disability, increasing the likelihood of receiving help from fellow commuters, particularly women (as reported in Studies 1 and 2). Additionally, using a cane facilitated obtaining tickets from the window without waiting in line, according to station regulations, to avoid quarrels with sighted commuters and ticket vendors. This highlights the need to create awareness at ticket windows among sighted commuters of special provisions for ticket purchases for disabled commuters to avoid quarrels (Study 1 & 2).

g) ***Use of Sensory Cues:*** Shedding light on the role of sensory cues, people with visual impairment rely on a personal and unique combination of sensory inputs to produce an organized and meaningful understanding and awareness of the spatial experience of the commuting system. Three types of cues were observed to be used and reported by participants in both studies: *Social, Spatial, and Object*. *Social cues* are the ones that are derived from the social environment of the system. *Spatial cues* are characteristics of the architectural elements that are immovable. *Object cues* are characteristics of the objects in the space that are movable. Social cues are vital in wayfinding in Mumbai Suburban Railways, particularly for PVIs, followed by spatial and object cues. Sensory cues are limited to developing an egocentric view of space among participants with no vision and low vision compared to those with sighted commuters, who benefit from a better exocentric view of the station building due to having the advantage of vision (Study 2). This highlights the pressing need to enhance wayfinding support for all aspects of navigation. Low-vision commuters utilize a greater variety of sensory cues than other groups, with auditory cues being most relied upon by no-vision commuters, followed by tactile and olfactory cues (Study 1 & 2). Conversely, the other two groups rely more on visual cues (Study 1&2).

h) ***Personal escorts:*** As pointed out in study 1, people with vision impairments, especially in the early stages of commuting, rely on personal escorts like friends, family, or peers to navigate local trains safely. They express apprehension about entering new stations alone and heavily depend on these escorts for guidance (as confirmed in Study 2). This guided experience helps build confidence and familiarity with the environment, eventually enabling independent navigation. Along the way, through repeated travel on the same station path and train route, they develop sensory cues to memorize routes for future travels. Additionally, individuals with disabilities often support each other's needs, forming a mutual assistance network to navigate public transportation challenges effectively. Relying on personal escorts for outdoor mobility imposes financial strain on the families of individuals with vision impairments. The escorts, which could otherwise be engaged in income-generating activities, are compelled to dedicate their time to ensuring the safety of their visually impaired family members due to the lack of a safe commuting environment.

Implications of the current scenario on participant's emotional well-being

Our studies on wayfinding experience and performance revealed that wayfinding in Mumbai Suburban Railways stations triggered emotional responses among participants tied to specific locations, behaviours, and significant events. Negative experiences extended beyond difficulty reaching destinations to encompassing feelings of vulnerability to encountering life-threatening situations on rail tracks, collisions, and a sense of helplessness. Factors contributing to negative emotions included uneven road and floor conditions, unmarked edges at floor transitions, obstacles, collisions with other commuters and with architectural elements, people, and belongings. Locations like the platform-train interface invoked fear of falling onto rail tracks, anxiety about finding the coach entry quickly and confusion about which side the coach would arrive. Heightened anxiety stemmed from the lack of effective visual and non-visual wayfinding aids, particularly affecting individuals with vision impairments who struggled to board desired coaches, navigate platforms, and locate foot over bridges.

Participants' adverse reactions were fueled by an ongoing sense of exploration in these settings, intensifying feelings of confusion and anxiety, particularly among inexperienced and visually impaired commuters. This discomfort peaks during rush hours. Additionally,

unpleasant odors from toilets added to their discomfort, while female participants with vision impairments felt uneasy seeking assistance from men, compounding their embarrassment. Rude treatment towards individuals with visual impairments by commuters and railway staff worsened their discomfort, along with difficulties understanding help from sighted commuters.

Conversely, finding landmarks and relying on sensory cues for wayfinding improved performance and led to positive emotional experiences, especially for those familiar with the station and train routes. Effective assistance, such as escorting participants with no vision, elicited feelings of gratitude. Initiatives like audio beepers and dedicated coaches for special needs passengers were appreciated for facilitating travel.

However, negative experiences deter individuals from using the commuting system, impacting user retention for public transit systems, especially among people with vision impairments and those who can afford to pay for higher ticket prices of other commuting systems of the city. Recollection of these moments overshadowed the entire journey, leaving a lasting negative impression of the transit system.

The findings from the study highlighted the inadequacy and ineffectiveness of current wayfinding design support for individuals regardless of their level of vision and familiarity with the Mumbai Suburban Railways. Consequently, a thorough examination is warranted to determine the necessary improvements for the existing wayfinding system. With numerous interconnected issues identified in studies 1 and 2, attempting to address all simultaneously would be impractical, especially given the scale of the commuting system with over a hundred stations and more than 2000 trains. Thus, the initial step in designing enhanced wayfinding support was to identify the priority order of wayfinding problems experienced by individuals with varying levels of vision. This approach would enable the proposal of incremental solutions, tackling the most severe issues before addressing others. This led to the subsequent research stage, involving thirty new participants to prioritize wayfinding problems based on their severity of impact on the participant's wayfinding experience.

RQ 3: What is the *order of priority* of wayfinding problems faced by people with different levels of vision?

The review of the Guidelines on Accessibility for PwDs and passengers with reduced mobility at Indian railway stations by the Ministry of Railways, Government of India, 2023, highlighted a significant gap in the implementation strategy. It revealed that Indian Railways primarily prioritizes modifying railway stations based on passenger traffic and commercial importance, with a preference for non-suburban stations over suburban ones in developmental timelines. As a result, only a handful of suburban stations receive attention for upgrades, leaving most stations for later improvement phases. This could potentially explain why the results from the field research were unfavorable towards the wayfinding support system of Mumbai Suburban Railways. The slow implementation and lower priority given to the suburban railways compared to non-suburban rail commuting systems may have contributed to these findings. Further, there is a lack of hierarchy in which wayfinding guidelines should be implemented or problems should be addressed. This approach results in unresolved critical issues spanning across stations and trains.

To address this issue, there is a need for a wayfinding problem severity matrix, identified from studies 1 and 2, to guide implementation priorities based on their negative impact on specific or all three user groups.

There is ongoing debate over involving users, evaluators, or both in usability tests. Bias is reported if evaluators rate severity, as their ratings may not reflect user experiences (Hertzum, 2006; Law & Havnnberg, 2004). Sauro (2014) reported that low reliability is observed between and within evaluators in earlier studies (e.g., Catani & Biers, 1998; Jacobsen et al., 1998; Lesaigle & Biers, 2000). Hassenzahl (2000), Law and Havnnberg (2004), Hertzum (2006, 2010), and Sauro (2014) highlight the need to explore involving users for better assessments. Multiple user assessments improve reliability compared to evaluator assessments (Nielsen, 1994; Hertzum, 2010; Sauro, 2014).

As guided by the literature review on usability research, a wayfinding problem severity matrix is constructed based on commuters' assessments. Seventy wayfinding problems identified in previous field studies were categorized into different task categories. The severity assessment of these problems was conducted by commuters using a rating technique, while the ranking technique was employed to categorize wayfinding task categories.

Ranking Results

The relative ranking of the most challenging tasks based on the associated wayfinding problems follows an expected order of importance: 1) Train boarding and disembarking 2) Platform Use 3) Foot Over Bridge Use 4) General 5) Use of station facilities 6) Station entry & exit 7) Ticket Purchase.

Rating Results

Problem Frequency (PF) assesses the number of participants affected by a specific wayfinding concern, following the methodology proposed by Nielsen (1994). Out of the 70 wayfinding problems, 58 wayfinding problems were rated by participants with a high problem frequency ranging from 0.7-1, followed by ten problems with a moderate problem frequency of 0.69-0.4, and only two issues with a frequency between 0.39-0. Only two wayfinding problems, as reported below, were found to have low problem frequency, i.e. below 0.39. These results also show that the participants in this study confirmed almost all wayfinding problems reported by the participants of earlier field studies, with high problem frequency.

The Severity Impact Factor (IF) gauges how significantly commuters are affected by a particular wayfinding concern. Out of 70 wayfinding problems, 27 wayfinding problems were rated as critical, 38 had a moderate impact, and five were deemed to have a minor effect. The results show that most wayfinding problems identified in the earlier studies had a critical to moderate impact on the participants of this study.

The Severity matrix establishes the hierarchy for addressing wayfinding problems, starting with those rated most severe in critical task categories. By following this matrix, the implementation of targeted measures across stations and trains has the potential to maximize positive impact. Improvements should commence at large-scale stations with complex layouts and overcrowding to address the most significant wayfinding challenges. The matrix provides designers, planners, and policymakers with a strategic framework for systematically addressing these wayfinding problems, enabling gradual yet significant improvements.

In this study, we observed a moderate positive linear correlation between frequency and severity for all participants (0.35), with reasonably strong positive correlations noted between problem frequency and severity for the No Vision (0.74) and Sighted (0.82) subgroups. However, we concur with Sauro (2013) that the severity of a problem remains independent of

its potential user impact. Moreover, evidence suggests that critical problems may occur less frequently than minor ones (Sauro, 2014). Sauro emphasizes that high-impact problems may not necessarily have a high frequency. Therefore, we advocate prioritizing problem severity over frequency, especially when devising strategies to benefit smaller user communities, such as those with vision impairments, compared to larger user groups, like sighted.

This study is one of its kind as it involves commuters with vision impairments in the severity assessment, providing a unique perspective and possibility of their participation in wayfinding evaluation studies in future. The severity matrix may be used as a checklist to measure and score the 'ease of wayfinding' in Mumbai Suburban Railways and be modified to evaluate similar commuting systems as a scope for future use. Another use of the wayfinding problem severity matrix is in designing a focused survey tool to take feedback on each station of Mumbai Locals.

Guidelines play a crucial role in design development by providing a framework and standards for creating compelling and cohesive designs. Guidelines help designers make informed decisions, solve problems, and address challenges by offering practical advice and recommendations based on research and user needs. Overall, they are a valuable tool for guiding and enhancing the design development process from conception to implementation. As a next step in designing support, we needed to review the Indian Railway guidelines to find out how they drive wayfinding support development to address the real-life wayfinding challenges identified in the research presented above.

RQ 4: **What design support may improve the wayfinding experience and performance of people with different levels of vision?**

The review of Indian Railway Guidelines gave us some crucial insights into the guideline development process and design. India has made strides in enhancing accessibility in public buildings, including rail systems, since the enactment of the Persons with Disability (PWD) Act in 1995. However, these efforts have primarily focused on improving physical access, overlooking crucial aspects such as wayfinding.

While the guidelines issued by Indian Railways in 2023 begin to address some wayfinding challenges identified in our user research, they predominantly concentrate on visual signage and architectural modifications, neglecting other important factors like social,

emotional, and behavioral aspects linked with wayfinding. Specifically, they limitedly articulated the design support required for commuters, especially those with visual impairments in all wayfinding stages. Further wayfinding needs that emerge from other interlinked human factors such as familiarity, gender and literacy are also not adequately addressed in the latest 2023, Indian Railway accessibility guidelines. Additionally, these guidelines lack a comprehensive approach considering universal design principles, as they offer separate solutions for individuals with and without visual impairments. This overlooks opportunities for solutions that can benefit all commuters regardless of their visual abilities. Moreover, the existing guidelines fail to differentiate between suburban and non-suburban rail systems, with an increased focus and priority on non-suburban stations. This oversight disregards the unique wayfinding challenges and needs within suburban systems, such as the Mumbai Suburban Railways. Most importantly, the lack of empirical research into wayfinding has further led to a weak foundation in the existing Indian guidelines. Based on a review of existing Indian guidelines, it becomes evident that there is a pressing need to develop specific wayfinding guidelines tailored to the Mumbai Suburban Railways.

To address the research question, wayfinding guidelines were developed as a 'design support', part of the Prescriptive stage of the design research methodology. Guidelines were developed and presented using a three-dimensional framework consisting of *wayfinding stages, design principles and enabling aspects.*

The strategic framework is based on seven wayfinding stages: 1. Station entry and exit 2. Ticketing 3. Foot over bridge/ Subway 4. Platform 5. Station facilities and services 6. Train boarding and disembarking 7. Non-Stage-Specific.

Seven design principles were identified in response to the challenges identified from empirical research. Wayfinding guidelines were developed using the design principles wayfinding guidelines that emerged from the problem categories: 1) Develop an accessible and comprehensible identification system 2) Ensure continuous path guidance for the desired destination 3) Provide orientation to cultivate a spatial perspective 4) Provide information and instructions about station use and train travel 5) Ensure the safety and security of commuters 6) Strengthen offsite, onsite and digital rail services 7) Devise strategies to strengthen social wayfinding.

The proposed guidelines have four aspects:

a. The *Architectural and Interior Design aspects* include guidelines for built environmental spatial interior elements such as accessible and defined parking, lighting, flooring, handrails, step-free movement, and safe and guided navigation.

b. The *Information Design aspect* includes guidelines for identification, directional and orientational, instructional and safety information systems disseminated through various sensory channels in digital and physical modes.

c. The *Service Design aspect* includes guidelines to strengthen wayfinding support provided by railway staff and other offsite and digital information and services offered through mobile applications and websites.

d. The *Social Wayfinding Design aspect* includes guidelines to strengthen wayfinding support provided by commuters to each other and by shopkeepers and vendors inside railway station buildings and trains.

Guidelines were proposed in all these four aspects of inclusive wayfinding. They are developed based on empirical and evidence-based research involving over fifty participants spanning three field studies. After the guidelines were developed, they were compared with recent Indian and International guidelines (from high-income countries) to distinguish between common and distinct guidelines. Based on the review, the guidelines were segregated into three levels: Existing, Modified, and Novel Guidelines. **Our work has added 14 new modified and 70 novel guidelines.**

7.3 Thesis Contributions

The thesis makes three significant contributions to the field of wayfinding research.

1) **Research Insights**: This qualitative wayfinding research conducted in the economically developing world presents a noteworthy contribution to the existing body of knowledge in this field, predominantly focused on contexts studied in economically developed nations. The distinctiveness of this research stems from the considerable differences in social factors, urban congestion, infrastructure, and technological landscapes between developed and developing regions. Studying wayfinding across the spectrum of vision along with

intersectional variables of familiarity, gender, and literacy differences is a unique aspect of our research. The existing wayfinding support provided by Mumbai Suburban Railways is analyzed, highlighting both strengths and limitations in various external factors such as the built environment, signage design, rail services, and overcrowding. Additionally, the impact of personal strategies such as social wayfinding, sensory cues, personal mobility aids, and the presence of personal escorts on participants' wayfinding experience and performance is discussed, drawing insights from empirical research.

2) **Wayfinding Problem Severity Matrix:** The severity matrix of wayfinding problems, which stemmed from empirical research, informs the order of priority in addressing wayfinding problems based on critical, moderate, and minor impacts as perceived by the commuters. The matrix is one of its kind to involve users, particularly those with vision impairments, in informing the order of priority of addressing wayfinding problems. The severity matrix may be used as a checklist to measure and score the 'ease of wayfinding' in Mumbai Suburban Railways and be modified to evaluate similar commuting systems as a scope for future use. Another use of the wayfinding problem severity matrix is designing a focused survey tool to take feedback on each station of Mumbai Locals.

3) **Guidelines:** The modified and new guidelines proposed to address the wayfinding problems that emerge from the ground research act as a design support for wayfinding design development. They are developed and presented using a three-dimensional framework consisting of *wayfinding stages, design principles and enabling aspects*. Unlike the earlier Indian Railway guidelines, the guidelines proposed as part of this doctoral work are inclusive as they represent wayfinding challenges, behaviour and needs of commuters independent of the level of vision and familiarity, gender difference and literacy. The guidelines are exhaustive as they recommend wayfinding support for each wayfinding task involved while travelling from local trains. Specific guidelines suggest a distinctive approach to strengthen social wayfinding, a unique aspect of the wayfinding framework.

The novelty of the guidelines is that they are developed to offer choices to people for assisted and independent wayfinding depending on their ability, literacy differences, experience of use and psychological comfort. Such an approach distinguishes the guidelines proposed in this thesis from other Indian and International accessibility and wayfinding

guidelines that solely propose the strategy for independent wayfinding. Further, looking at the advancements in the field of wayfinding design, proposed guidelines can be used as a framework to design effective wayfinding aids and services to convey spatial information to all commuters.

7.4 Generalizability

The guidelines are primarily proposed to improve the wayfinding in the existing infrastructure of Mumbai Suburban Railways. However, the proposed guidelines can be used to develop wayfinding support in new stations and trains of Mumbai Locals. The proposed guidelines will also help improve the wayfinding of other suburban commuting systems, non-suburban train commuting systems, metro and monorail. The guidelines are intended to be used by railways bodies, architects, designers, disability advocates, and NGOs working on wayfinding and accessibility. The study initiates a dialogue on creating inclusive wayfinding systems suitable for different levels of visual ability. The research and evidence indicate that the findings would offer advantages to the broader population in navigating journeys within the built environment.

7.5 Strengths and Limitations

Several strengths of this study are worthwhile to highlight.

i. Wayfinding in the context of social and public environments is very different in economically developed nations compared to economically developing nations like India. Literature on wayfinding, in general, is dominated by research done in economically developed countries, even though 45% of visual impairment occurs in India and China (LESH, 2023), and India is home to over 20% of the world's blind population (Sharma, 2020). Our research addressed this gap in the existing body of literature on wayfinding by conducting empirical, evidence-based, user-centered qualitative wayfinding research.
ii. The study has delved into the wayfinding experiences of individuals with different levels of visual abilities within one of the world's busiest and most expansive rail transit systems. There has been limited exploration of travelers' experiences with varying levels of vision in crowded public environments, particularly in rail transit settings worldwide. Existing

research indicates a paucity of empirical studies on wayfinding behavior and challenges in rail commuting and similar metro systems, especially regarding people with vision impairments (PVIs). While previous studies have advocated for implementing universal design principles to enhance old and new commuting systems, there remains a gap in wayfinding research that comprehensively addresses commuter diversity across the vision spectrum.

iii. Existing studies had separate and exclusive focus on architecture (Kuliga et al. 2016; Raheja & Tyagi, 2016), signage (Nen, 2015; Whitfield, 2013; Zheng et al., 2007; Chen, 2006), and social aspects of wayfinding (Ferri & Pop, 2022), missing out on the interrelationship between these factors. Our research has captured the holistic view of the wayfinding scenario from four aspects: 1) Architectural and Interior design aspects, 2) Information design aspects, 3) Service design aspects, and 4) Social wayfinding aspects.

iv. A three-step methodology of studying wayfinding experiences was used through interviews, wayfinding performance in real–life rail environments and severity impact assessment of wayfinding problems involving participants with vision impairments. Such a methodology to study the wayfinding scenario in real-life settings is rare. Hence, the approach used within this current research study is distinctly new. This user-centred research, being qualitative, is performed on more than 50 participants, collecting and analyzing data from more than 150 hours of audio and more than 50 hours of video recordings. The methodology was instrumental in conforming to the wayfinding challenges reported by different user groups based on past experiences and actual wayfinding performance on a real site.

v. The findings from the study added a unique perspective on social wayfinding from a commuting system, which is crucial, contrary to developed countries, where this culture is considered ‘awkward’ (Balata et al., 2014; Afrooz et al., 2012; McIntyre, 2011; Mckeen, 2011). Furthermore, adding the experiences and perspectives of people with vision impairments to the existing literature on social wayfinding adds to the study's novelty.

vi. Seventy novel and fourteen modified wayfinding guidelines emerged from the firm foundation of empirical user research. Such an approach was lacking in the earlier Indian Railways guideline development process.

There are also some limitations of the study:

i. On-site observational research of signage design and installation and reviewing the spatial layouts of multiple stations with varying architectural scales could have strengthened our research. This study was done only at the preliminary research stage.

ii. The study could have been enriched if the perspective of other stakeholders, like architects, railway officials, station service providers such as vendors, help desk staff, and disability activists, were taken at different stages of research. However, we could only study their perspective in the preliminary research stage. Our main study is limited to the commuter's perspective.

iii. Obtaining permission from Railway authorities for photography and videography at railway stations and inside trains proved to be highly difficult, thus limiting our study to only a few stations.

iv. Finally, identifying and requesting participants (especially those with vision impairments) with specific participant profiles to participate in field studies posed difficulties, ultimately leading to a small sample size.

v. The study primarily explores the impact of three levels of vision on wayfinding. Further, it also studied how familiarity, gender, and literacy (as secondary variables) impacted wayfinding. The study could have benefitted from a more extensive exploration of other socio-economic factors, such as language differences, onset of blindness, etc., influencing wayfinding in Mumbai Suburban Railways.

7.6 Future Scope

This thesis is a starting point for further research, extending understanding, and initiating responses to identified issues in economically developing countries like India. Numerous research directions and scope for intervention design and testing have emerged for further investigation, as stated below:

7.6.1 Assessment of Way-finding Scenarios: Participants and Buildings

Exploring the navigation experiences of individuals across a spectrum of abilities, uniting diverse individuals encountering similar circumstances through the methods outlined in this study, holds a significant interest. Acknowledging the range from permanent disabilities to

situational impairments and temporary disabling experiences prompts a reevaluation of how design can inclusively reach a wider audience (Microsoft Design, 2016). Continually exploring the challenges faced in wayfinding experiences should continue to drive the discussion forward.

Applying the methods from this research in future studies on wayfinding in different building types could be beneficial for generating data and improving the overall understanding of wayfinding. Our study paves the way for future research in other large-scale public environments such as shopping malls, educational campuses, public hospitals, large festivals and exhibition sites, etc. More research in different types of settings will help to trace how the purpose and the design of the building influence wayfinding experiences and performance.

The study has paved the way for quantitative research to broaden the generalizability of problems across a larger commuter diversity. The research findings will assist in designing survey forms. The severity rating matrix proposed in the study can be used to develop an incremental prioritization plan to address wayfinding problems with maximum negative impact followed by moderate and minor ones.

7.6.2 Implications on Design Wayfinding Solutions

The research findings were used to develop wayfinding guidelines for railway bodies, architects and designers, policymakers, NGOs, disability advocacy groups, and other stakeholders. These guidelines provide scope for designing interventions that respond to the wayfinding context studied in this research and similar computing contexts. The research findings can be used to develop targeted interventions to mitigate the wayfinding problems. A framework for different design approaches to improve the wayfinding of the Mumbai Suburban Railway is proposed below (Figure 7.1)

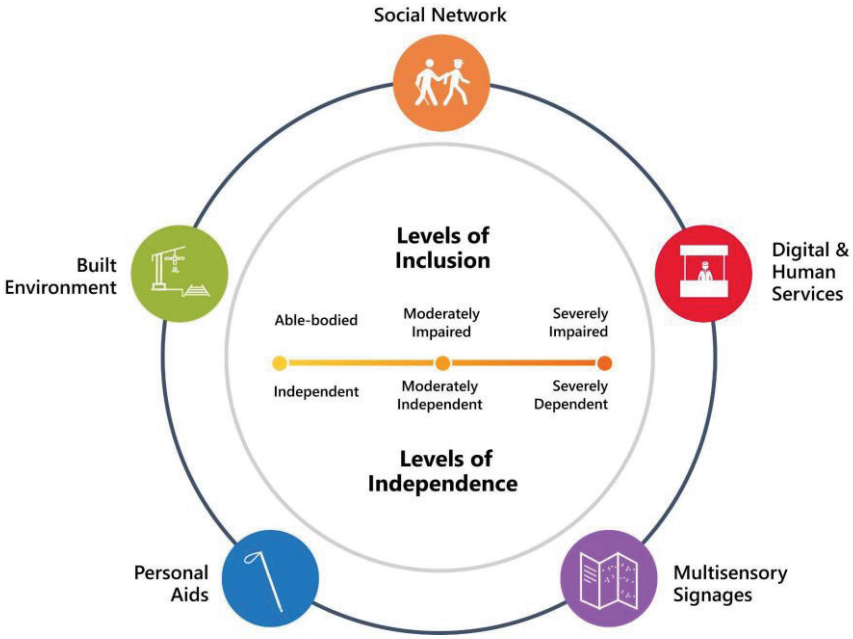


Figure 7.1 Design Approaches to Wayfinding

(i) Levels of inclusion can be explored while designing wayfinding solutions using available human and non-human resources and technology for designing personal, hybrid and environmental wayfinding aids. Three levels of 'inclusion' can be explored (Benktzon, 1993):

1. Mainstream wayfinding aids for everyone, including people with disabilities.
2. Mainstream wayfinding aids that can be customized for use by people with disabilities; and
3. Specially designed products tailored to the requirements of people with severe disabilities.

(ii)Level of Independence can be explored while designing wayfinding solutions using available human and non-human resources and technology for designing personal, hybrid and environmental wayfinding aids. Three levels of 'independence' in wayfinding can be explored:

1. Independent wayfinding with the help of spatial physical and digital solutions, digital and onsite services, educational tactile aids of Railway station and train coach composition (for children with vision impairments).
2. Moderately dependent wayfinding by strengthening verbal assistance from social networks.

3. Severely dependent wayfinding can be strengthened through effective escorting provided by personal escorts, Rail *Sahayaks* and staff and train commuters.

(iii) Multi-Sensory Signage*:* The wayfinding guidelines can be used as a framework to develop information plugins in the form of multi-sensory sign systems, digital signage and indoor wayfinding mobile applications. Some intriguing findings in this study concern the unexpected sources of sensory cues—social, spatial, and object-based—that participants with vision impairments utilize as strategies to gather spatial information through various sensory modalities. Exploring and intentionally replicating these characteristics of the built environment in spatial design could offer standardization in real building sites or simulated prototypes, such as digital and physical game design or play aids, to enhance orientation and memorization. Downscaled models of railway station interiors and train layouts, along with the order of train coaches, can aid in better understanding the site. Exploring opportunities to design such play aids could significantly improve the spatial orientation of people with vision impairments. Visual signage in the built environmental design should focus on having design considerations by including commuters with low vision as an intended viewer. In the context of extremely crowded, jam-packed environments like those of Mumbai Suburban Railways, the placement of visual signage should be above eye- level in line with the moving crowd. Advertisement hoardings and posters should be minimized or avoided as much as possible to reduce the visual clutter.

(iv) Digital and Human Services*:* Caution must be taken in designing indoor wayfinding mobile applications with audio instructions for extremely crowded environments as they may not be audible or may mask the environmental information crucial for wayfinding and navigation for people with vision impairments, especially in peak hours. Instead, localized audio beepers, talking signs, braille markers and olfactory cues placed within the reach of the people, that could be sensed or accessed by feet, cane or hand may be more effective ways of communicating environmental information. Guidelines for strengthening services offered by Rail *Sahayaks* can be strengthened by following the guidelines proposed in the thesis.

(v) Social Networks: Creating awareness and sensitivity among the sighted world about challenges faced by people with vision impairments through storytelling, audio and visual

advertisements will play a crucial role in creating empathy in the society towards those who see and feel the world with a hazy lens or without vision. Furthermore, communication aids can be designed to create awareness among the general public about special facilities, services and features offered by Indian Railways for people with disabilities so that the general public may act as an enabler in helping people access them instead of getting into quarrels and fights. Social networks (comprising commuters, vendors, cobblers, and shopkeepers) used for wayfinding on railway stations should be strengthened by creative awareness through creative media about using moral etiquette, such as the use of the right terminology and gestures, in offering help people both with and without vision impairments.

(vi) Built Environment & Interiors*:* Existing guidelines on architectural accessibility are quite extensive. The guidelines proposed in this thesis may be followed for better spatial organization and design of internal elements. For example, colours used in the design of doors, windows, handrails, girders, and poles should take into consideration the visibility and distinction of commuters with low vision. Further, standardization of internal amenities such as ceiling fans, drinking water facilities, toilet stalls, and furniture across all platforms of all stations following a particular thoughtful standardized order will improve platform orientation for all commuters, especially those with vision impairments. Similarly, deployment of station facilities like shops, toilet stalls, help desks, etc., should be carefully deployed following a standardized sequence. Otherwise, signage systems need to be strengthened to enable people to easily locate these facilities in case of non-standardization.

(v)Personal aids: Identity markers could be developed to differentiate individuals with vision impairments, thus making them easily identifiable among other commuters. This design concept could be expanded to encompass vulnerable commuters with limited mobility, including those with mobility impairments, senior citizens, and pregnant women. These markers serve several purposes:

- To signal Rail *Sahayaks* among commuters, facilitating assistance when required, particularly in emergencies.
- To alert sighted commuters to be mindful of their hurried movements and prevent collisions with these individuals.

Other Aspects

Economic implications for developing countries should also be checked for developing design interventions. Solutions that are cost-effective, easy to implement and have the potential for high positive impact, referring to wayfinding problem severity matrix, can be targeted to be developed, tested and implemented first.

Environmental adaptiveness of the solutions should look into factors like durability, maintenance, suitability to weather and different times of the day, adaptiveness to digital and physical architecture, monitoring, etc.

Human Factors: Wayfinding design should respond to the wayfinding behavior and human factors that have a direct impact on the wayfinding abilities, experience, performance, psychology, and emotional well-being of people, as presented in this research. The guidelines have prompted design directions that address intersectional differences in human diversity that cut across abilities, familiarity, gender and literacy).

7.7 Final Reflections

In India, social wayfinding compensates for the limited wayfinding design support that Indian Railways provide. However, it is essential to acknowledge India's significant technological revolution in the past five years. This transformation is marked by rapid advancements in information technology, telecommunications, and digital services. Factors such as widespread smartphone adoption, increased internet accessibility, and governmental emphasis on initiatives like Digital India have been pivotal. Furthermore, initiatives such as smart city development, expanded connectivity, and the rollout of 4G and 5G networks have further propelled India's technological landscape.

This technological revolution has not only transformed how people live and work but has also positioned India as a global leader in the tech industry. Considering the present and future trajectory of India's technological landscape, we advocate for an incremental strategy for technology integration. This approach involves a combination of non-tech environmental solutions, upgrades to digital platforms, and the reinforcement of human-driven services and social wayfinding for both assisted and independent wayfinding.

It is crucial to recognize the interconnectedness between individuals, technology, and the environment to design systemic support. Therefore, as part of future initiatives, we propose giving additional attention to these interconnections to enhance wayfinding experiences effectively. In addition to enhancing the rail ecosystem to facilitate efficient wayfinding, it is crucial to strengthen healthcare infrastructure and extend widespread accessibility to provide effective mobility training, Braille education, and employment and educational opportunities to marginalized segments of society, such as people with disabilities. This approach aims to empower individuals with the skills and confidence to actively participate in society and venture beyond the confines of their homes.

1. Appendix A1

The Impact of Indian Railway Policy on The Accessibility of People With Disabilities

Abstract: The suburban local trains in Mumbai, India, rank second among the world's busiest mass transit systems, serving the fourth most populated city. Dependency on these trains is high among the working class, both with and without impairments, due to their affordability, speed, and connectivity. Consequently, they have become heavily utilized. Current accessibility policies include ticket concessions and a reserved train coach for people with disabilities.

To assess the impact of these policies on mobility, qualitative methodology employing in-depth semi-structured interviews with individuals with mobility and vision impairments, along with disability advocates, is utilized. Common concerns among these commuters include a lack of information in alternative formats, hindering independent navigation within railway stations. Additionally, the coach reservation policy is ineffective during peak hours, as non-disabled commuters often occupy these spaces. Lastly, the gap between the train and the platform poses boarding and alighting difficulties. Recommendations for updating the policy are proposed based on field insights.

Keywords: Accessibility, Mumbai local trains, people with disabilities, Indian Railway Policy

1. Introduction

The skewed pattern of urban development in India has produced megacities with inadequate infrastructure and large proportions of poor urban citizens with little or no access to basic services. Mumbai, with over 65 per cent of the population living in slums, is a case in point. It is the capital city of the Indian state of Maharashtra. It is India's most populous metropolitan area and the eighth-most populous city in the world, with an estimated city population of 18.4 million and a metropolitan area of 20.7 million as of 2011. The suburban local trains serve as a critical mode of public transportation in one of Mumbai's most densely populated cities. The Mumbai Suburban Railway consists of rapid transit on exclusive inner suburban railway lines augmented by commuter rail on main lines serving outlying suburbs to

serve the Mumbai Metropolitan Region. Spread over 465 kilometres (289 mi), there are 130 local train railway stations, and the suburban railway operates 2,342 train services that carry more than 7.5 million commuters daily. By annual ridership (2.64 billion), the Mumbai Suburban Railway is the busiest rapid transit system in the world (Soans, 2014). The Suburban Railways are the lifeline for people living in Mumbai. Thus, overpopulation has led to abundant pressure on Mumbai's local trains that cater to the needs of millions of passengers. Railway planners and policymakers focus on increasing local train infrastructure by adding coaches, introducing new train lines, building more railway stations, and introducing new modes of public transport like monorail and Metro projects to share the traffic load. However, the 165-year-old train system has hardly undergone any design changes addressing commuter diversity's safety and usability needs. The rapid rise in the commuter population has resulted in overcrowding, jam-packed travelling conditions inside train coaches, traffic blockage at railway stations, and frequent accidents and deaths. Mumbai Railways is also the only sector amongst the other metros where Railways profit. Despite this, for the past 45 years, the allocation of funds to Mumbai Railways by the Centre was the lowest compared to the other Metros. All this resulted in the collapse of rail services in Mumbai. The current rail system is challenging for all commuters, though the challenges' severity and nature depend on different user characteristics.

If commuters find it difficult to travel on the local train, then what about people with disabilities who travel on this same train? People with disabilities form a significant proportion of daily commuters on suburban railway lines, yet no statistics are available. People with disabilities are found to be highly vulnerable due to poor accessibility in the infrastructure design of trains and railway stations. Mobility and vision impairments are primary characteristics that account for poor usability and restricted access due to non-enabling environments of local trains and station environments. They are primary characteristics that account for poor usability and restricted access due to non-enabling environments of local trains and station environments. Mobility-impaired commuters find it hard to use the staircases, steep ramps, and two-way mobility of incoming and outgoing crowds. Vision-impaired commuters, especially first-time and occasional commuters, cannot navigate inside the station without public help and route guidance information in non-visual formats. Both mobility and vision-impaired commuters avoid using toilets on platforms due to long walks, absence of route guidance signs and unhygienic and dirty environments.

It is essential to recognize that people with disabilities, like other able-bodied people, have the right to travel on the train safely, and they also have the right to ask the railway board to provide the facilities, keeping in mind their diversity in disability. Thanks to the disability rights movement in the world, which is related to equal rights, full opportunities, and accessibility in public places, people with disabilities in India demand that the railway board make railways disability friendly.

Disability was recognized as a user diversity issue in India due to the formulation of the Person with Disability (Equal Opportunities, Protection of Rights and Full Participation) Act, 1995. The act was given effect when India became a signatory and adopted the proclamation on the Full Participation and Equality of People with Disabilities in the meeting convened by the Economic and Social Commission for Asia and Pacific held at Beijing on 1st to 5th December 1992. The PWD Act, 1995 states,

" establishment in the transport sector shall, within the limits of their economic capacity and development for the benefit of persons with disabilities, take extraordinary measures to adapt rail compartments; install auditory signals for the benefit of persons with visual handicap; provide engraving on the edges of railway platforms for the blind or persons with low vision; devise appropriate symbols of disability; provide warning signals at appropriate places and Installations of ramps in public buildings". (Gazette of India, Ministry of Law, Justice and Company Affairs, 1996).

This Act helped to spread awareness about the issues of disability and the concerns of disabled people among the non-disabled population, and this act gave a weapon to the disabled population to fight for their rights. They firmly believed that if the public transport system did not cater to the needs of the disabled population, their livelihood would be denied, and that would affect their rights.

India had moved on to attempting to set standards at the international level. It was one of the 27 countries in the working group to draft the UN Convention on the Rights of Persons with Disabilities. India ratified the UNCRPD without reservations in 2007. To fulfil obligations under the UN CRPD, India must promote accessibility in public transport systems as per Article 9 of the Convention.

2. Railways Policy for Population with Disabilities

As a follow-up to “Persons with Disabilities (Equal Opportunities, Protection of Rights and Full Participation) Act 1995”, in 1998, the Government of India through the Central Public Works Department (CPWD) as well as Indian Railways through Research Designs Standards Organization (RDSO) independently prepared guidelines to make their respective built environment accessible to Persons with Disability, i.e. make them barrier-free. The CPWD’s 85-page guidelines are more comprehensive than the RDSO Guidelines of 24 pages.

Under the Persons with Disability Act, 1995, the planning authority of Mumbai local trains formulated and implemented several rules to ensure access to persons with disabilities inside railway stations and trains. The reservation of coaches for people with disabilities on the local train was the first step in this direction. The reserved coach was named 'handicap coach'. The coach was also shared with commuters with cancer. A single coach was reserved for people with disabilities and cancer patients in a 9-coach composition train. A motorman's cabin was converted into a coach by removing the workstation and installing a bench accommodating only six people. Later, with increased railway infrastructure, two coaches in 12 coach trains and three coaches in 15 coach trains were reserved for people with disabilities and cancer patients. These coaches individually offer an increased capacity of sixty passengers. With additional coaches being provided to people with disabilities and cancer patients, commuters with other short-term and long-term health conditions and senior citizens demanded access to the handicap coach as it was very challenging for them to travel in overcrowded general coaches. As a result, Railways - revised rules and allowed access to commuters with temporary and permanent health conditions in handicap coaches. One needs a valid certificate of disability to board the compartment. Failure to do so may result in a penalty.

To avoid the long ticket queues, Railways has initiated a pass system for the general public and people with disabilities commuting daily from local trains. People with disabilities are offered a 50 % concession on the passes if they travel independently and 70% if escorted. A unique ID no. is mentioned in the pass that permits them access to the handicap coach. There is a rule that occasional or first-time commuters with a disability should not stand in the queue for tickets. They can directly go and buy tickets from the counter.

Architectural modifications are in progress in the existing station environments. Ramps and escalators are being installed at major stations that all commuters can use. Textured tiles are laid at the platform's edge at a few stations to avoid falls on railway tracks and facilitate vision-

impaired commuters in finding the handicap coach entry. There is signage at the handicap coach exterior for coach identification among sighted people with disabilities, and locational signage at the platform marks the waiting area where the reserved coach stops. At some stations, *'Beep-Beep-Beep'* sound indicators are installed with the signage that helps identify the platform's waiting zone for vision-impaired commuters.

3. Benefits of the facilities and Challenges faced

Despite giving facilities as a part of a policy by the Railway Board, it is essential to find out how these facilities helped improve the accessibility of people with disabilities. It is said that the facilities or policy can be more effective if it creates smooth accessibility for people with disabilities. Therefore, it is felt that there is a need to get the opinion of people with disabilities who travel by train regularly. It would help us to examine the impact of railway policy and facilities and how we need to change or add them to make railways disability-friendly. For that, qualitative methodology with in-depth semi-structured interviews with people with mobility and vision impairments and interviews with disability advocates was adopted. A total of 16 people with disabilities between the age group of 24 and 67 years were interviewed. Of these, nine respondents have mobility impairments (MI), whereas 7 have visual impairments (VI). Among nine respondents with MI, six were male, and three were female, and they were using callipers and crutches. Out of them, two people were crawling while travelling by train, and one among them parked his tricycle out of the station. Among seven respondents having VI, four were male, and two were female.

It also summarizes responses of disability advocates who have been proactively working to push the agenda of accessibility rights of people with disabilities in Mumbai local trains by taking their interviews. Out of three expert activists, two activists have filed Public Interest Litigation in the High Court to make stations accessible for people with disabilities, and the third has won an online petition against Railways. Their domain expertise helped me get a variety of perspectives on the issue of accessibility in local trains.

3.1. Adapt Rail Compartments

In local trains, two types of rail compartments differ in capacity. Old coaches were small in size as compared to later ones. People with disabilities benefit from having a special

compartment, “Handicap Coach”, as they can travel by train without much tension. They felt that old coaches are too small, as a maximum of 10 people travel against the capacity to carry six people, and it becomes difficult to get in during peak hours and delayed trains. They reported that the new coach, which consists of 60 people, is comfortable for them to travel in, and they get adequate seats accessible in boarding, alighting, and ventilation. A commuter with VI responded that reserved coaches allow outdoor travel for people with disabilities. Despite that, the people with disabilities felt that there are several usability problems with the old and new coaches that have been classified under sub-topics like 1) Public behaviour, 2) Information, 3) Technology, and 4) Coach interior design.

3.1.1 Public behaviour: Both mobility and vision-impaired people reported that general commuters without disabilities board the 'handicap coaches' as they offer more space to board than the jam-packed general coaches. Overcrowded train environments and shortage of time evoke insensitivity and self-centred attitudes among people, which are responsible for such public behaviour. These behaviours of general commuters create problems for people with disabilities to board and disembark from local trains and reduce the chances of getting seats. General commuters travel with fake appearances and fake disability identity cards to get access to the coach. The newspaper in Mumbai reported that thirty-seven per cent of the offences registered on Central Railway from January to May this year about illegal travel in coaches reserved for the disabled. Such commuters were imprisoned and heavily fined.

Both mobility-impaired and visually impaired respondents reported that the general commuters pushed them during boarding/disembarking. Over-crowded environments created a perception of poor safety. The lack of closing doors on the coaches has resulted in two respondents being pushed out of the running train. One of them lost both legs in the accident, and the other, already a crawler, had minor injuries. A VI respondent reported that his stick often breaks due to hasty public behaviour. Shortage of space makes people quarrel over seats.

Besides, handicap coaches were also boarded by railway security officials, which further increased the crowd. The revised rules grant access to people with temporary and permanent health conditions, such as senior citizens, pregnant women and cancer patients. People with disabilities report the lack of acceptance of people with disabilities by all

commuters with and without health conditions inside the handicap coach. It adversely affects train travel comfort and the safety of people with disabilities.

Most MI respondents perceived that general commuters have a sympathetic outlook and lack of understanding of the needs and difficulties faced by people with disabilities. Women with disabilities reported problems with eve-teasing inside the handicap coach. Men with disabilities harass women with disabilities inside the coach, or able-bodied men harass them from neighboring coaches from see-through partitions. They demand exclusive trains or coaches for women with a disability or reserved seats in handicap coaches. An MI respondent wants a separate train for people with disabilities. They strongly felt that action should be taken against commuters without disabilities. There is a penalty provision for those without disabilities who travel in handicapped coaches, but general commuters violate the rules without security. In order to avoid the discomfort due to entry of the general public into the handicap coach, people with disabilities negotiate crowd in the following ways - avoid travel in peak hours, leave home early to manage time as they might lose the opportunity to board the desired train, prefer travel in general ladies coaches and tolerate public behaviour. They felt that other people with disabilities are much better than commuters without disabilities as people with disabilities are helpful towards each other. Visual-impaired commuters offer seats to the mobility impaired and assist them in boarding/disembarking from trains.

3.1.2 Coach Interior Design: People with MI expressed concerns about environmental support, such as a lack of support in spaces between two seats, resulting in poor balance. Hanging grabs are inaccessible to people with disabilities that have short heights. They do not support manoeuvring when the train is in motion. They also found old coaches too small, offering less seating capacity, no space to rest mobility aids, poor ventilation and non-enabling environmental supports. The respondents with arm and elbow crutches and callipers felt the need for horizontal supports for manoeuvring and balancing, broad seats and provisions to keep mobility aids for their safety.

3.1.3. Information: Information concerns inside the train are reported both by mobility and vision-impaired commuters, such as lack of information about the allocation of handicap coaches to first-time users, lack of audio/visual alerts about time left for train departure from the platform or halts in the middle of the journey. In the new coaches, audio/visual displays of

upcoming station names are present, but they do not inform about the entire train route and stations at which the train will halt. There is a lack of information about the left and right sides of the platform location inside trains. Such an information crisis creates a risky situation for people with vision impairments.

Respondents prefer buses more than trains as bus drivers ensure all people have boarded or disembarked from the buses, whereas in trains, there is no contact with train drivers. In local trains, transfer between train and platform becomes scary, unpredictable and challenging for people with disabilities. A respondent with elbow crutches reports getting down quickly and taking someone's help. Crutch users suggested increasing train stoppage time to allow more time for boarding.

In the absence of information updates about the upcoming stations, people with disabilities make inquiries with different commuters several times to ensure information reliability. They suggested providing audio-visual dynamic information updates of the entire train route and station stops.

3.1.4 Technology*:* The vast gap between the train and the platform is a significant concern for people with disabilities. Wheelchair people cannot transfer without help; they must get out of the wheelchair, roll down on the platform, and then drag the wheelchair down. A crutched respondent reported jumping inside the coach as she had difficulty bending her knees. A no-vision commuter and elbow crutch user reported high chances of slipping in the gap. Some people with mobility impairments negotiate level changes by taking the help of family members and other commuters, but it is not possible for other people with disabilities.

According to activists, users are understood as homogeneous people with similar needs by the Railways Board. There are no classifications based on user typology, i.e. age, gender, mental and physical conditions, the purpose of use, frequency of travel, etc. and how the needs and challenges differ based on user characteristics. There is also a lack of awareness and interest in addressing the needs of people with disabilities, as it is considered an additional expenditure that will only benefit a small proportion of commuters.

It seems that the Railways have allocated a reserved coach for people with disabilities without adapting it to the needs of people with disabilities. Unlike other developed nations, where all trains are accessible to the needs of people with disabilities. Since millions of commuters commute daily from local trains, it is impossible to make the whole train accessible

to people with disabilities. Hence, allocations of reserved coaches for them ensure better access, comfort and safety opportunities. However, several usability issues have not been resolved in the existing handicap coach like entry of general commuters inside the coach, poor environmental support, lack of information about time left for train departure during boarding and alighting, lack of visual display of the train journey map and platform locations and numbers, lack of information about the reservation of handicap coach to first-time users and the route guidance to coach location, gap between the train and platform, security of women commuters, mismatch in the parking location of handicap coach with the audio/visual signage installed on the platform.

3.2 Ticket rules

Railways have issued passes for regular commuters to reduce long queues for tickets. However, first-time and occasional commuters have to queue for tickets. As a result, first-time and occasional MI commuters perceive ticket buying as a painful task. Respondents with elbow crutches, callipers and arm crutches find it hard to stand in the ticket queue. There is a rule that people with mobility impairments can buy a ticket from the ticket window without standing in the queue. However, commuters report that the rule is not standardized across all stations, or there is a lack of awareness among the public and ticket vendors. As a result, other commuters quarrel if MI commuters buy tickets from the counter without standing in the queue. Long walks and staircases used to reach ticket counters are complex and time-consuming. VI commuters report a lack of route guidance at ticket counters. Public help is the only way to reach ticket counters. A vision-impaired commuter reported that the sound of a fan is a reference to identify the counter. Another VI respondent follows the crowd to find the ticket counter. As a result of practical difficulties, they avoid buying railway passes, and they travel without passes to avoid visiting ticket counters.

First-time commuters are unaware of ticket concessions, passes and queue rules. As a result, they become part of a long queue. The informed commuters find the rule of direct purchase of tickets without a queue and pass system enabled. However, they felt that community education and awareness of their rights must be there.

Disability advocates suggested that automated coupon/ticketing vending machines be made accessible to people with disabilities, and tactile tiles should be installed to guide the

route to the ticket counters and platforms. No. ticket counters should be based on commuter flow 2) Incorporate new technologies like mobile ticketing systems or handheld ticket dispensing machines to reduce queues 3) Incorporate a commuter grievance system that ensures accountability.

As a result of the media pressure, railways have futuristic plans to decentralize ticket purchases from fixed station counter purchases. Railway tickets will be available in grocery stores. Booking tickets through Android phones is soon to be launched (Seth, 2013).

3.3 Install auditory signals for the benefit of persons with visual handicaps.

A buzzer is installed at the platform for vision-impaired commuters to indicate the position where the handicap coach will align. People with VI reported that the buzzers are absent at many stations. Without a buzzer, people find it hard to find the waiting place on the platform. Finding a waiting place is more challenging for VI commuters new to stations. The buzzer has limitations as it only informs about the coach's location on the platform. The people with VI find it hard to locate the coach entry from the platform. There is tactile paving only on a few stations that guide the VI commuter to the coach entry. However, trains do not align with the tactile path, so it is not easy to anticipate the location of coaches for VI commuters.

In the absence of buzzers on platforms, the people with VI refer to ladies' voices as an indicator to locate the handicap coaches, as the general ladies' coach is next to the handicap coaches. Another person with a VI goes towards the sound of a fan, and another VI take the reference of fixtures like the wash basin on the platform. Without any coping mechanism, people with VI get help from the public or family members and friends. All visually impaired commuters find audio beepers to help locate the waiting place on the platform, and they suggested that all stations' platforms should have this feature. All people with VI suggested that they need a reference to locate coach entry, and there should be standardization in the alignment of handicap coaches that aligns with the reference.

3.4. Provide engraving on the edges of railway platforms persons with low vision and no vision.

Very few stations have engraved tiles on the edge of the railway platform. All vision-impaired respondents report that they have witnessed other vision-impaired commuters falling on the track or they have had a fall in the absence of tactile engravings on platforms. Public help by pulling aside the commuters walking close to the platform's edge or those who have fallen on the railway tracks. VI respondents suggest the installation of tactile tiles on the platform as an indicator to avoid falls on railway tracks. Respondents report that they frequently collide with other people; their goods and luggage are kept on platforms, poles and girders. Most collisions take place on a platform. Vision-impaired commuters prefer walking on the extreme ends of the stations with one-sided tracks to negotiate collisions and falling on rail tracks. The platform on the end has a wall on one side that serves as a guideline for walking for VI commuters. So far, no safety measures have been taken to prevent collision, falls and injury on platforms.

3.5. Devise appropriate symbols of disability

The handicap coach is marked with a pictogram of the wheelchair user and a cancer sign. The same is present as a visual signboard on the platform, where the handicap coach aligns. A mobility-impaired respondent finds the signboards and signage on the train compelling as they help identify the coach.

3.6 Provide warning signals at appropriate places

There is no warning signal installed at any place inside the trains or any place inside stations, according to people with disabilities. All people with disabilities felt that railways should provide warning signals for their safety.

3.7. Installations of ramps in public buildings

In the general architecture of local train stations, staircases connect platforms and overpasses. In recent years, ramps and escalators have been installed at a few platforms on several major stations. However, ramps are steep; as a result, mobility-impaired commuters reported several difficulties using them with mobility aids. Long walks for ticket counters and platform change are challenging for commuters with mobility impairments. Crawlers report that crawling inside the station is complex and tiring. MI commuters find railings installed at

two ends of ramps and staircases supportive. To negotiate level differences, commuters avoid wheelchair use; they prefer to crawl or use other mobility aids to help them stroll. Few carry tricycles and wheelchairs inside the station, seeking public help. A respondent discussed that he has two tricycles. He parks them at two stations, where he commutes daily for work and prefers to crawl inside the station.

Collisions between incoming and outgoing crowds are common on staircases and ramps. Broken staircases are risky for first-time VI commuters. MI and VI commuters find all zones, i.e., the station's immediate exteriors, platforms, overpass and staircase, have slippery floors.

Commuters with vision impairments report difficulty finding the way to staircases and ramps from platforms or station exteriors without any route guidance system. VI commuters have developed a strategy of referencing the wall of two extreme platforms, which leads to staircase use. A commuter follows the shadow of the wall. Most commuters prefer to take public help for route guidance. They felt that in the absence of public help, it took more time to find the staircase.

3.8 Other Issues

Many user concerns have not been discussed in the media, nor have railways taken measures to address them. They are as follows:

The adaptations done for people with disabilities in the existing station environments have little consideration for the information needs, especially those who are new or seldom users of local trains and disabled. Complete loss of vision or poor sightedness further handicaps commuters accessing information crucial in train travel. For example, both MI and VI commuters reported a lack of route guidance signs in alternate formats that help in finding a way and identifying various station facilities like toilets, food and water stalls, station exit points, seating places inside the station, and help desk services. Commuters heavily rely on caregivers and other commuters for route guidance to such facilities or avoid using them to save time if travelling unescorted. Some regular commuters with vision loss lack awareness of facilities like help desks and water stalls. VI commuters identify food stalls and toilets with smell.

Information regarding platform and train selection and route guidance to the desired platform is also missing. Both sighted and non-sighted commuters face this problem. The people with VI also complained about waiting for the public announcements to figure out whether the train was standing on the platform or not. Waiting for the announcement leads to delays in train boarding and eventually leads to missing trains. A VI commuter suggested that train timetables be printed in braille to avoid dependency on public announcements. Many commuters reported that there is a significant dependency on other commuters for wayfinding in the absence of information availability in alternate formats. Public stations help voluntarily. The public is a significant support in wayfinding stations for unfamiliar commuters, both sighted and non-sighted. However, public help has many disadvantages. It is not reliable, and there is a high chance of misunderstanding that leads to accidents and falls. Much time is invested in multiple inquiries due to poor information reliability and misunderstanding. As a result, visually impaired commuters negotiate in several ways. For example, avoid visiting new stations and travelling on new trains, prefer travelling with caregivers, avoid visiting station facilities in both unknown and unknown stations, prefer seeking help from reliable sources like shopkeepers and station staff and avoid asking the public. In the case of women with mobility impairments, they prefer seeing help from women for security reasons.

Apart from the poor wayfinding design, railway stations have no parking facilities for commuters with mobility impairments. There are no provisions to park tricycles and wheelchairs. A respondent reported that he lost his tricycle at the station in the absence of security and the provision of a parking place. Many MI commuters reported no luggage-carrying services at local train stations. Commuters travel with luggage to reach stations and board long-distance inter-city trains. The absence of luggage-carrying services and non-enabling station architecture discourage independent travel with luggage on the station for all users, specifically those who are mobility impaired. As a result, such commuters depend on friends and family to handle luggage. There are no provisions at the station that assist people with disabilities to take another mode of travel once they exit from the station. A respondent with vision impairment reported that he faces great difficulty finding autos outside the station, and there is a chance of accidents on the road.

This research has revealed several issues that people with disabilities, both MI and VI, face while using local train railway stations and trains. Some pressing issues highlighted were concerns to MI and VI respondents or individual user groups (Table 1 below).

Table 1: Pressing issues across people with mobility and vision-impaired commuters

	Issues	**Users**
1.	The general crowd in handicap coach	MI, VI
2.	Difficulty in using the staircase	MI, VI
3.	Limited use of toilets at the station	MI, VI
4.	Poor information provision in alternate formats discourages independent wayfinding	MI, VI
5.	The absence of an alert about train start creates chances of falls and anxiety	MI, VI
6.	The presence of a gap between the train and the platform creates difficulty in boarding and alighting	MI, VI
7.	The handicap coach does not align with the audio/visual signage on the platform	MI, VI
8.	Lack of route guidance to ticket counters	VI
9.	Difficulty in locating a place to wait on the railway platform where the handicap coach will align	VI
10.	Difficulty in locating the coach entry of handicap coach	VI
11.	People fall on railway tracks	VI
12.	Collisions with luggage, poles, girders and people on platforms	VI
13.	Difficulty in handling luggage creates dependency on caregivers	MI
14.	Poor environmental support inside the handicap coach	MI

From the user insights, we can infer that the Railway policies positively and negatively impact the accessibility of people with disabilities. Many user concerns were never discussed in any newspaper articles. The policies do not address many of the issues discussed above.

4. Recommendations

After a critical examination of user concerns, recommendations made by disability advocates and railway initiatives, in this section, we collate insights from all the above sections and then propose several recommendations that are either modifications of the existing recommendations made by advocates or new recommendations that are formed to address the challenges faced by people with disabilities and incorporate their suggestions. The recommendations are made considering the modifications in the existing station and train environments.

4.1 Handicap Coaches

The advocates have suggested recommendations in the parliament to be implemented for improved access, such as protection to avoid falling in the gap between two coaches and on railway tracks while boarding /disembarking train, incorporating dynamic announcements inside the trains that inform users about left/ right direction of platforms and their number; install cameras in handicap coach so that driver is informed whether commuters with disabilities have boarded /disembarked from the train; appoint Railway Police Officials inside the coach to clear the unauthorized commuters from the coach; provide a complaint mechanism in multiple formats i.e. video, audio, written, braille, sign language etc. on all platforms.

In response to the suggested recommendations by the advocates, Railways have started raising the platform heights at a few stations; they have appointed women staff to control the entry of general commuters inside handicap coaches and avoid eve teasing. Audio and visual announcements of immediate station names are also implemented in more prominent coaches of local trains.

The following adaptations are required for handicap coaches:

1. Environmental supports inside handicap coaches should be redesigned to provide standing, balancing, maneuvering, boarding and alighting functions. Incorporate horizontal supports at appropriate places. Support should be accessible to people with less height, like children.
2. As suggested by advocates, installing cameras for the motorman information about commuters' boarding and alighting status is inadequate. The communication should be two-

way. Incorporate dynamic audio/visual alert systems in the trains that inform users about the time left for train departure.

3. Install dynamic visual journey maps that inform users about the train journey and station halts in all rail coaches.
4. Incorporate audio announcements inside all train coaches that inform users about the left/right side direction of platforms and their numbers of upcoming stations
5. Provide information to all the first-time commuters with disabilities about the provision of handicap coaches on local trains
6. Signage or environmental references should help commuters to predict the exact location of the handicap coach before the train stops on the platform.
7. Provide separate seats reserved for women with disabilities in handicap coaches. The benches inside the coaches should be incorporated with armrests.
8. Vulnerable populations include men, women, children with disabilities, temporary and permanent illness/health conditions/injuries, families travelling with babies, expected mothers, and senior citizens. Such commuters represent a considerable proportion of local train commuters. The allocation of several reserved and general coaches should be proportionate based on commuter statistics. The handicap coach should allow access to all such vulnerable populations. The terminology 'handicap' used for reserved coaches should be revised.
9. Promote boarding and alighting in queue.

4.2 Ticket Buying Policy

Some of the major issues suggested by respondents regarding ticket purchase are long queues for tickets, long walks to reach the ticket counters, and lack of route guidance signs to reach ticket counters. Disability advocates suggested automated coupon/ticketing vending machines should be made accessible to people with disabilities, and tactile tiles should be installed to guide the route to the ticket counters and platforms. No. ticket counters should be based on commuter flow 2) Incorporate new technologies like mobile ticketing systems or handheld ticket dispensing machines to reduce queues 3) Incorporate a commuter grievance system that ensures accountability. As a result of the media pressure, railways have futuristic

plans for decentralizing ticket purchases from fixed station counter purchases. Railway tickets will be available in grocery stores. Booking tickets through Android phones is soon to be launched (Seth, 2013).

The following updates are required for the ticket-buying policy:

1) Information, physical assistance, and access to other sources of ticket purchase for first-time and occasional commuters with and without disabilities. As suggested by advocates, automated coupon/ticketing vending machines should be accessible to people with disabilities.

2) Incorporate route guidance signs or assistance to help first-time and occasional commuters with and without disabilities locate ticket availability zones inside the station. Tactile tiles are inadequate; route guidance signs should be in multiple formats to serve the needs of people with and without sensory impairments.

4.3 Safety on Platforms

Platforms are sensitive places as the maximum number of accidents, falls, and collisions occur, as reported by train commuters. However, there is a rule to provide engravings on the edge of the railway platforms to avoid VI commuters falling on railway tracks. Disability advocates also recommend such a guideline. However, this guideline has not been implemented in many stations. This guideline does not address the collision of vision-impaired commuters with architectural fixtures on platforms, for example, poles, girders, seating places, beggars, vendors and shoe-shining men sitting on the floor and other train commuters. Disability advocates have only suggested avoiding hawkers on foot over bridges as they disturb movement in the walkways. Platforms need to be incorporated in this suggestion.

We recommend the following:

1) Conscious allocation of dedicated walkways or other sensory signals that avoid collision with physical and human beings on platforms.

2) Vendors should not be allowed seating in high-traffic zones of stations like staircases, foot over bridges, platforms, or ticket zones.

4.4 Signage

The signage for people with disabilities is represented by wheelchair use. However, there is hardly any wheelchair use on railway stations. Commuters prefer crawling or using tricycles lifted with the help of caregivers or other train commuters. Installing lifts and ramps at all railway stations will take a long time. Hence, such signage is misleading for commuters with other disabilities and people with health problems. There is a need to redesign an appropriate symbol that represents the usage of a facility or service with a broader population.

4.5 Warning Signals

There is no warning signal installed at any place inside the trains or any place inside stations, according to people with disabilities. Many stations have audio/visual warning signs incorporated at rail tracks to prevent people from crossing. Visual warning signs are placed to maintain distance from electric circuits on platforms and overpasses. However, such signs are inaccessible to vision-impaired commuters.

Recommendations

1) Warning signs should be in alternate formats

2) Warning signs should include time left for train departures on platforms. They should be installed at places close to collision with architectural fixtures like girders, poles, etc. and safety from electrical circuits.

4.6 Ramps and Staircases

No measures are taken and suggested to avoid falls, collisions on the staircase, and direct incoming and outgoing crowds.

There is a need for the following considerations: 1) Replace small steps with curb cuts 2) Install continuous ramps without staircases with fewer gradients 3) The floor material used on new or existing ramps, staircases, platforms and other circulation paths should be anti-skid. 4) Strategies for crowd management on the staircase and overpass for exclusive tracks for incoming and outgoing commuters to avoid collision 5) All staircases, ramps, platforms and escalators should have roofs and side walls to prevent rainwater inside the station.

4.7 Other recommendations

1. Incorporate route guidance system in alternate formats that help people with and without sensory impairments, both first-time and occasional commuters, to find a way to various station amenities like food stalls, toilets, seating places, station exit points, trains, platforms, and reserved coaches.
2. Toilets on a railway station should be provided at three to four points. The toilet location should be standardized across all platforms and stations. They should be easy to clean and maintain, as suggested by disability advocates.
3. Provide safe parking places for commuters with tricycles and wheelchairs. Provide security at these locations to avoid theft.
4. Provide accessible communication service and complaint mechanisms in alternate formats that help people to contact Railway staff for assistance in situations like theft, accidents, eve-teasing, luggage handling, lifting wheelchairs and tricycles or body support as suggested by disability advocates.

The work prospects involve categorizing recommendations based on short-term, medium-term and long-term goals. These recommendations need to be validated by diverse users with and without disabilities. Recommendations further need to be supported by design guidelines that further help in execution.

5. Conclusion

Insufficient research attention has been given to understanding the travel needs of individuals with disabilities, which is a worldwide issue. This study aims to effectively evaluate and tackle the specialized travel requirements of people with disabilities. Railway planners and policymakers show little interest or priority in understanding and accommodating the needs of this demographic. Policies are often formulated based on subjective experiences and personal understanding of railway authorities, lacking post-occupancy evaluation research into the real-life challenges of train commuters, particularly those with disabilities.

The findings of this research suggest that many travel constraints experienced by people with disabilities can also apply to individuals with health conditions, the aging population, and the able-bodied population. For instance, steep ramps pose difficulties for all commuters, and two-way mobility increases the risk of collisions for everyone. Additionally, inadequate information discourages fast and independent mobility within stations for all passengers.

Regrettably, service providers often fail to recognize these overlaps and thus struggle to make a positive impact across diverse populations, neglecting the principles of Universal Design. The research indicates that policies aimed at improving accessibility for people with disabilities often lack a foundation in thorough user-centered research. Consequently, these policies fail to address the numerous challenges inherent in the travel process, from station entry to exit.

This exploratory study identified various usability issues within the travel process. This knowledge will be valuable in designing supportive train and station environments that include people with disabilities.

2. Appendix A2

Observational Study on Commuter's Travel Behaviour in Mumbai Suburban Railway

1. Introduction

Mumbai Local train transit system is one of the world's busiest mass transit systems that serves India's fourth most populated city, Mumbai. Dependence on train services is very high for working-class society due to the low cost, fast service, and excellent connectivity. The commuting system caters to the mobility needs of 7.2 million daily commuters with an annual ridership of 2.64 billion people (MRVC, 2014). Due to the unprecedented commuter growth, local trains have become over-consumed. Infrastructure expansion supersedes the usability and accessibility of existing and upcoming infrastructure. Railway policies, so far, have been only able to provide ticket concessions and an exclusive train coach reserved for people with disabilities. The presence of physical and informational barriers and countless crowds has made local train travel challenging for all users. However, the degree of difficulty depends upon personal factors such as age and impairment. The study discussed in the paper is based on a universal design concept that propagates social inclusion by designing inclusive and enabling environments for conditions like ageing, impairments, childhood and other temporary and permanent health conditions.

Accessibility is understood from a travel chain perspective in a limited way by the Railway planners. Public satisfaction and trust depend upon the cumulative experience of a whole journey; if one link is missing or bitter, it can lead to a poor service image in the customer's mind. There is a massive gap between the understanding of transportation planners and policymakers and the actual day-to-day struggles of commuters. There is a need for evidence-based research that generates data on environmental behaviour interaction. The data generated should be used to form practical norms and guidelines that address raised concerns.

2. Previous Studies and Research Trends

Understanding human-environment interaction is essential to develop knowledge to make public transport user-friendly for all users. Traditional survey methods used by Wretstrand et al. (2009), Golledge & Stimson (1998), and Soltani et al. (2012) lack flexibility in collecting data on personal experience as they are based on pre-decided concepts that lack experiential knowledge. Personal interviews and focused groups used by Small et al. (2012), Yau et al., (2004), and Carlsson (2004) are retrospective as they are memory-based and disconnected from the actual setting. There is a possibility of error when it comes to memory during an interview, and it is also difficult for the researcher to visualize the experience through only words and identify what affected respondent perception. Capturing real-time data during interaction with the environment in a natural setting is more valid in human environment behavioural studies (Echeverri, 2005). Observing behaviour implies watching individuals and small and large groups of people using the environment. Observations include how activities are related in social and physical space (Zeisel, 2006). Observations are crucial when the research is at the exploratory stage. Observations do not infer the perceptual processes of commuters, like feelings and thoughts, but they can be used to assess manifest behaviour (Russell et al., 2011). Naturalistic observation does not interfere with the people or activities under observation. Observations can be made before and after interviews. Interviews are subjective methods based on self-reports, whereas observations are objective methods. Both approaches are needed to confirm the findings from the field (Stahl et al., 2008). Observations are documented by taking field notes, sketches, annotated diagrams, photographs and videos. This paper only discusses video-based methodology as a source of data collection as part of observational studies.

3. Video-based methodology

Video-based observation enables researchers to capture dynamic events. There are limited studies in transport literature on observation-based studies on commuter behaviour during travel. The method is helpful in understanding the patterns, chain of events, and causes of events during human-environment interactions. Echeverri (2005) used ‘think aloud’ and ‘video-based’ methodology in real-life settings, assessing commuters’ experiences for developing accessible, safe and functional public transport environments. The study showed that spatial layouts, communication symbols, guiding sound, and non-spatial elements like noise are important cues for functionally challenged and infrequent commuters. The study concluded with a recommendation to simplify the navigation system in the transportation

environment so that access is provided to all citizens. Similarly, Hwangbo et al. (2012) used a video-based methodology to investigate the relationship between ergonomic comfort and the provision of accessibility features in low-floor buses. The objective of this study was to document the usability issues that are the outcome of the interaction between commuters and station and train environments using videography as a research method.

3.1 Setting

As part of the exploratory research, Kanjurmarg station was chosen as a site for the study. Kanjurmarg has a single platform. Hence, it represents the small-scale station typology. The station has four entry/exit points, two overpasses, and three ticket zones, one on the ground floor and the other two placed on the overpass. The station has six giant and two small staircases. Three types of trains park at local train stations: 1) Fast trains that halt at a few intermediate stations, 2) Slow local trains that halt at all intermediate stations and are slower as compared to fast trains, and 3) Long-distance intercity trains. At Kanjurmarg station, only slow local trains stop.

3.2 Data Collection

The study was conducted in November when the weather was neither too hot nor too cold. A video camera is mounted at primary zones on railway stations, such as station entry and exit, stairs, overpass, ticket counter, and platform (Figure 1). All videos were 5 minutes in duration. The point of camera view at each zone was identified before the final shoot. Camera locations for all days of the shoot and frames for each point of view were fixed. The researcher did not interfere in the phenomena documented. Since the camera was installed on the tripod, some people were aware of the camera, but many overlooked it due to haste. Videos at each zone were taken three times a day – morning between 7-10 am (peak hours), afternoon 12-4 pm and evening 5: 30 - 8 pm (non-peak hours). All videos were taken on regular working days with the highest crowd turnover. Videos shot at different times of the day helped to understand the impact of crowd density on the usability of stations and trains, the behavioural changes of commuters in peak and non-peak hours and travel patterns over time.



Figure 1 Annotated Station Layout of Kanjurmarg Station with red dots highlighting camera positions.

3.3 Analysis

Videos were analyzed using the Observations-Inferences – Design Questions format. Videos were run, and observations were made on individual and group behaviour. Observations were later interpreted to determine what behavioural- psychological- and physical environmental factors impact each other for any observed interaction. Design questions are the outcome of the analysis and highlight important interrogation issues through interviews and experimental research. All videos were explicitly analyzed for station zones like entry/exit points, overpasses, staircases, platforms and ticket zones. Videos were analyzed across different times, morning-afternoon-evening, to understand how time differences impact crowd and individual behaviour and what spatial transitions happen due to changes in time. Analysis was also done across typologies of commuters, such as people with impairments in lower extremities, vision loss, people walking with luggage, vendors, parents with young children, adults, and senior citizens.

4. Findings

Findings from the environment interaction-based study are common and specific to each primary zone of the station. The environmental issues discussed are causes, and the behaviour is the outcome of the cause. The relationship will help to understand the commuter's experiences in the whole travel chain from station entry to train travel and vice versa.

4.1 Zone1: Station Entry/exit

There were common station entrance and exit points. Many commuters were found walking fast while looking down due to broken flooring. They collide with the commuters coming in opposite directions. Floor conditions of entry/exit zones are exposed to exterior weather conditions. They have no rooftops and are prone to environmental degradation due to monsoon rains. Cracks develop on floor tiles (fig 3). The broken floors create difficulty in walking, especially among those who move with mobility aids or have vision loss, people with arthritis and other ailments in the lower extremities. In hastiness, people wobble on broken floors. Narrow station entry/exit slows down traffic movement during peak hours. Protrusions and potholes further create chances of getting hurt for commuters (fig 2). The presence of the staircase (fig 4) and the steps themselves is an environmental component and a barrier to

wheelchair users. Staircase use will be hard for commuters with heavy luggage and vendors with goods and merchandise as their speed slows down compared to other commuters.

Emerging questions from the inferences are-

How can station entry/exit design offer regulated traffic flow?

How can station entry/exit floors be designed to ensure safe access for train commuters?

How can barrier-free access be provided inside the station?



Figure 2 Protrusions



Figure 3 Broken floors



Figure 4 Steps at the entrance

Zone2: Staircase

On the staircase two ways, traffic flow slows down the speed of the traffic on the staircase, especially in peak hours. Traffic flow sometimes stagnates, disturbing the activities of other neighbouring zones, like platforms and overpasses. The influx and the density of the outgoing crowd (towards entry/exit) compared to the incoming crowd (towards the train) are more significant when the train unloads at the station. This leaves little space for the incoming crowd to use the stairs (Figures 4, 6 and 7).



Figure 5 Outgoing crowd in the morning using stairs



Figure 6 Outgoing crowd in the evening using stairs

Hasty use of stairs is observed, especially among physically fit users like teenagers and adults, both during peak and non-peak hours. Men use staircases in more haste than women (Fig 8, 9, 10). Hasty use of stairs among such commuters affects those not physically fit. Such behaviours create chances of collision with commuters moving in the same and opposite directions. The behaviour is more evident among the incoming crowd (towards the train) than the outgoing crowd (towards the station exit) as they hurry to board the train.

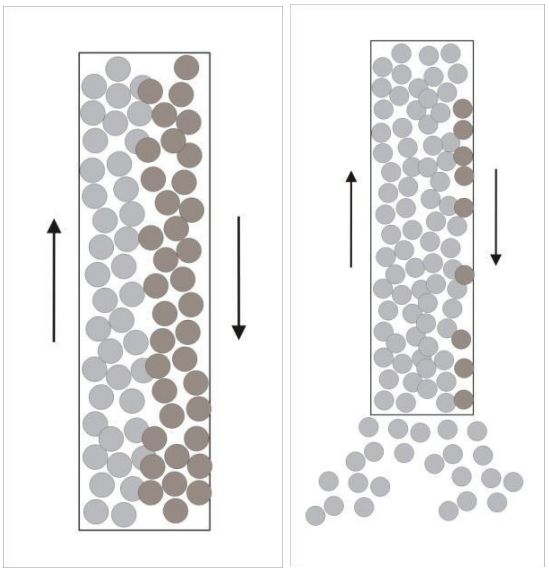


Figure 7 Difference in traffic flow on stairs when the train unloads.



Figure 8: Incoming (towards train) male commuters using stairs in haste in the morning (peak hour)



Figure 9: Incoming (towards train) male commuters using stairs in haste in the afternoon (non-peak hour)



Figure 10 Incoming (towards train) male commuters using stairs in haste at night (peak hour)

Handrail use is more visible among men and women in middle age and senior citizens (Fig 11, 12, 13). Handrails installed at two extreme sides of the staircase enable stair climbing among such commuters. Handrails are at multiple levels that help children climb and get down the stairs. The handrail is a flat, narrow strip that does not allow a firm grip (Fig 12).







Fig 11, 12, 13 Handrail use

The staircase is used in the wrong direction (Fig 14, 15, 16). There is a common understanding among the crowds that incoming traffic (towards the train) uses the left-hand side of the staircase, and outgoing traffic (towards the station exit) uses the right-hand side of the staircase. However, people often used opposite directions, probably due to inexperience in local train travel. Such behaviour leads to sudden collisions and disturbs the traffic flow of the crowd, especially in peak hours. There is no directional signage that directs traffic flow on stairs.







Fig 14, 15, 16 Use of stairs in wrong direction

Stair use in sari is inconvenient. Women in sari are conscious of stair use; they lift the sari in one hand while using the staircase as there are chances of fabric getting entangled between the feet while climbing a staircase. Women amble, looking down while ascending or descending the staircase to ensure safe use (Fig 17, 18, 19).







Fig 17, 18, 19 Stair use

The use of stairs with children and luggage is rugged in the presence of a crowd (Fig 20- 22). Vendors find station navigation tiring without any provision of luggage and goods-carrying services, mainly due to level changes through the staircase (fig 23- 24). They carry heavy goods on their heads. Travelers with luggage also face similar problems as they need to lift their suitcases on the staircase (Fig 22).







Fig 20- 21 Parents using the stairs with children

Fig 22 A man and woman lift the luggage together





Fig 23- 24 Vendors carry luggage on head and shoulder

Emerging questions from the inferences are-

-What challenges do vendors and luggage users encounter while going through the station? What service intervention will help them transport their goods and luggage from the train to the station exit and vice versa?

-What challenges do caregivers encounter while providing help to children or adults on the staircase?

-What environmental design interventions can address collision and ensure quick traffic flow?

-Why do people use stairs in the wrong direction? What visual/oral/tactile cues can help orient incoming and outgoing crowds on stairs?

-How does clothing impact staircase use?

Zone 3: Ticket Zone

In the ticket zone, coupon and ATVM machines are either absent or, if present, are non-working due to maintenance issues. People are not informed about the non-working machines, and they are not informed when they start working. Repeated trials with the machines inform users about the state of the machine. Poor lighting conditions (Fig 25) make viewing information displayed inside the ticket zone difficult. All methods of buying tickets, i.e. coupons, intelligent card use and paper tickets, are available in one service zone. A centralized mode of payment from a particular zone invites a massive crowd influx. The long serpentine queue is regular for buying paper tickets from the ticket window (Fig 28). Commuters who do not have intelligent cards or coupons lose time standing in long queues. Queue formation affects traffic movement in neighbouring zones; narrow entry to the ticket zone inconveniences commuters moving in and out of the ticket zone (Fig 25-27).



Fig 25- 27 Long queue for ticket

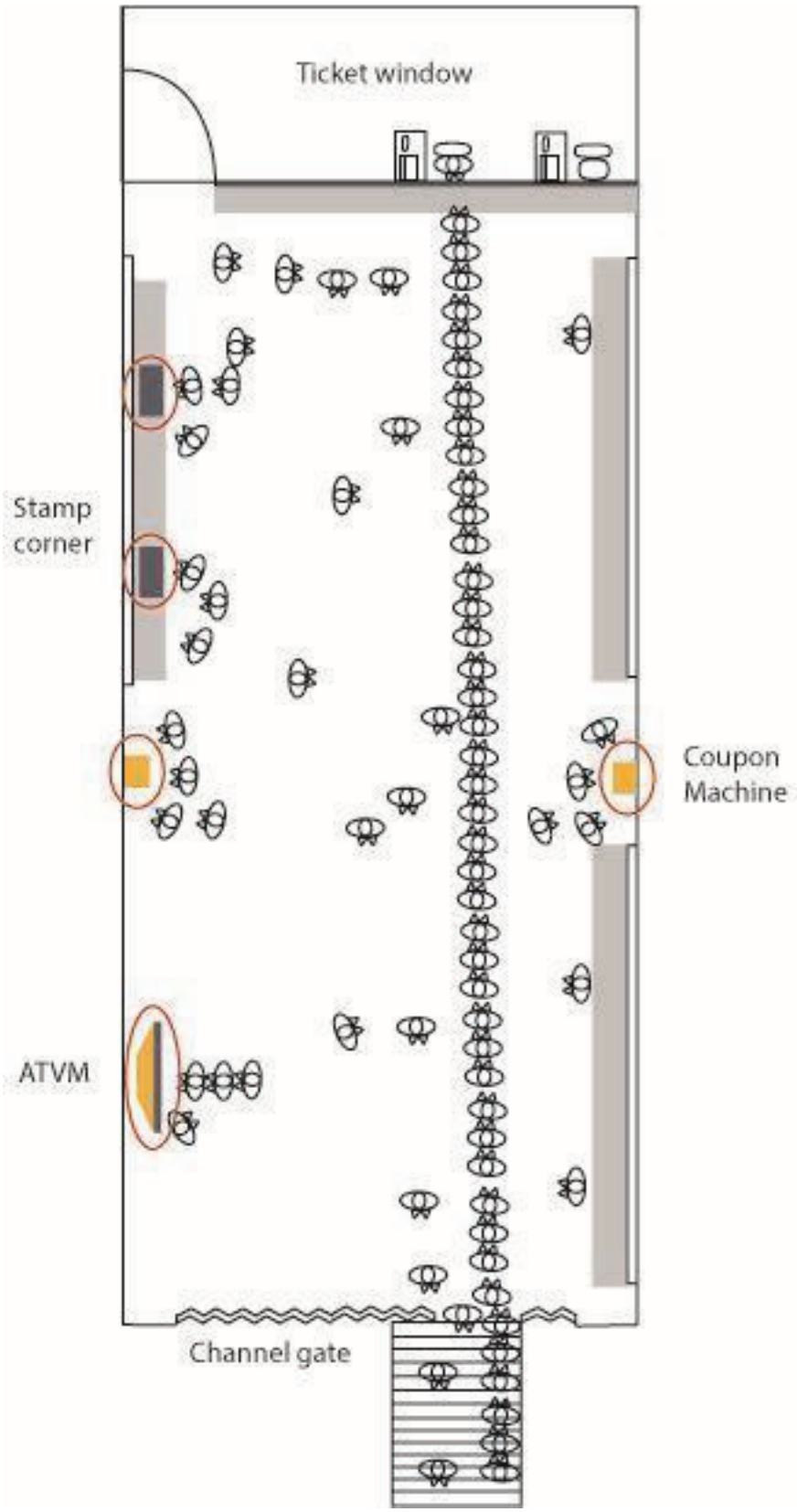


Fig 28. Ticket zone

How ticketing system can avoid long queues?

Zone 4: Overpass

Ambient conditions such as announcements and the sound of the train trigger hasty movement among physically fit adults and young boys. This creates an opportunity for collision with other commuters. Vendor stalls on the overpasses leave less space for traffic movement, especially during peak hours. The long queue for tickets disturbs the traffic flow at the overpass (Fig 29).

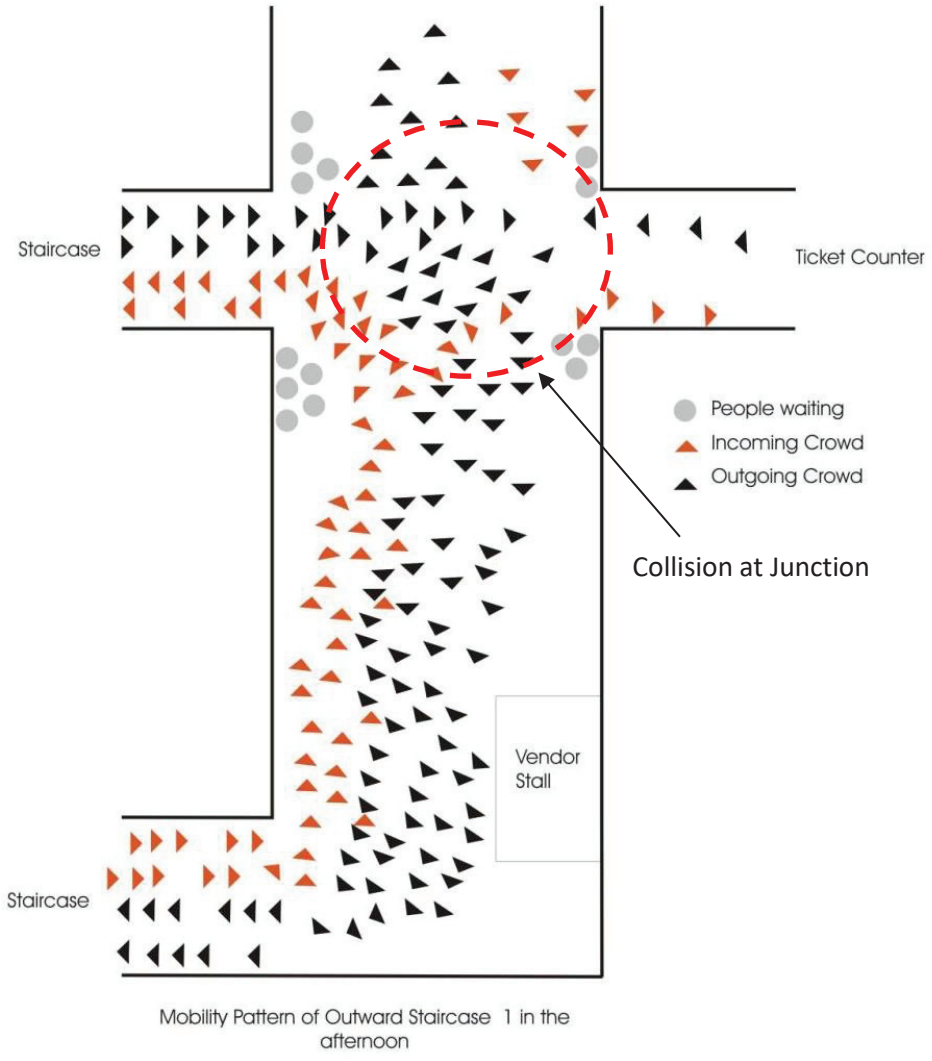


Fig 29: Crowd mobility pattern on an overpass in Kanjurmarg Station

What psychosocial reasons lead to hasty behaviour among men and young boys when they hear announcements of incoming trains, and how does that affect traffic flow? What problems are due to the illumination of the overpass, and how does that contribute to collision?

How can the ticket purchase system avoid the long queues? How does the presence of a ticket zone on the overpass contribute to a disturbance in traffic flow in the zone?

Zone 5: Platform



Fig 30: A man with crutches walking towards the handicap coach

Platform Coach stops do not coincide with the signage earmarked at the platform. As a result, people with mobility impairments lose time walking towards the coach, leading to psychological and physical stress to board the train in haste.
How do commuters cope with inconsistency in stoppage time and parking location while boarding/exiting the train?

The lack of signage for luggage coaches on the platform and some train interfaces creates restlessness among the commuters regarding their positioning on the platform. This results in people boarding coaches that fall nearest to them or running to look for the desired coach. Secondly, there is a lack of floor guidelines on the platform that coincide with the coach entry. Without such guidelines, people with walking difficulties, like senior citizens and people moving with mobility aids, lose time in walking the extra distance (Fig. 30). Vision-impaired commuters are left unguided when locating the entry to the coach.

What difficulties do people with vision loss and walking difficulties encounter from the absence of platform navigation systems? How effectively do train and station interfaces communicate information about coach parking and identity to the rail commuters?

3. Absence of queue making system:

The lack of barricades and security checks do not support train boarding in the queue. People spread on the entire platform and rushed toward the nearest coach, leading to a collision. People spread on the entire platform and rush toward the nearest coach, leading to a collision on the platform (Fig 31 and 32)



Fig 31 and 32: Men and women rushing towards the coach to get inside the train

4. Lack of visibility in existing markings on coaches

The information displayed on the coach interfaces lacks visibility. The information is either written or symbolic and loses clarity because many trains are painted with commercial ads (Fig 33), or the font size is small (Fig 34). This creates confusion among the commuters, who board the wrong coaches and pay a heavy fine if caught by the ticket checker. In Fig 35, many occasional and first-time infrequent users are unaware that the red-striped coach is meant for 1st class users.

-Lack of signage for luggage coaches on the platform and some train interfaces creates restlessness among the commuters regarding their positioning on the platform.

What challenges do infrequent users encounter with the current information display boards?







Figures 33, 34 and 35: Train coach identity of First class, Luggage coach and general coach

5. Absence of level boarding

The absence of level boarding creates risky situations and difficulties in boarding and disembarking for different users. In Fig 36 -38, people walking with mobility aids suffer from level differences as they cannot transfer their bodies from one level to another. Similarly, people with polio and arthritis face difficulty bending their knees to change their levels. In such situations, people need the help of caregivers or passersby commuters to give physical support (Fig 39). Non-level boarding also creates difficulty for people moving with heavy goods and suitcases. As the train stops for 15- 20 seconds, boarding and disembarking becomes very taxing for people with luggage and goods, especially in the presence of a crowd. Non-level boarding creates risky situations for people falling into the gap between the platform and the train.

What environmental interventions can prevent risk-taking practices among rail commuters while boarding and disembarking from local trains?



Fig 36-39 Commuters with mobility aids and luggage having difficulty getting in and out of the train due to non-level boarding

6. Absence of doors

Train coaches lack safety solutions at the coach entry/exit. The absence of doors and level boarding/disembarking springboards for safety and access is a significant issue of this zone, leading to commuters boarding and disembarking in a moving train (Fig. 40 to 48); children form habits at an early age, and this has shaped into social behaviour. People with mobility impairments also stand near the edge of the coach even though the coach is empty to save time in disembarking (Figure 49-52). Parking near the edge of the coach is shared among all commuters. People hold protruded ridges and side rails for support. Travelling in such conditions is extremely risky and does not guarantee safety to all train commuters.

What psychological and environmental factors influence commuters to board and disembark from the running train and parking close to the entry/exit zone inside the coach?

















Fig 40-48 Commuters of all ages and genders boarding and getting off from the running train.



Fig 49-52 Commuters with and without disability travelling in the train, positioned close to the edge of the open coach

7. Two-way entry-exit from a single point

See Fig 53 and 54. Two-way entry/exit from all the coaches creates collisions and high stress among commuters. People fight with each other; they push and pull and hurt each other in a restless state as the train stops for 15- 30 sec. In this state, many people get hurt or abandon taking the train when it is highly crowded.

What will help minimize collisions on the platform while boarding/exiting the train?



Figures 53 and 54 Men and women rushing towards the train for boarding.

8. Poor design of grab rails and handles.

The design of the supports provides some assistance to people to board and disembark from the train. Without support, it is tough for people with walking difficulties to board and disembark from the train. The commuters hold any protrusion on the exterior of the train, like a window protruding out, or the ridge on the roof, to enable them to board and balance themselves in the moving train (Figures 55 and 56).

How does environmental support work for people with walking difficulties and vision loss?



Figures 55 and 56 Commuters are shown using the grab bars of the local trains.

5. Discussion

As previously described, the study aimed to explore the dynamic and interactive aspects of the environment and human behaviour using an advanced qualitative method based on a video-recording procedure. The method helped conduct crowd-based observation. The interpretations in the study are limited to the researcher's understanding. There is a need to extend the understanding of the experience of train travel from the perspective of commuters.

The findings shared in the report are limited to people's visible behaviour and activities. However, although the data were authentic and evidence-based, there were some problems with conducting video shoots in a real-life environment as it is an uncontrolled space. There are minimal options for camera installation as the station is a highly crowded public space. Low-lit station zones in the evening reduce the quality of video. The camera was visible, and a few commuters were inquisitive about the video shoot. The present study was conducted in one local train station. Since the study only focuses on primary zones and overall crowd behaviour, some important issues for future research need to be examined in other stations.

The questions developed from the study can be used as cues or triggers to instigate responses from the commuters in the next phase of interrogation. At the commuter's level, it was apparent that physical attributes, spatial factors, self-service ticket machines, communication signs (or lack thereof), public announcements and transport noise are important cues that contribute to the usability of a space. If these are inappropriate, the travel process is perceived as difficult, less accessible, and unsafe. Because of these problems, passengers with functional limitations hesitate to use public transport, resulting in social segregation and high community costs. Local train travel is only limited to regular able-bodied commuters, as they can cope with the environmental challenges compared to those who are 'physically weak'. Occasional and first-time commuters find it hard to navigate the transit environment due to the non-inclusive information communication system.

6. Conclusion

The present study tested a methodology for capturing customer perceptions and provided new insights into what happens within dynamic and interactive customer processes. The method gives rise to new ideas on how to develop research into design interventions that address real-life problems of the commuters of local trains.

Investigation into contextual aspects of environment behaviour studies. In the current context, the local train commuting system is facing significant challenges in accommodating the frequent rise of commuters each day. Mumbai Rail Vikas Corporation is investing money to increase the infrastructure. The manager's vision is limited to addressing the problem with increased infrastructure. However, they cannot identify how to make the system usable by all, promising its commuters safety, security and comfort. Nobody is accountable for frequent accidents and deaths due to unsafe designs and security checks. Eve- teasing and women harassment are rampant in trains and on stations. People with disabilities, women, senior citizens and infrequent commuters use local trains only when there are no choices left. However, at the same time, travel is also completely unavoidable as it is the cheapest and the fastest mode of travel in the city and not all users can afford private vehicles and cabs. Therefore, the commuting system needs concrete improvements based on customer's experiences. There is a need for change in the perception of what constitutes "quality" in public transport. Service processes need to be accessible, safe, and secure, and there must be a non-discriminating transport system. A wide range of findings from the empirical study highlight potential areas for quality development.

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3. Appendix A3

Railway Station Spatial Layout Analysis Using Annotated Drawings

1. Introduction

Annotated drawings are simplified drawings of products or spaces used for explanatory purposes or to indicate areas of relevance. Recording activities on floor plans, diagrams or maps is particularly convenient if researchers want to observe large-scale physical environments. Looking at the spatial layouts, researchers can comment on the usability of a space. The method is unobtrusive. Drawing spatial layouts implies investigating chief spatial elements that make a physical environment to understand the connections, missing links, and separations (Zeisel, 2006; Lynch, 1960).

As part of the observational study, annotated maps of Railway stations are drawn to understand the relationship between the primary zones of the station, which are entry/exit, staircase, overpass, ticket zone, and platform. The method is well suited to understand the spatial organization briefly in a two-dimensional plane. It gives a bird's eye view to understand the relationship between parts of the space and how they affect the overall usability of a space. As part of the annotated drawings, complex architectural details of the station and train environment are coded into standard symbols marked in specific colours to make the data comparable with different stations and trains.

The study's objective was to understand how the current train and station spatial organization impact crowd mobility and usability of the space and to develop knowledge on how spatial elements and their use are affected by the scale of the station.

As part of the annotated drawings, three stations were selected based on the size and scale of the station. 1. Kanjur Marg represents the small station type with two platforms where only slow trains park. Trains of only central line park at this station. 2. Kurla station is a medium-scale station with eight working platforms and two non–working platforms. The

station served both the harbor and the central lines. 3. Dadar is one of Mumbai's biggest local train stations, with eighteen platforms. It is the most populated and used station in the middle of a business hub. Trains of two lines, both Western and Central Park, are at this station. On Dadar, there are both long-distance and local train parks.

Architecturally, the station layouts have some essential common characteristics, such as all stations having parallel platforms connected through foot over bridges or underpasses. Entry/exit points are located close to the end platforms. Entry to the station is on foot over a bridge, platform, or ticket hall. Ticket halls are on the two extreme platforms or the foot-over bridge. However, each station differs in its layouts regarding the positioning of its primary zones, thereby making station use, predominantly wayfinding, unpredictable.

2. Data Collection

Two-dimensional drawings were used as tools to capture the station layouts. The study allowed us to investigate the architectural details of the station in its natural settings and how people use the spaces. Rough sketches were drawn in parts by physically navigating through the station and were later redrawn and refined on graphic software, Adobe Illustrator, for clarity and analysis. Drawings in real-life settings build an experience of a useful space for data analysis. It allows anticipating reasons for design decisions behind the organization of a space and usability issues in and around it.

3. Data Analysis

Drawings of all three stations highlighted six primary zones. These zones were symbolically represented and colour-coded for accessible communication and analysis. A typology is formed within each zone. For example, ticket zones are of two types: (1) on the ground floor and 2) on the first floor. Each station zone is analyzed separately and compared across station types on medium- and large scales. See Figure 1, which shows three stations' symbolic and colour-coded maps. The report shares the analysis of 4 zones: Entry/exit, staircase, ticket zone and overpass. Analysis of platform and train interiors is in progress.

4. Findings

4.1 Zone 1: Entry /Exit

Entry/exit to the station is always from the two extreme sides of the station. All entry-exit points lie close to the first and last platform of the station. The entry/exit can be from the ground floor and the first floor (Figure 2).

No. of entry-exit points

Frequency	Kanjur Marg		Kurla		Dadar	
	East	West	East	West	East	West
Ground Floor	0	0	3	1	2	3
First floor	2	2	4	4	3	1
Total	4		12		9	

Table 1 No. of station entry-exit points on three Railway stations

a) No. Of entry-exit points: A high number of entry-exit points ensures more choices for taking different routes to exit the station. Kurla has maximum entry-exit points (12). Dadar, a giant station, has only nine entry/exit points, giving fewer options for crowds moving in and out.

b) Distribution of entry-exit between two levels: 2. All stations have two levels of access: ground level and first floor. If entry/ exit points are equally divided among the two levels, that helps crowd distribution among both levels and reduces pressure on 1st and last platforms. In Kanjurmarg, traffic inflow and outflow points are limited to the first floor. In contrast, the eastern side of Kurla and Dadar provides better access due to the more significant number of entry/exit points on both the first and ground floors than the western side of both stations.

c) Location of the entry-exit points: Decentralization is achieved if the entry/exit points are well spread on the entire platform length and connected to the overpass. The widespread distribution of entry/exit covers the maximum size of the station compared to the eastern zone. Such a layout contributes to the fast distribution of crowds.

a) *Typology of level change*







Figure 4 a Full stairs Figure 4b Stairs cum ramps Figure 4c Ramps

All stations have maximum staircase installations. Kurla has stairs cum ramps installed at 3 points, which is risky for people with low vision or complete vision loss as they will be taken by surprise by the sudden change in the walking surface. Dadar has eight full ramps. Out of 8, 3 ramps are installed on platforms where long-distance trains park. Walking on a slope is less tiring than climbing stairs. Ramp installation will be helpful for all commuters.

b) Connection between overpass and platform: Stairs connect the overpass with the platform. The stair installation is on either one side or both sides of the overpass. Sometimes, there are no stairs from the overpass on either side. In Kanjur Marg, stairs are only on one side of the overpass. This creates problems for the commuters as they have only two routes to exit and enter from the station. In Kurla, stair provision is also on one side of the overpass. On platforms 1 and 2, two stairs are only provided at two points of intersection where there are no stairs on either side of the overpass (See Fig 1.3; points are marked with a cross). This creates confusion for the occasional and 1st-time commuters, who must take long routes to reach the platforms. In Dadar, most intersections between the platform and the overpass have double stairs. Kanjur Marg has the poorest connectivity as compared to bigger Kurla and Dadar. Maximum 7- 4 stairs are installed on the platform. Connect connections at each intersection point between the 1st and ground floors. The number of connections for each platform should be more than two to offer more choices to commuters who need to take different routes.

c) Connection between the overpass and entry/exit zone: The provision of stairs from both ends of the overpass allows commuters to access the station from multiple points and routes. Kurla provides better connectivity to the entry/exit zones as six ends of 4 overpasses are connected to the entry/exit. In Dadar, only four ends of 6 overpasses are connected with entry/exit. All overpasses should provide entry/exit points at both ends to make stations better accessible.

Distribution of Ticket Zones: Dadar has better spread and equal access to ticket zones from both station sides. It has two ticket zones on either side of the station on the ground floor, and three ticket zones are built on the overpass to facilitate ticket buying to change lines. Ticket zones are unequally distributed in Kurla and KanjurMarg. They are not evenly distributed at the station, creating access problems and long walks in Kurla. Wayfinding for the ticket zone at the station entry is easy for first-time and occasional commuters.

Provide multiple ticket zones that are well distributed and spread across the length and width of the station at different scales. The ticketing system should avoid queues and crowd centralization to allow free mobility of the crowd undisturbed. Stations should have ticket booths on the platforms themselves to prevent the use of stairs and long walks. All entry points to the station should have ticket zones. This will help 1st time and occasional commuters find ticket zones easily and avoid crowd centralization at only a few ticketing zones. Apart from manual ticket procurement, e-ticketing should be made available through the Internet and mobile applications for regular users. Provide installation of coupon machines on various points of the overpass and platform.

1. Connectivity between Overpass: Dadar has better crowd distribution on the 1st floor than other stations. The connection between single-line and double-line overpasses allows commuters to navigate easily without stairs, as walking is less tiring. Dadar has three double lines and three single-line overpasses that provide multiple routes for navigation and distribute crowds between the ground and the first floor. At the same time, Kurla needs to be more robust in connecting overpasses and has three overpasses on all platforms. KanjurMarg is the worst among the three stations, with just two distant overpasses, which makes them very crowded. The station does not provide intermediate routes to allow crowd distribution. Allocating another overpass will help share the load from the existing overpasses.

Recommendation: Provide connectivity between the overpasses to reduce stair use and distribute crowd pressure between the ground and the first floor.

2. Entry/ Exit: KanjurMarg station can be accessed only through an overpass, helping commuters to access the station from both sides. On the other hand, Dadar platform ‘e’ and Kurla platform ‘b’ are the only overpasses that can be accessed outside the station.

Recommendation: Incorporate entry/exit from both sides of the overpass, providing equal opportunity for commuters from both sides of the station to access the platforms.

3. Provision of connection between overpass and platform: Dadar has ramps installed at three points on three platforms. Similarly, two ramps cum stairs are provided at three points at Kurla Station. Provide full ramps from one side of the overpass on all platforms. Ramp installation will help luggage users and people who are weak in mobility access stations with ease.

5. Conclusion

The study involved an analysis of station layouts. It helped develop an understanding of the strengths and shortcomings of the existing station infrastructure through a comparative study of station layouts of three different scales of stations. Architecturally, station layouts are a common characteristic. The chief characteristics of the primary zones of all stations are: 1) All stations have 1st floor. 2) Ramps and stairs connect the overpass and the platforms. 3) Entry/exit points are on the two extreme ends of the station; entry/exit is from via platform, ticket counter or overpass. 5) Ticket counters are located towards the outer side of the station parallel to the 1st and last platform or on the overpass.

These primary characteristics are inconsistencies in the spatial layouts of different train stations under study. For example, the location of the ticket zone could be more consistent: Kurla has no ticket zone on any of the overpasses, Dadar has three ticket zones on two overpasses, and KanjurMarg has two ticket zones on two overpasses. Similarly, in Dadar, most overpasses have a double-sided staircase, and Kurla and KanjurMarg have one-sided staircases. At some points of intersections, no staircase is provided in Kurla and Dadar. Such inconsistency in spatial architecture brings surprises, confusion and dependency. The difficulty is aggravated by non-supportive visual, informational cues that orient the commuter about space layout.

With the increase in the station's size, the complexity of the station architecture increases as the primary zones multiply. Frequent or regular commuters have adapted to the system through prior experience and use; they are least affected by the design. The impact is less on occasional commuters as they use the station based on memory, familiarity with the information display system and some direction from the service providers or passersby. The complex station architecture most impacts first-time or rare commuters and needs maximum guidance from

informational and spatial cues. It is not easy to visualize the space at a glance; people need to be made aware of the routes. Frequent questions the commuters ask: What are the ticket counter locations are. Where is the destination platform? Which platforms are dedicated to specific lines, such as central-western harbour? Which platforms allow parking for slow or fast trains and long-distance trains? Where are the station's exit points? Which exit point will lead me to the destination or feeder services (taxi and bus)? How do we differentiate between the east and west sides of the station?

From the current scenario's viewpoint of the station design, local train stations are challenged by the increase in no. of commuters using local train services. The station infrastructure must address the mobility needs of lakhs of commuters daily. The management of traffic flow within limited space is a significant issue that environmental interventions need to address. The interventions could be long-term futuristic stations, or they could be short-term applicable to the existing stations. Ecological interventions in the existing station can be addressed with an information communication system design and minor modifications in the architectural design.

The findings from this study helped develop preliminary recommendations that can help formulate standard architectural guidelines. The recommendations are essential station characteristics that can be replicated in all stations. This will reduce the stress of navigation and the uncertainty of wayfinding.

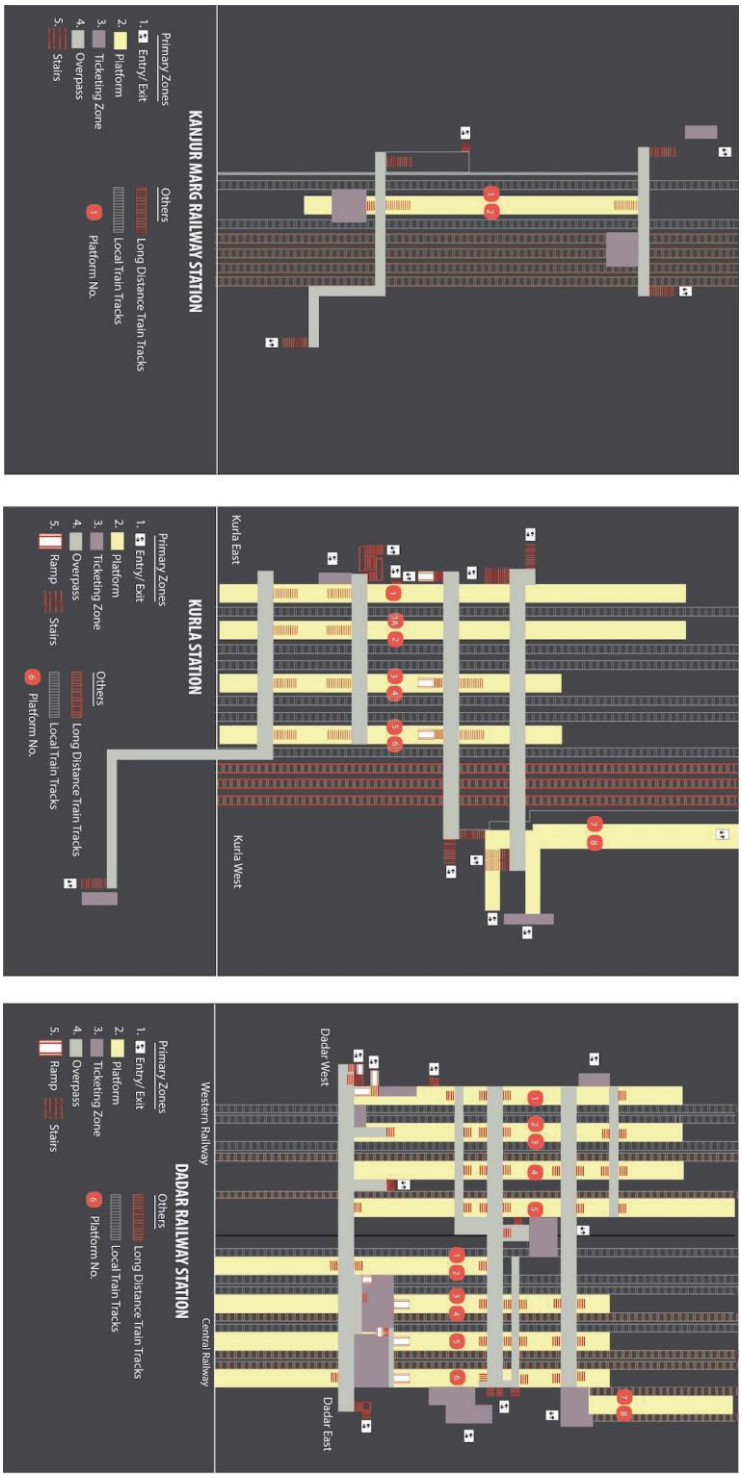


Figure 1 Station drawings of KanjurMarg, Kurla and Dadar station

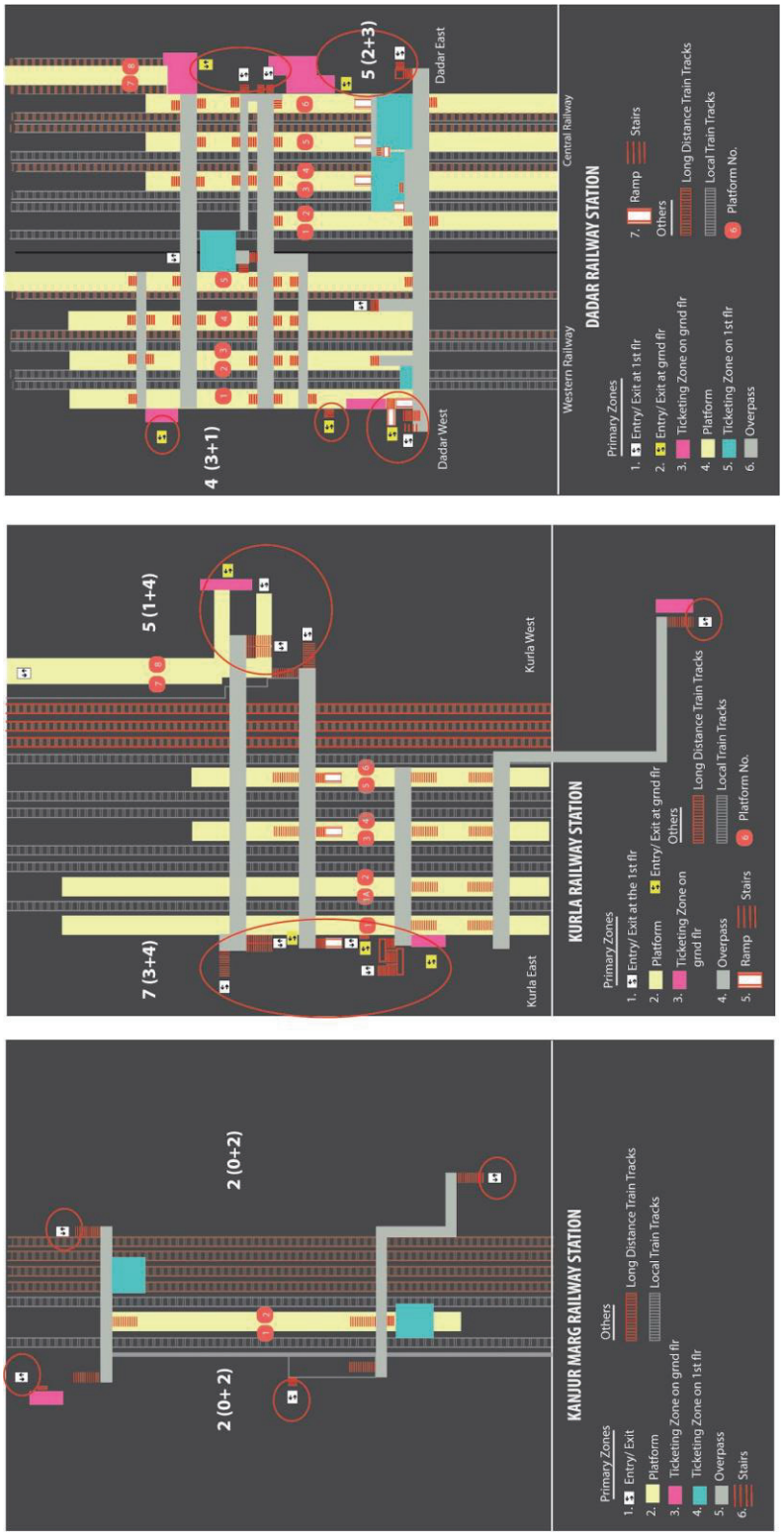


Figure 2 Entry/Exit zone of KanjurMarg, Kurla and Dadar station

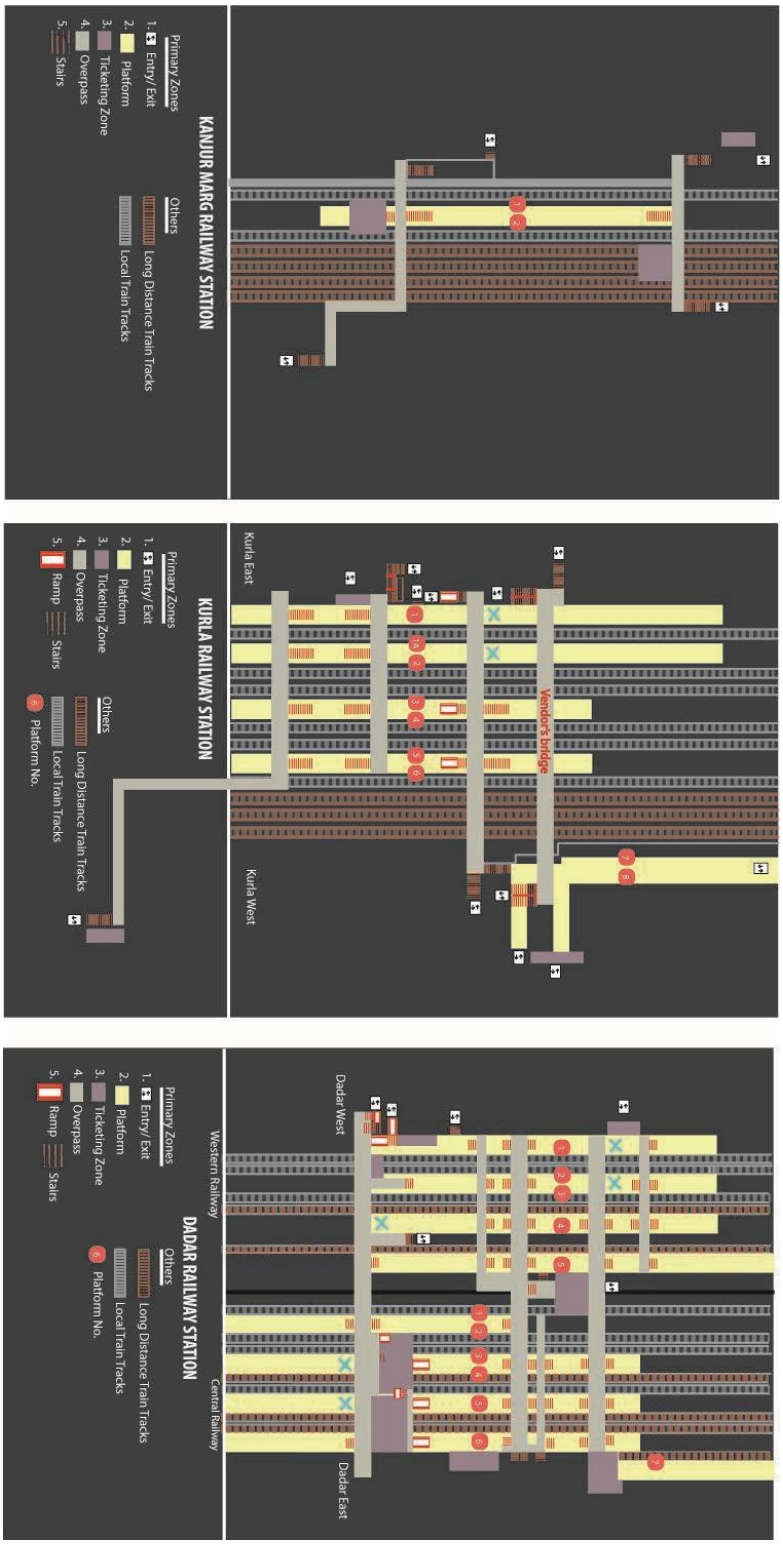


Figure 3 Staircase zone of KanjurMarg, Kurla and Dadar station

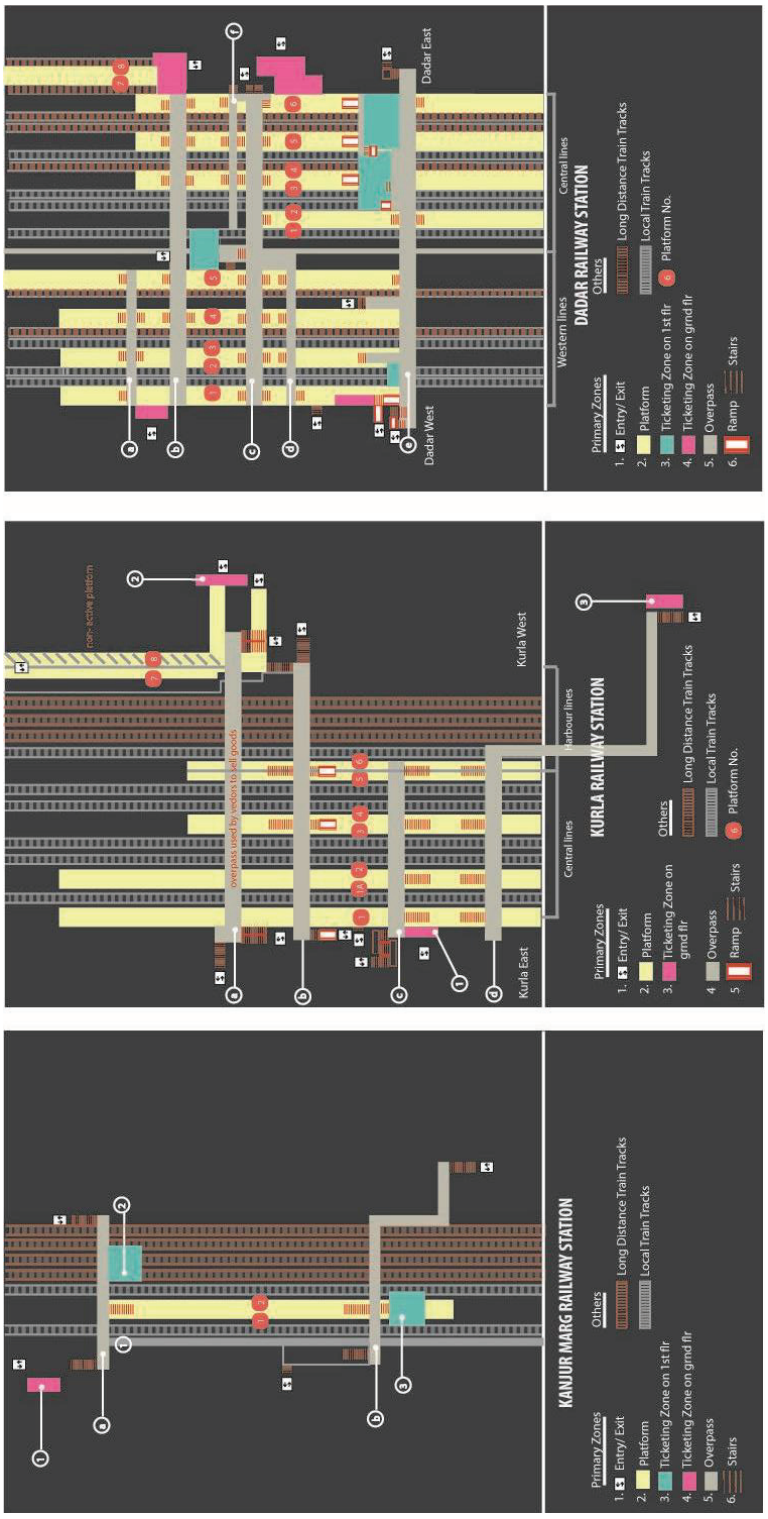


Figure 4 Staircase zone of KanjurMarg, Kurla and Dadar station

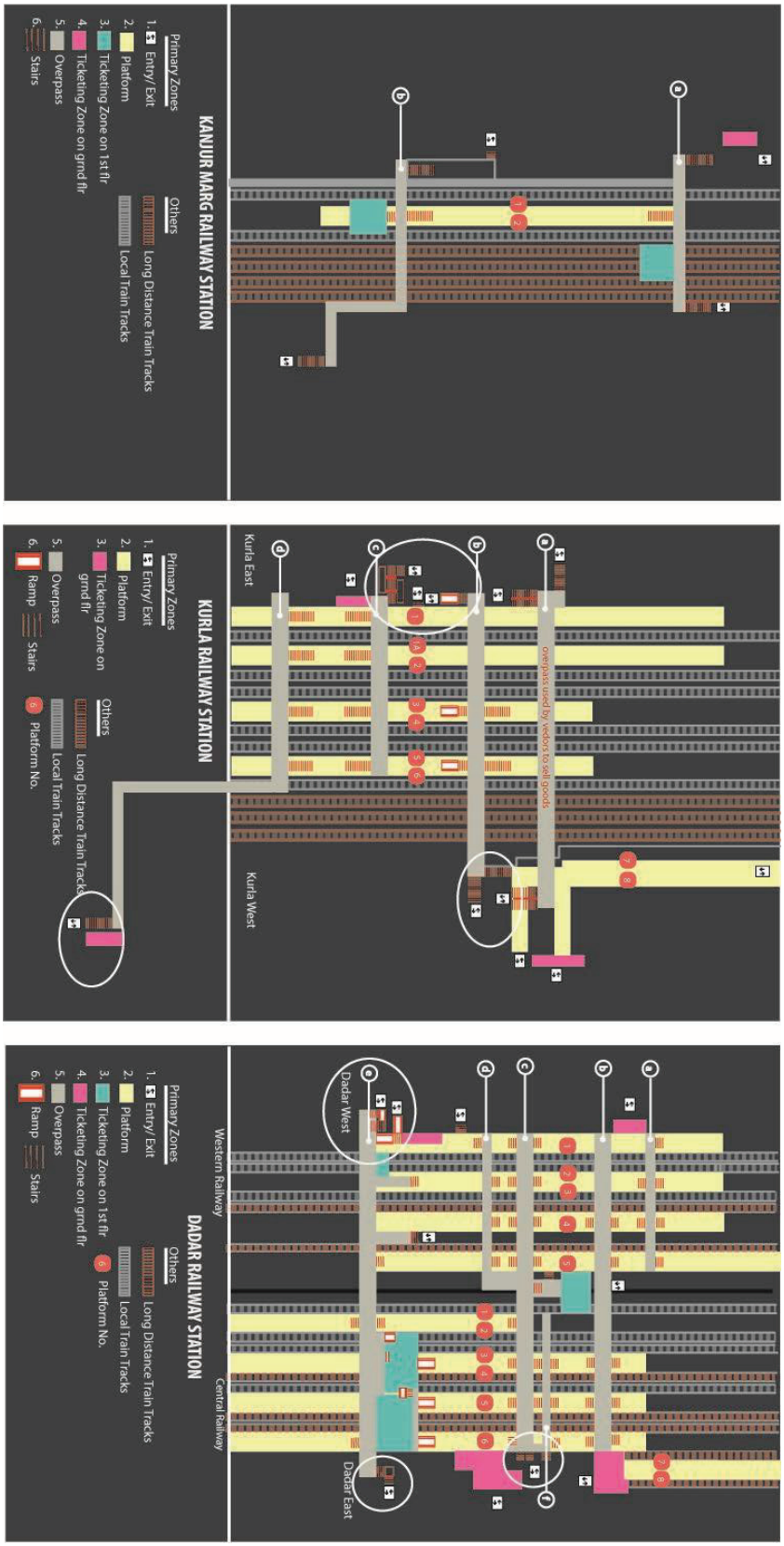


Figure 5 Overpass zone of KanjurMarg, Kurla and Dadar station

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4. Appendix B

Pre-Walkthrough Questionnaire (Study 1)

Table 1. (*) Denote the question asked to a particular user group. No-vision (NV), Low-Vision (LV), Sighted (S)

1a. Personal Background Information	**NV**	**LV**	**S**
What is your full name?	*	*	*
How old are you?	*	*	*
Where are you staying in Mumbai, and for how long?	*	*	*
What is your gender?	*	*	*
What is your current Marital Status? 1. Un Married 2. Currently married 3. Separated 4. Divorced 5. Widowed 6. Cohabiting	*	*	*
How many family members do you stay with? Describe their relationship with you, including age and gender. Mention if they have any disability as well.	*	*	*
What is your education level?	*	*	*
Which describes your current work status best? 1.Self- Employed 2. Paid Employed 3. Student 4. Homemaker 5. Retired 6. Unemployed (health reason) 7. Unemployed (other reason) 8. Other Please Specify Probe: What is your Income	*	*	*
What languages can you speak and read?	*	*	*

Do you have access to a phone at all times? Probe: If not, whose phone is this, and at what time can we speak to you on this number? Is it a smartphone? Yes / No	*	*	*
Do you use a computer?	*	*	*
1b. Vision Impairment			
Visual acuity functions Binocular acuity (Seeing functions of sensing size, form, and contour, using both eyes) for distant or near vision. OR Monocular acuity (Seeing functions of sensing size, form and contour, using either the right or left eye alone) for distant or near vision. What is the measure of your visual acuity? (sharpness measured by Snellen chart)	*	*	
Quality of Vision 1. Light Sensitivity (Sensing the minimum amount of light and light difference) 2. Color Vision (Seeing functions of differentiating and matching colours) 3. Contrast Sensitivity (Separating figure and ground) 4. Visual picture quality (Seeing functions involving the quality of the picture)	*	*	
Since when you have vision impairment: Congenial (inborn) or Acquired at the age.	*	*	

Probe: How did you lose your eyesight?			
Do you have mobility training? Probe: If yes, how many years has it been since? Where have you taken the mobility training? What is offered in the mobility training course? Probe: Indoor /outdoor environment?	*	*	
Can you read and write in Braille?	*	*	
What was your psychological reaction to the Visual Loss? Probe: 1. Accepting and dealing 2. Denying and refusing 3. Depression and anxiety	*	*	
What was the impact of loss of eyesight on your: 1. Self Image 2. Independent function 3. Education 4. Family life 5. Career 6. Outdoor Travel 7. Use of Public/Private Transport	*	*	
2. Public Transport Use	**NV**	**LV**	**S**
What mode of public transport have you travelled with in Mumbai? Local train Bus Taxi Monorail Metro Auto	*	*	*

3. MLTCS use	**NV**	**LV**	**S**
What are the primary, secondary, tertiary reasons for local train use?	*	*	*

1.Work 2. Education 3. Health 4. Recreation 5. Socialization 6. Connecting travel 7. Others			
Since how many Years-Months-Days have you been travelling from Local Trains?	*	*	*
What are the different train lines for local trains? Rank the following train lines you are most experienced in travelling with (Rank 1 to the most experienced and then follow the rest) Western Line Central Line Harbor Line Tras Harbor Line	*	*	*
What are the local train stations you are most familiar with?	*	*	*
Which coach do you prefer to travel to and why? Probe: 1st Class Ladies Coach 2nd class general ladies 1st class general coach 2nd class general coach Handicap coach Luggage coach	*	*	*
What are the different station facilities/ amenities available at the local train station? Probe: What facilities have you used?	*	*	*

4. Wayfinding in MLTCS	**NV**	**LV**	**S**
Personal Assistance			
Do you **travel with a companion who needs your help** using local trains?	*	*	*

Probe If yes please specify? Spouse Child Parent friend any other relative Probe: What kind of help do you provide to the companion?			
Do **you need personal assistance** with local trains? Probe: If Yes, who do you rely on? Spouse Child Parent friend any other relative Station staff Other commuters Probe: What kind of help do you need to travel by local train?	*	*	*
Mobility Training			
How has the mobility training course helped you to wayfind in local train stations and travel from local trains?	*	*	
Assistive Aids			
Do you use **assistive aids** to travel from local trains? Probe: If yes, please specify. Probe: How does the used aid help you in wayfinding in local train stations and inside trains?	*	*	*
Familiarity			

Do you **gather information** about trains and stations **before reaching the site**?	*	*	*
Describe **your first experience of traveling by train from local trains.** Probe: Do you visit local train stations alone if it is the first time? If yes, how do you find the information you need to tell you where you want to go?	*	*	*
What **difference in experience do you find when you visit familiar and unfamiliar stations**?	*	*	*
Ticket Buying			
Do you buy a ticket for the local train each time you visit the station? Probe: If yes, what are the different modes of ticket purchase available to the public? How do you pay for the train travel? Do you carry a pass each time you travel from the local train? How do you find the ticket counters?	*	*	*
Toilet			
Do you prefer to use the toilet at the station? Probe: What was the experience? How do you find it? How do you differentiate between male and female stalls?	*	*	*
Platform			
How do you find the platform number to board the desired train?	*	*	*

How do you differentiate platforms of different train lines?	*	*	*
Have you encountered situations when the train arrives at unexpected platforms? Probe: If yes, how do you cope with such situations when inside the train or on the platform?	*	*	*
Foot Over Bridge			
How do you decide which bridge to use to reach the desired location on the station?	*	*	*
Station Exit			
How do you manage to exit from an unfamiliar station exit?	*	*	*
Train Use			
How do you decide which train to board?	*	*	*
How do you get information about whether the train is standing or not on the platform?	*	*	*
How do you get information about trains standing on a signal or platform?	*	*	*
How do you get information about train delays, mega blocks, and sudden changes in train lines?	*	*	*
How do you inform yourself about the upcoming station name and platform location while inside the train?	*	*	*
Safety			

Have you ever encountered situations of **eve teasing, accidents** inside trains or on platforms or other parts of the station yourself or witnessed others in such situations? Probe: How do you deal with such situations? Do you ask for help? If yes, from whom? Probe: What places on the station do you find unsafe and why? How do you cope with which situations to avoid risks? Probe: Fall on rail tracks. The gap between the two coaches, platform and stair use, seek the help of passerby/station staff, help for medical reasons or security reasons.	*	*	*
Visual/ Audio Signage System			
Have you ever found some element/service in a building that helps in wayfinding in stations and trains travelling? Probe: If yes, what are they?	*	*	*
What is your preferred information format on local train stations: Braille / large text format /audio? Probe: If Braille is your preferred information format? Since how many years have you been learning Braille, and where were you able to use your braille knowledge in local train stations?	*	*	
Do you think public announcements are helpful inside trains and stations? Give reasons. Probe: aubility, delays, incorrect inf., language	*	*	*

Are beepers helpful in 12 and 15-coach composition trains? Probe: Discuss the reasons for the answer	*	*	
Do you ever use signage? Probe: Do you find some types of helpful signage? – Colours, text etc		*	*
Public Help			
Do you use public help to find the station and inside the train? If Yes Probe: What are your good and bad experiences? For what information do you need public help the most? What places on stations do you need public help? What are the limitations of public help? Do you have any selection criteria for asking for help?	*	*	*
Use of Senses			
How do you try to **familiarize** yourself **with a new station environment**? Probe: Do you tend, when you come into a building, and you are leaving it again do you pick up clues on the way in that you use on the way out? Do you try to memorize such clues for later use?	*	*	*
Have you found that you have developed any **personal techniques or tricks** that you use to enable you to find your way?	*	*	*

Probe: Maybe skills that were not taught but you have learned enable you to find something about your surroundings on the station or inside the train?			
How do you make sure that you are **walking in the right direction**?	*	*	*
How do you **use other senses, such as sound, smell and touch, to get information about the trains and stations**? Explain the use of each sense.	*	*	*
Physical Obstacles			
What kind of **obstacles** have you encountered at the station? Can you avoid obstacles within the environment using your senses? If yes, how? Probe: pole, luggage, people, furniture etc.	*	*	
Environmental Factors			
What **light conditions** do you prefer on stations and inside trains - brightly lit/ dull light/ artificial light/ natural light – How well does your sight cope with fluctuating light conditions indoors/outdoors? Probe: Do poor lighting conditions after sunset create a problem getting the information you need on the station, or are there any other hazards? Probe: Can you talk a bit about your **depth perception**? If you have no depth perception, how do you try to get the information that depth perception provides?	*	*	*
Does crowd presence during peak hours affect the ability to make station and train use decisions?	*	*	*

If yes, probe: How? What are the most affected zones?			
How **does weather change impact the** use of local trains?	*	*	*
Do you find **colour contrast** quite crucial to you? Which part of the station and train do you find such contrast helpful?		*	*
Psychological Impact			
How do you think the difficulty in wayfinding is a limitation for you when travelling from local trains? Probe: Have you ever become lost in a station? If so, how do you cope in such circumstances? What helps you to find your way around an unfamiliar building? Probe: Do you find that you get worked up – or stressed when wayfinding? Have you ever been late when trying to find your way? Probe: Has there been a specific station where you have struggled to find your way? Probe: Have you ever just given up and left the station – or felt you wanted to?	*	*	*
How does the current use of trains and stations affect residence, work and employment opportunities, social networks, outings and entertainment, and household tasks? Probe: difficulties, delays, opportunities Probe: Can you think of anything now off the top of your head? Are there any significant	*	*	*

difficulties/issues/frustrations you face when wayfinding?			
What are your **suggestions** for improving the system regarding wayfinding?	*	*	*

5. Past Knowledge of Kurla Station	**NV**	**LV**	**S**
How many times have you visited Kurla Station? Everyday few days in a month Once never	*	*	*
How many experienced visitors do you find yourself in Kurla Station? Experienced Somewhat experienced Stranger	*	*	*
Describe Kurla Station and local trains that come on Kurla Station from your experience. Probe: Describe all the station facilities from your past memory that are available at the station or specific to Kurla Station.	*	*	*
Have you had any specific positive/negative experiences in Kurla Station that are unique from any other station?	*	*	*

5. Annexure C

Post Walkthrough Questionnaire (Study 2)

1. Where did you think the information was missing to help you decide on place identification, route orientation and warning?
2. What sensory clues in your path have you collected that helped you to complete the task given to you? (Tactile, sound, smell, visual). How have they helped to make sense of the route you are travelling on?
3. How did you use your cane while moving inside the station? How does it help you to provide different types of information?
4. When did you realize you were walking in the wrong direction?
5. What obstacles have you encountered while walking inside the station?
6. What made you feel unsafe while walking inside the station?
7. What past experiences helped you to develop an understanding of the current station route you just navigated?
8. What were the reasons behind your verbal frustrations?
9. Why did you halt at specific locations on the station?
10. Rate the level of difficulty/ Confidence for different tasks accomplished.
    1. Very Difficult 2. Difficult 3. Medium 4. Easy 5. Very easy

Find the stairs for climbing up.

Find the stairs for climbing down.

Finding the bridge

Finding the platform

Find the place to wait for train on the platform

Identification of train

Reaching the door of the handicap coach

Finding the ticket counter

Find the ticket window.

Find the toilet.

11. In cases of poor confidence, what did you do to ensure that you were moving on the correct path for each decision?
12. What tricks and techniques have you used during the station walk?

Here is a list of statements. Please select which best reflects your natural feeling or situation. (Lawton wayfinding scales)

Rate the statements on a scale 5-point likert scale of level of agreement.

1. Strongly agree 2. Disagree 3. Neither agree or disagree 4. Agree 5. Strongly agree

13. When I was inside the station, I always kept in mind which direction I was moving while I was making turns (e.g. north, south, east, or west)

14. I always kept in mind the direction from which I had entered the building

15. I kept track of where I was in relation to a reference point outside the building.

16. I mentally noted the distance I traveled on different sections of the path.

17. I kept track of the relationship between where I was and the next place where I had to change direction.

18. I made a mental note of the time I took on different sections of the path.

19. I visualized a map of the area in my mind as I went.

20. I needed much mental effort to figure out my direction.

21. Indicators on bridge were helpful

22. Indicators on the platform were helpful

23. Audio Announcements were helpful

24. Sign boards for different coaches were helpful on platform

25. Signs painted on the train coaches were helpful

26. Help desk service was helpful in providing information

27. Beepers helped identify place to stand on the platform

28. Rate the level of helpfulness of Information provided by all Passersby one by one on a 3 point likert scale
    1. very helpful 2. partially helpful 3. Not at all helpful
    2. What problems did you encounter while seeking verbal help from passersby?
29. What are your suggestions for improving the current state of information communication services for local trains?
30. What was your overall experience of Kurla local train station information communication services? Give reasons

1. very easy 2. easy 3. Neutral 4. Difficult 5. Very Difficult.

31. How confident would you be in giving directions to a person who is a stranger to the station on the route you just visited?

1. Very confident 2. confident 3. neutral 4. less confident 5. not at all confident.

6. Appendix D1

Wayfinding Challenges from Study 1 and 2

Challenges								
1.1	**Limited signs to identify spatial zones, facilities, trains**							
			Study 1			**Study 2**		
a	Spatial Zones	Codes	NV	LV	S	NV	LV	S
	Platform	difficulty in finding platform no. to board in desired train.			3	2	4	3
		difficulty identifying the waiting area of the handicap coach due to poor functioning of auditory beepers	2	2		10	9	
	Foot Over Bridge	difficulty in identifying the staircase				10	7	
	Station entrance	difficulty in picking the right station due to the usage of acronyms			1	9	7	4
	Trains	Unable to find handicap coach entrance without help	1					
1.2	**Limited direction signs to reach from one place to another**							
a	Spatial Zones	Codes	NV	LV	S	NV	LV	S
	Platform	difficult to find, walking in the right direction or not		1	4	1	5	1
	Bridge	difficult to find a bridge from the platform.	3		1		4	3
	Station exit	difficult to find directions to the station exit when arriving by train.	3	3	2	1	5	2
	Ticket hall	difficulty in finding ticket counters from the platform	2		2			
		difficulty in locating the ticket hall			2	1	4	1
b.	Station Facilities	Codes	NV	LV	S	NV	LV	S

	Toilets	difficulty in finding the toilet	4		1	9	10	7
1.3	**No orientation of station layout and train routes**							
a	Spatial Zones	Codes	NV	LV	S	NV	LV	S
	Bridge	too many bridges lead to confusion in locating the desired one	2	2	3	1		
	Station exit	difficult to locate east or west side to exit from stations.	1		1	7	9	8
		lack of information about upcoming platform location	2	2		9	9	9
1.4	**Lack of updated information to enable the use of facilities, station infrastructure & trains**							
a	Spatial Zones	Codes	NV	LV	S	NV	LV	S
	Platform	Poor Quality of Public Announcements on platform	5	3	3	10	8	7
		difficulty in understanding LED display and signage boards			1		13	
		incorrect information given by indicators on platform			1			
	Trains	late public Announcements inside Train about change in platform				10	9	7
		difficulty in understanding the indicators			2		7	9
		Not enough information on which direction train comes from		1				3
		handicap coach doesn't stop exactly near beepers	3	1		1		
		people don't know the whereabouts of braille signages	1					
		people board wrong coach	1	1		1		1
		lack of information about train standing or not on platform				7	4	

b.	Station Facilities	Codes	NV	LV	S	NV	LV	S
	Toilets	hygiene problem			2	1	1	
1.5	**Poor safety while Navigating station and train environment**							
a	Spatial Zones	Codes	NV	LV	S	NV	LV	S
	Platform	people forget directions in the presence of the crowd	1	1	4	2	3	1
		people feel anxious	2		2	1		
		affects the ability to make decision	3		3			
		Audibility of PA decreases	3		1	10	8	7
		people push others	1	3	1	1	3	
		People collide with objects and people	3	1		8	6	
		People fall on rail tracks while boarding	5	3	1	7	3	
		poor lighting conditions	1	1		5	9	8
		harmful/unnecessary interactions with people	1	2		2		
	Bridge	challenging to locate bridges on a platform in a crowd			1	2	3	1
	Trains	boarding and getting down is life-threatening	1	2	2	10	8	6
		People collide with objects.						
		people fall on rail tracks while getting down	1			10	8	6
		gap between the train and the platform is uncomfortably large		2		11	8	6
1.6	**Difficulty in Receiving, comprehending & and trusting public help**							
a	Spatial Zones	Codes	NV	LV	S	NV	LV	S
	help desk	wastage of time due to incorrect directions			1	5		
	commuters	people provide incorrect information	4	2				
		difficulty in comprehending directions.	6			1		
		people misbehave			2	2		
1.7	**Difficulty in task accomplishment**							

a	Spatial Zones	Codes	NV	LV	S	NV	LV	S
	Station entry and Exit	difficulty in choosing the appropriate station exit				1	5	2
		Difficulty in entering the station due to stalls/vehicles				3	4	
	Ticket windows	Difficulty in locating ticket windows in smaller stations					4	
		difficulty in choosing the appropriate ticket window				1		3
	Bridge	Difficulty in locating the right bridge from the platform					4	3
	Platform	Difficulty in reaching the platform from the bridge				1	5	1
		Unable to identify directions of trains present on the platform						
		difficult to detect the edge of the platform				3	2	
	Train	Difficulty in navigation after disembarking from the train					1	
		Inconvenience is caused when a coach does not stop at the right place.				2		1
		difficulty in choosing the appropriate coach				3		5
		Difficulty in disembarking and boarding due to crowd				2		
		difficulty in detecting coach entry				1		
	Indicators (PA, Beepers)	tactile tiles are challenging to detect underfoot				1		
	information channels	Difficulty in using M-indicator				1		
		Difficulty in reading signs in bright sunlight					5	
		Difficulty reading signs with low contrast					12	
	Non-specific	Difficulty in wayfinding due to crowd				2	3	1

		Dark spaces created difficulty in navigation				2	7	2

7. Appendix D2

Participant's Suggestions from Study 1 and 2

Participant's Suggestions								
		Study 1				Study 2		
Spatial Zones	Codes	NV	NV	LV	S	NV	LV	S
Ticket Hall	put some machines on the stations which check your PNR Status				1			
Platform	Provide safety measures to avoid falls on railway tracks.		1			1		
	Incorporate changes in surface texture as a warning sign to detect platform edge, staircase, and steps.	1						
	Information regarding platform numbers should be provided in an accessible format, as it is difficult to see them at night.			1				
	provide more info. on signage boards and might increase the no. of boards to reach the desired location.	1			3			
	There should be a timetable for trains on the platform in braille.	1			1			
Foot Over Bridge	Provide audio inputs at different decision points on the foot over bridge informing about different platform numbers	1		1	1			
Trains	Public announcements should provide information on train stop locations in the middle of the train journey.	1	2	2		2	4	3
	Provide audio or tactile cues to locate handicap coach entry,		2	1		2		

	Install dynamic maps inside local trains and station layout maps. A map inside the train should help commuters visualize the train route and its platform direction. The map on the station should be interactive, and commuters should be informed about the station layout and the location of services and facilities. Further, it should also inform commuters of the station location.			1	1			
	There should be a security guard of RPF in the handicap coach to control the general crowd on the train.		1			5	3	
	Handicap coach positions should be fixed on the platform for all trains.	1						
	handicap coach should be bigger			1		1		
Non stage specific	There should be continuous audio inputs that help in making wayfinding decisions from station entry to exit.	1	1	1	1	8	7	1
	Incorporate changes in surface texture as a warning sign to detect platform edge, staircase and steps.	1						
	Use bright colours and pronounced contrast in signboards for better readability, even at night.			1	1			
	Big fonts should be used to easily identify ticket halls, washrooms and station exit from a distance.				1		16	
	Station environment should be well lit.			1				
	Develop indoor wayfinding app for all railway stations				1			

	provide customer service that help in answering questions through phone call		1			1		
	The information system should be improved for all disabled not just for no-vision. People who are in wheelchairs etc.		2					
	provide better announcement and indicators			1	1			
Spatial Facilities	Codes							
Help Desk	Increase no. of help desks and place them at locations like station entry, platforms and other junctions where people ask for maximum help.		1					1

8. Annexure E

Questionnaire for Rating and Ranking (Study 3)

(NV: No Vision, LV: Low Vision, S: Sighted)

1.	**ENTER & EXIT FROM STATION**	**Rating**	**Rank**
1.1	Lack of installation of station names at each station entry (NV, LV, S)		
1.2	Lack of information about the availability of public transit stops (Bus, auto, taxi stand) outside each station exit (NV, LV, S)		
1.3	There needs to be direction signs to find the desired station exit from each platform. (NV, LV, S)		
1.4	There needs to be more information on the bridge, platform, and station entry/exit to detect the eastern and western sides of the station. This is crucial to get out of the station. (NV, LV, S)		
1.5	In stations with more than one station entry/exit point, more information must be needed to differentiate one station entry/exit from another. (NV, LV, S)		
1.6	There is a lack of ways to help people choose station exits based on the commuter's city destination (NV, LV, S)		
1.7	The presence of vehicles at the station entrance leads to chances of collision. (NV, LV)		
1.8	Lack of Information about which station entry is through which part of the station, whether it is from the platform, ticket hall or bridge (NV, LV)		
2	**TICKET PURCHASE**	**Rating**	**Rank**
2.1	Lack of information on different ways in which local train tickets can be purchased like from a ticket window, ATVM		

	machine, Jan Sadharan Ticket Booking sevak, UTS mobile app. (NV, LV, S)		
2.2	Lack of information on different types of tickets sold at each window leads to standing in the wrong queue (NV, LV, S)		
2.3	There needs to be direction signs to reach the nearest ticket hall from the platform and the station entry. (NV, LV, S)		
2.4	Lack of information to detect the ticket hall door. (NV, LV, S)		
2.5	If there is more than one way to get out of the ticket hall, there needs to be more information about which part of the station each one leads to so that people can select the right exit gate. (NV, LV)		
2.6	There needs to be more walking guidelines to reach the ticket window and get out of the ticket hall. (NV, LV)		
3	**USE OF STATION FACILITIES**	**Rating**	**Rank**
3.1	There needs to be more information to make new commuters aware of what type of facilities are available at each station (medical facilities, Railway police office, ATVM machines, police office, book, water and food stalls) and where they are located. (NV, LV, S)		
3.2	There is a lack of clear/no information to differentiate between male and female toilets (NV, LV, S)		
3.3	Lack of direction to reach the nearest toilet on station (NV, LV, S)		
3.4	All audio, visual signage, and help desk services are not in three languages: Hindi, English, and Marathi (NV, LV, S)		
3.5	There is a lack of information to detect the exact toilet door (NV, LV)		
3.6	Help desk service is unused due to non-visual signs (NV, LV)		
3.7	Lack of provisions to create awareness among new commuters about the purpose of the help desk at the station. (NV, LV, S)		

3.8	Help desks are challenging to locate, as they are not at critical locations such as platforms and station entry points. (NV, LV, S)		
3.9	Help desks are very few in number. As a result, their reach requires a long walk. (NV, LV, S)		
3.10	It isn't easy to locate the help desk since their location is not fixed. (NV, LV, S)		
3.11	Help desk services are not very effective as many times service providers are not on the desk. (NV, LV, S)		
4	**FOOT OVER BRIDGE USE**	**Rating**	**Rank**
4.1	The ramps are very steep. As a result, it isn't easy to use them. (NV, LV, S)		
4.2	Lack of information on what parts of the station each bridge connects before climbing it. As a result, people climb on the wrong bridge (NV, LV, S)		
4.3	While walking on the bridge, people need to be made aware of each turn leading to different parts of the station. (NV, LV, S)		
4.4	There are no warning signs at the floor transition between steps to the slope and step to the floor on the bridge. As a result, people fall. (NV, LV)		
4.5	There needs to be walking guidelines to locate the staircase of the bridge from every platform and station entry. (NV, LV)		
5	**PLATFORM USE**	**Rating**	**Rank**
5.1	Lack of information at station entry and inside the ticket hall about the platform of upcoming trains (NV, LV, S)		
5.2	There are no direction signs to walk in the right direction on the platform to locate the waiting area for the desired coach of the upcoming train. (NV, LV, S)		
5.3	There is no way to identify platforms based on train lines, local and intercity platforms, slow and fast trains (NV, LV, S)		
5.4	Public announcements have limitations like poor audibility in peak hours, especially at platform ends (NV, LV, S)		

5.5	The coach signage on the platform does not match the train coaches when trains of 9/12/15 coaches come on one platform. This needs to be clarified in both the direction and detection of the coach. (NV, LV, S)		
5.6	There are no warning signs on the floor transition from platform to track. As a result, people fall on the track. (NV, LV)		
5.7	Beepers are not located on all platforms. Even if they are present, they are often not working or are unheard of during peak hours. All these factors create difficulty in detecting PwD coach waiting areas (NV, LV)		
5.8	There are no provisions on the platform to avoid collision with physical obstacles like walls, poles, furniture and stalls (NV, LV)		
5.9	While walking on a shared platform, there is no confirmation to maintain walk on the desired platform (NV, LV)		
5.10	There needs to be more timely updates through public announcements on the station, such as whether the train is standing on a platform. (NV, LV)		
5.11	Train Indicators and public announcements are not synchronised (LV, S)		
5.12	I need help understanding train indicators due to the use of acronyms. Sometimes, there needs to be more timely updates, or they need to be fixed. (LV, S)		
5.13	Platforms have overlapping numbers, or platforms of two train lines have the same numbering system. (NV, LV, S)		
6	**TRAIN BOARDING & DISEMBARKING**	**Rating**	**Rank**
6.1	Lack of information about mega block date, timing, station and train routes affected, on the web and on the station. (NV, LV, S)		

6.2	The status of the train and any changes in the train arrival time and platform are not timely updated inside the train nor on the station (NV, LV, S)		
6.3	There are no provisions on the station to make commuters identify and differentiate local trains such as slow/fast/ intermediate trains, their train lines, train routes (NV, LV, S)		
6.4	There needs to be information inside trains about upcoming station names, platform directions, time left for the station to come in and the name of the platform on which the train is stopped. (NV, LV, S)		
6.5	The gap between the platform and the train is unsafe; it creates difficulty in climbing and getting down from the train (NV, LV, S)		
6.6	Local trains do not have provisions to save people from running trains. (NV, LV, S)		
6.7	Lack of ways to ensure boarding in the queue. As a result, boarding becomes difficult for all. (NV, LV, S)		
6.8	There is no provision to avoid a fall in the gap between two coaches while boarding the coach. (NV, LV)		
6.9	There is no information to detect the exact location of the coaches reserved for PwDs. As a result, commuters deviate. (NV, LV, S)		
6.10	There is no information inside the train to detect where the train is standing: signal or platform. (NV)		
6.11	The sign painted on the train coach and installed on the platform looks different. Hence, it isn't easy to follow them. (LV, S)		
6.12	All train coaches do not have visual signs on the platform, e.g. Luggage, general coach. (LV, S)		
6.13	The Pole in the centre of coach entry disrupts quick crowd transfer. (LV, S)		

6.14	The presence of health patients, pregnant women and general commuters in handicapped coaches makes train travel difficult for handicapped people. (NV, L)		
6.15	If there is some connection between the motorman cabin and other coaches, then it will be better to detect when the train is about to start and stop. (NV, LV, S)		
7	**GENERAL**	**Rating**	**Rank**
7.1	There is a lack of a mobile service system to assist people with any train and station-related inquiry on a mobile phone before reaching the station. (NV, LV, S)		
7.2	Lack of information about the general station, train boarding and ticket rules and special provisions (for people with disabilities, health conditions, and senior citizens). This leads to a violation of rules and penalties. (NV, LV, S)		
7.3	Poor lighting at station entry and exit and other parts of the station, like the staircase and platforms, create unsafe walking conditions. (NV, LV, S)		
7.4	Walking surfaces at station entry, bridge and platform are subjected to elevations, potholes and breakage. (NV, LV, S)		
7.5	Lack of rooftop cover leads to rainwater coming inside the station and creates difficulty in walking (NV, LV, S)		
7.6	Information sign boards are challenging to locate due to poor placement (S, LV)		
7.7	Poor lighting leads to difficulty in reading information boards after sunset. (S, LV)		
7.8	Advertisement posters create visual clutter on the station. As a result, difficulty is faced in locating and reading the train and station-related information. (S, LV)		
7.9	Lack of awareness of provisions for instant help in case of emergency and security measures in running trains and on the station. (NV, LV, S)		

7.10	The small font size of the information boards inside the station makes them difficult to read from a distance. (S)		
7.11	Redundant old information boards are kept from the station, people follow them and get misguided. Such boards add to the visual clutter. (S)		
7.12	Lack of good colour contrast on the information sign boards leads to poor readability (S)		

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10. Publications

1. Agarwal, S., Mullick, A., & Ray, G. (2013). An observational study on usability issues in Mumbai local trains. Proceedings of the Human Factors and Ergonomics Society Annual Meeting/Proceedings of the Human Factors and Ergonomics Society. Annual Meeting, 57(1), 531–535. https://doi.org/10.1177/1541931213571114

2. Agarwal, S., Mullick, A., Ray, G.G. (2017). Wayfinding Challenges and Strategies in Mumbai Suburban Railway. In: Chakrabarti, A., Chakrabarti, D. (eds) Research into Design for Communities, Volume 1. ICoRD 2017. Smart Innovation, Systems and Technologies, vol 65. Springer, Singapore. https://doi.org/10.1007/978-981-10-3518-0_14

3. Agarwal, S., Bokil, P. (2023). Severity Assessment of the wayfinding problems faced by commuters with different levels of vision in Mumbai's Local Train Commuting system. In The 4th Asian Conference on Ergonomics and Design jointly with Humanizing Work and Work Environment (HWWE) & BRICSplus HFE Conference 2023 (Presented the Full Paper in the conference, Shortlisted in 1st round for Springer Journal Publication)