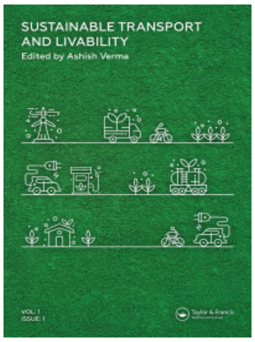

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Sustainable Transport and Livability

ISSN: 2994-1849 (Online) Journal homepage: www.tandfonline.com/journals/tstl20

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To cite this article: Oshin Agarwal, Mohit Dhingra & Deepty Jain (2025) Development of route based assessment framework for lanes in Chattarpur village, Delhi, Sustainable Transport and Livability, 2:1, 2518200, DOI: 10.1080/29941849.2025.2518200

To link to this article: https://doi.org/10.1080/29941849.2025.2518200

Published online: 05 Jul 2025.

SUSTAINABLE TRANSPORT AND LIVABILITY
2025, VOL. 2, NO. 1, 2518200
https://doi.org/10.1080/29941849.2025.2518200

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Development of route based assessment framework for lanes in Chattarpur village, Delhi

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ABSTRACT

The relationship between street design, land use, and surrounding environmental features has remained a central theme in walkability research since the 1990s. The rapid expansion of Indian cities has led to the assimilation of urban villages into the metropolitan fabric, transforming them from rural settlements into integral yet distinct parts of the city. The socio-cultural, spatial, and infrastructural characteristics of these urban villages are different from those of planned urban areas, presenting unique challenges. To explore these context-specific challenges, we evaluate the associations between street, built, and natural environments based on 21 attributes grouped into five dimensions of safety, comfort, accessibility, connectivity, and environment along four designated routes in Chhatarpur village, Delhi. These five dimensions were further grouped under the broader categories of street, built, and natural environment to frame targeted recommendations. The study helps in formulating a Route-Based Assessment Framework (RBAF) that can be adopted for lanes with similar characteristics across urban village areas. The study results show that no single route consistently performs well across all dimensions, underscoring the need for an integrated approach to improving walkability. The Route-Based Assessment Framework (RBAF) can be adapted for similar urban village contexts to guide targeted interventions and enhance pedestrian environments.

ARTICLE HISTORY Received 15 December 2024; Accepted 5 June 2025

KEYWORDS Walkability; lanes; urban villages; route-based assessment framework; Delhi

1. Introduction

Walkability has emerged as an essential concern in urban planning discourse, especially as cities worldwide transition to more sustainable, inclusive, and human-centred development models (Rišová, 2020). In the past, research on

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walkability was primarily concerned with urban form and street infrastructure (Southworth, 2005). However, it has since expanded to include the built and natural environment, with contemporary studies highlighting the significance of factors such as connectivity, land use diversity, residential density, and environmental quality in shaping walking behaviour and pedestrian experiences (Rišová, 2020; Westenhöfer et al., 2023). In order to comprehensively evaluate pedestrian experience, recent research has emphasized a multi-dimensional understanding that incorporates socio-demographic, perceptual, and contextual variables (Tobin et al., 2022).

In the Indian context, the implementation of walkability standards faces significant challenges, particularly in unplanned or informally developed areas like urban villages. These areas, which were once settlements, have been integrated into the urban landscape without a corresponding transformation in infrastructure or governance (Shaw, 2005). The outcome is a mix of narrow lanes, insufficient pedestrian infrastructure, encroachments, and mixed land uses that jeopardize walkability and safety.

India's New National Urban Transport Policy 2006, amended in 2014 (Ministry of Urban Development & Singal, 2014) focusing on moving people rather than just transport, services, and infrastructure, addresses these concerns for wider urban lanes, highways, and expressways through IRC guidelines. While IRC:106-1990 and IRC:86-2018 cover local streets, there remains a gap in specific design guidance for extremely narrow lanes (e.g. 2–4 m wide) commonly found in dense urban villages, which often fall below the minimum recommended ROW and carriageway widths (IRC:86-2018, Table 4.1). This hinders mapping walkability in a majority of the urban streets and identifying relevant interventions for improving walkability.

In this study, we propose a Route-Based Assessment Framework (RBAF) for evaluating walkability along routes in Indian urban settings. The framework integrates an observational-based assessment covering all 21 attributes with a perception-based assessment conducted for 14 of these attributes. For this purpose, we considered five dimensions of safety, comfort, accessibility, connectivity, and environment, further categorizing them into built, street, and natural environment categories. By calculating route-based dimension scores and overall walk scores, the study offers a systematic approach to assess walkability and derive strategic recommendations for improving pedestrian infrastructure in similar urban village settings.

This paper is structured as follows: Section 2 presents the need for the study and reviews existing literature on walkability assessment frameworks in urban areas; Section 3 outlines the research methodology used for describing RBAF, observation and perception-based assessment methods including data collection and analysis; Section 4 presents the results, Section 5 discusses practical implications, limitations, and further recommendations; and Section 6 concludes with insights for policy and future research.

2. Need for the study

Walkability is widely recognized as a key attribute of urban environments that supports public health, sustainability, and liveability. Over the past three decades, the concept has evolved from a reaction against car-centric urban planning to a central element in urban policy and design (Ramos et al., 2022). Foundational frameworks such as the "5Ds" (density, diversity, design, destination accessibility, and distance to transit) have been instrumental in shaping the measurement and understanding of walkability, particularly in planned urban areas (Ewing & Cervero, 2001).

Recent systematic reviews highlight that built environment attributes such as proximity to destinations, mixed land use, residential density, sidewalk presence, and connectivity are consistently correlated with increased walking (Bödeker et al., 2022). More comprehensive frameworks now incorporate up to nine dimensions of the built environment, including connectivity, diversity of land use, residential density, traffic safety, surveillance, parking, experience (aesthetics), greenspace and community interaction (Bödeker et al., 2022). These frameworks are increasingly used to inform health impact assessments, urban design, and policy integration (Ramos et al., 2022).

Despite these advances, most walkability research and indices have focused on formal, planned urban environments and often overlook the unique conditions of informal settlements and urban villages, which are prevalent in many rapidly urbanizing regions. Studies in Indian cities have found that existing indices may not fully capture the diverse physical, psychological, social, environmental, and policy factors influencing walkability in heterogeneous urban environments.This gap is especially pronounced in areas with high population density, poor pedestrian infrastructure, and mixed land use, where conventional indices may not be directly applicable (Srinivas et al., 2024).

Emerging research on informal settlements in the Global South reveals that walking is often the dominant mode of mobility, not by choice but by necessity, due to challenging topography and inadequate infrastructure (Oviedo et al., 2021). Residents frequently resort to improvizations such as self-constructed routes and informal amenities to navigate these environments. These studies underscore the importance of context-specific, participatory, and flexible frameworks that account for both objective and subjective conditions of the walking environment, including accessibility, safety, and convenience (Oviedo et al., 2021).

Emerging approaches highlight the need for context-sensitive tools. The UX Mobility Route Planner, which weights user preferences (e.g. safety, aesthetics), demonstrates how adaptive routing systems can address diverse needs

(Transform Transport, 2025). Similarly, data-driven models improve route choice predictions but lack integration with qualitative factors like community engagement (Lo, 2009). The RBAF we propose in this study addresses these gaps by evaluating 21 attributes across five dimensions (safety, comfort, accessibility, connectivity, environment) along specific routes, enabling prioritized interventions tailored to unique challenges in urban villages.

2.1. Research gap

Despite considerable research on walkability in planned urban settings, there is a significant absence of context-specific frameworks for evaluating walkability in the narrow, mixed-use lanes typical of urban villages in rapidly urbanizing cities like Delhi. Current walkability indices and guidelines, including those from the Indian Road Congress, insufficiently tackle the distinctive challenges presented by narrow lanes (2–4 m wide), significant encroachment, informal land use, and inadequate pedestrian infrastructure. This study fills the contextual void by creating a route-based assessment framework specifically designed for the unique attributes of urban village lanes, which are inadequately represented in existing urban planning literature.

2.2. Objectives

General Objective: To develop a Route-Based Assessment Framework (RBAF) for evaluating walkability in the lanes of Chattarpur Village, Delhi.

Specific Objectives:

1. To assess the current state of walkability across selected routes in Chattarpur Village using observational and perception-based methods.
2. To identify the key attributes influencing pedestrian experience under the dimensions of safety, comfort, accessibility, connectivity, and environment.
3. To compare the performance of different routes based on walkability scores derived from the RBAF.
4. To recommend targeted interventions for improving pedestrian infrastructure in urban village contexts.

3. Research methodology: RBAF

This study adopts a structured methodological approach to develop and apply the Route-Based Assessment Framework (RBAF) for evaluating walkability in the lanes of Chattarpur Village, Delhi. The methodology consists of three key stages as specified in Figure 1. First, the study area and pedestrian routes were identified based on contextual relevance between two fixed points. Second, the RBAF was

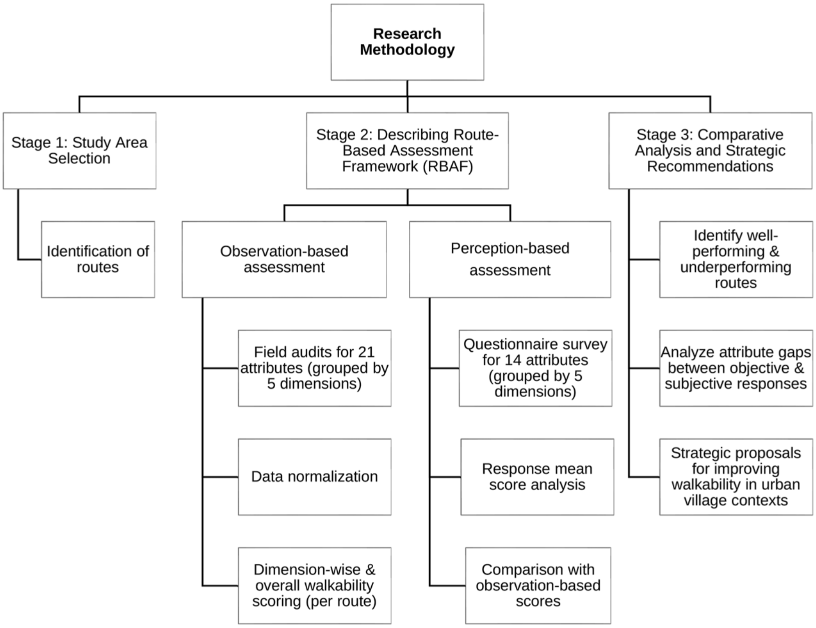

Figure 1. Research methodology process. *Source*: Author.

implemented through two complementary components: (i) an observation-based assessment covering 21 walkability attributes under five dimensions- safety, comfort, accessibility, connectivity, and environment, and (ii) a perception-based assessment involving user feedback on 14 selected attributes, aimed at validating observed trends. The observation-based data were used to calculate both overall and dimension-specific walkability scores for each route. Finally, a comparative analysis was conducted to identify walkability gaps and derive targeted recommendations for improving pedestrian conditions in similar urban village contexts.

3.1. Study area

Chattarpur, located in Zone J of New Delhi, has significantly transformed from a rural village to a rapidly urbanizing locality. With a population of 46,776 (Census 2011), the village has evolved from an agricultural settlement, it now sits at the crossroads of Mehrauli, one of the ancient cities of Delhi, and Gurgaon, a peri-urban settlement. The area has evolved due to migration, housing demand, and urban expansion. This transformation has led to the degradation of the built environment and the vitality of the street. In terms of road infrastructure, Chattarpur village is characterized by narrow lanes often of the width 2 – 4 m, mostly encroached at sides by vendors, parking and shops, and poor maintenance as shown in Figure 2.

In this study, we assessed four different routes in the urban village between Rajpur Crossing (28°29′41.35"N, 77°11′3.93"E) and Bansal Cycles (28°30′1.99"N,

Figure 2. (a) Mixed traffic; (b) poorly maintained infrastructure; (c) illegal parking on the carriageway, *Source*: Author (2024).

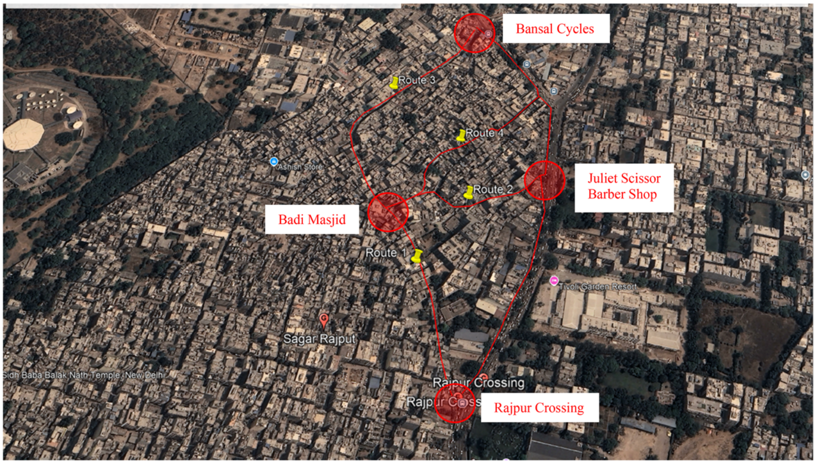

Figure 3. Study area – Chattarpur Village, Delhi, Source: Google Earth Pro (Version 7.3.6.10201, 64-bit). Imagery date: 15 October 2024, Rajpur Crossing (28°29′41.35"N, 77°11′3.93"E) to Bansal Cycles (28°30′1.99"N, 77°11′0.35"E).

77°11′0.35"E). Rajpur crossing is a major pedestrian node connecting residential lanes to commercial activity areas and the Chhatarpur metro station, whereas Bansal cycles mark the residential edge and serve as a well-known local landmark for neighbourhood access (Figure 3).

The characteristics of the four selected routes are shown in Table 1. As per the table, Route 1 is a relatively shorter stretch with a high mixed-use environment, featuring several religious landmarks and commercial activity, making it a key pedestrian generator. In contrast, Route 4, though the longest, traverses predominantly residential areas with minimal mixed traffic, but its walkability is compromised by factors such as open drains, foul odour, and a narrow carriageway.

Table 1. Four routes and their characteristics in the study area

Route	Length of route	Characteristics
Route 1: Rajpur Crossing to Badi Masjid	350 m	The area exhibits a predominantly mixed-use character, featuring multiple pedestrian generators, including prominent religious landmarks such as Badi Masjid, a major mosque; Durga Ashram, a spiritual centre dedicated to the worship of Goddess Durga; and a Gurudwara, a Sikh place of worship. Additionally, there is presence of grocery shops and hawkers at various locations. Mixed traffic was observed.
Route 2: Badi Masjid to Juliet Scissor Barbershop	320 m	Predominantly residential with a major barber shop on the street edge, and a small mosque. Mixed traffic was observed.
Route 3: Bansal Cycles to Badi Masjid (R1)	450 m	Predominantly mixed use with major pedestrian generators like Bansal cycle-a cycle shop, mechanic shop at the street edge, and multiple grocery shops. Mixed traffic was observed.
Route 4: Bansal Cycles to Badi Masjid (R2)	550 m	The area is predominantly residential, with significant pedestrian activity generated by significant landmarks such as Ramleela Chowk, a major intersection known for hosting the traditional Indian cultural event of Ramleela, which draws substantial crowds during the festive season. Mixed traffic was minimal; the route is majorly pedestrian. The presence of open drains, foul smell, and a 2.5 m average carriageway width negatively impact walkability.

Source: Author (2024).

3.2. Describing route-based assessment framework (RBAF)

We propose RBAF as a tool that integrates observation-based data regarding all 21 attributes, and street users' perception for 14 selected attributes, as outlined in Table 2. The route-based assessment is a two-step procedure, as shown in Table 1. In step 1, we collected data using observations on surveyed routes for the identified 21 attributes that influence walkability and normalize the scores for comparative assessments, in step 2, we collected street users' perception for 14 of the 21 attributes and compared it with observation-based data. The framework helps in integrating observation-based data collected by different stakeholders to determine the overall walkability score at the route level. This score is used to identify priority locations and strategic recommendations to enhance walkability. The selection of attributes is based on a literature review and the contextual understanding of the researchers (lanes in urban villages). Such an approach is useful to identify context-specific strategic recommendations to enhance walkability in lanes of urban villages.

3.2.1. Observation-based assessment method

We identified 21 attributes that may affect walkability in the lanes of urban villages from the literature (Table 3). These were initially classified into six types as Pedestrian and Traffic Movement, Infrastructure Quality, Traffic and Pedestrian Volume, Cognitive Perception and Navigation, Resident and User Experience, and Environmental Conditions. For better understanding, the 21 attributes were

Table 2. RBAF framework.

Steps	Methods used	Tasks	Description	Outputs
1. Identify and categorize the physical, infrastructural, and perceptual attributes, collect and normalize subsequent data	• Literature review • Field observations • Data normalization	• Understanding major attributes affecting walkability in urban village lanes • Categorization of attributes into specific dimensions • Conduct direct field observations of pedestrian behaviour • Gather positive and negative responses for each dimension	• Attributes are identified through real-world observations • Normalized data is used for analysis	• A list of walkability attributes specifically relevant to urban village lanes • Route based dimension scores
2. Assess the street user perception on urban village lanes	• Questionnaire survey conducted for 14 out of 21 attributes • Descriptive statistical analysis using mean scores	• Analyze perception data • Compare with observation-based results	• User-rated importance of each attribute • Perception vs observation-based data comparison	• Mean perception scores for 14 attributes • Gaps identified between perceived and observed conditions

Source: Author (2024).

later grouped into three categories as built environment, street environment, and natural environment, and five dimensions as safety, comfort, accessibility, connectivity, and environment. Given the potential complex relationship between the attributes, the identified dimensions cannot be exclusively grouped within the built environment, the street environment, or the natural environment. For example, built environment category consist of building height and access to public transport. Building height influences comfort, while access to public transport measures accessibility. Furthermore, an observation-based assessment technique was employed for all 21 attributes, while a perception-based assessment, conducted for validation and better understanding, was applied to only 14 out of the 21 attributes. Table 4 presents the list of attributes, the categorization of attributes, and the respective assessment techniques utilized for each attribute.

3.2.1.1. Data collection. Data for all 21 attributes was collected through repeated field visits conducted between August and September 2024 on 7 days of the week at different times of the day. The process involved

Table 3. Attributes for street audits.

Type	Attributes
Pedestrian and Traffic Movement	Surface quality (Lo, 2009), Pedestrian density (pedestrians/hour), Type of destination (pedestrian generator) (Tobin et al., 2022), Light poles/100 m, Resting area/100 m (Janaagraha, 2023; Wang et al., 2022), Vehicle density (vehicles/hour), Route-specific major land use (Ewing & Cervero, 2001)
Infrastructure Quality	Surface quality, Potholes/100 m, % of road width encroached (Lo, 2009), Dustbins/100 m, Distance to public toilets (Delhi Development Authority, 2019;), Building height (Ewing & Cervero, 2001), Footpath availability (N. M. Rashid et al., 2017)
Traffic and Pedestrian Volume	Pedestrian density (pedestrians/hour) (Tobin et al., 2022), Vehicle density (vehicles/hour), % share of non-motorized transport (Ewing & Cervero, 2001)
Cognitive Perception and Navigation	Number of route diversions (Lo, 2009), Time taken to traverse 100 m segment (Tobin et al., 2022)
Resident and User Experience	Average walk trip distance (m), Type of destination (pedestrian generators), Duration of stay of users, Perceived walkability satisfaction score (Tobin et al., 2022), Distance to amenities (public transport, grocery stores, eateries, parks, schools, healthcare) (Ewing & Cervero, 2001)
Environmental Conditions	Temperature range (°C) (Tobin et al., 2022), Relative Humidity (RH, %) (Chidambaranath & Bitossi, 2018), Average noise level (decibels) (Westenhöfer et al., 2024)

Source: Author (2024).

Table 4. Attribute categorization.

S.no.	Dimension	Attribute	Category	Observation-based assessment	Perception-based assessment
1	Safety	Light poles/100 m	Street	Yes	Yes
2		% of road width encroached	Street	Yes	Yes
3		Potholes/100 m	Street	Yes	Yes
4		% share of NMT	Street	Yes	No
5	Comfort	Surface quality	Street	Yes	Yes
6		Resting area/100 m	Street	Yes	Yes
7		Dustbins/100 m	Street	Yes	Yes
8		Time to traverse 100 m	Street	Yes	Yes
9		Route diversions	Street	Yes	No
10		Building height (m)	Built	Yes	No
11		Walkability satisfaction score	Street	Yes	Yes
12		% covered drains	Street	Yes	Yes
13	Accessibility	Distance to public transport (m)	Built	Yes	Yes
14		Effective carriageway width (m)	Street	Yes	No
15		Distance to amenities	Built	Yes	Yes
16	Connectivity	Destination type	Built	Yes	Yes
17		Pedestrian density	Street	Yes	No
18		Vehicle density	Street	Yes	No
19	Environment	Temperature range (°C)	Natural	Yes	Yes
20		Relative Humidity (%)	Natural	Yes	No
21		Avg noise level (dB)	Natural	Yes	Yes

Source: Author (2024).

on-ground visual inspections, route walkthroughs, and photographic documentation (Figure 4a). To ensure structured data collection, audit sheets were used to collect quantitative data. For most attributes like 1)

Light poles per 100 m, 3) potholes per 100 m, 4) percentage share of NMT 5) surface quality, 6) resting areas per 100 m, 7) dustbins per 100 m, 8) time to traverse 100 m, 9) route diversion, 10) Building height (m) 11) walkability satisfaction score, 12) percentage of covered drains, 13) distance to public transport, 14) effective carriageway width (m) 15) distance to amenities, 16) destination type, 17) pedestrian density, 18) vehicle density, 19) temperature range (°C), 20) relative humidity (%) and 21) average noise level (dB) absolute data was collected. Some attributes like surface quality and destination type, we rated the route on the Likert scale of 1 to 5, where 1 represented very poor conditions (uneven, broken surfaces), and 5 represented excellent conditions (very smooth, clean, and comfortable for walking). For destination type, a scale from 0 to 1 was used, with 0 representing residential areas, 0.5 indicating mixed commercial/residential, and 1 representing shops.

For quantifiable attributes, such as the percentage of road width encroached, we individually recorded values based on field measurements. Encroachment is measured as the percentage of road width encroached on each audited route. For this purpose, we split the route into equal segments and collected data at regular intervals of 100 m along the entire route length. For each segment, we recorded the total road width and the encroached portion (occupied by vendors, parked vehicles, or other obstructions).

Cognitive mapping was used as shown in Figure 4b to gather subjective information about how pedestrians perceive the lane's walkability. The researchers took turns and walked through each route and covering a distance of 1 km (±250 m) with GoPro cameras to track their walking routes, and record reasons for detours. This data was analyzed to assess common walking patterns and identify areas with accessibility or safety issues.

Figure 4. (a) Photographic survey; (b) cognitive mapping using GoPro camera; (c) environmental data collection. *Source:* Author (2024).

Environmental conditions such as temperature, humidity, and noise levels were measured to understand how these attributes impact the comfort of pedestrians. Temperature and humidity were measured using the HT-86 2 in 1 Portable Digital Humidity and Temperature Meter as shown in Figure 4c. Noise levels were monitored using the Decibel Meter app on Google Play Store to capture both peak and average decibel levels.

3.2.1.2. Data analysis. The raw values of all 21 attributes gathered using observation surveys were standardized through min–max normalization. Normalization was applied to enable comparative analysis across attributes measured on different scales. For this purpose, we considered the min-max normalization method using Equation (1). For the attributes where lower values are better, the normalization method was reversed as per Equation (2).

$$\textit{Normalized score} = \frac{x_i - \min(x_i)}{\max(x_i) - \min(x_i)} \tag{1}$$

$$\textit{Inverted Normalization Score} = 1 - \left(\frac{(x_i - \min(x_i))}{(\max(x_i) - \min(x_i))} \right) \tag{2}$$

where, x_i is the measured value of each attribute.

3.2.1.3. Route-based dimension scores. The normalized scores for attributes can be aggregated using equal weightage score or variable weighing scheme, as may be desirable depending on the context and methods using Equation (3).

$$\textit{Dimension Score} = \Sigma W_i \; X \; \textit{Normalized Attribute}_i \tag{3}$$

where $i = 1$ to n, the number of attributes under that specific dimension, and W_i is the attribute-specific weights.

The overall walk score (OWS) for each route was determined by summing the individual scores of all five dimensions, as shown in Equation (4).

$$\textit{Overall Walk Score}(OWS) = \sum_{i=1}^{5} D_i \tag{4}$$

where D_i represents the route-based score for each dimension (e.g. safety, comfort, accessibility, connectivity, and environment).

3.2.2. Perception-based assessment method

This step involved a perception-based assessment of 14 selected walkability attributes to capture user experiences along Chattarpur Lane. A structured questionnaire survey was carried out with pedestrian respondents (Appendix). The responses were analyzed descriptively and categorized under three key dimensions: existing problems, change required, and other perceptions Appendix

3.2.2.1. Data collection and analysis. A perception-based assessment was conducted for 14 out of the 21 attributes including 1) *Light poles per 100 m, 2) percentage of road width encroached, 3) potholes per 100 m, 5) surface quality, 6) resting areas per 100 m, 7) dustbins per 100 m, 8) time to traverse 100 m, 11) walkability satisfaction score, 12) percentage of covered drains, 13) distance to public transport, 15) distance to amenities, 16) destination type, 19) temperature range (°C), and 21) average noise level (dB)* to gather subjective insights from users regarding the walkability of various routes in Chattarpur Lane. The survey was conducted with 100 pedestrians in September 2024, selected using purposive sampling to ensure representation of different users of the lanes. Informed consent was obtained from each participant before proceeding with the survey.

Some attributes were assessed in terms of problems experienced while walking, including 2) encroachments, 3) potholes, 5) surface quality, 12) covered drains, 19) temperature, and 21) noise levels. For these, users were asked whether these issues posed difficulties during their walk, rated on a Likert scale where 1 indicated "not at all a problem" and 5 indicated "serious problem." For attributes requiring improvement, such as 1) street lighting, 6) resting areas, and 7) dustbins, users were asked to rate the priority for improvement on a scale from 1 ("not a priority") to 5 ("essential").

Other attributes were explored to understand broader user perceptions and behaviour. For 8) time to traverse 100 m, participants were asked how long it took them to walk 500 m, with response options ranging from "0–5 minutes" to "more than 15 minutes," to estimate the average time required to cover 100 m, which was later calculated based on the obtained responses. For 11) walkability satisfaction score, users indicated their satisfaction while walking on a scale from "very dissatisfied" to "very satisfied." For accessibility-related attributes 13) distance to public transport and 15) distance to amenities, users rated how accessible they found them, using a scale from 1-"not at all accessible" to 5-"very accessible" For 16) destination type, users were asked the purpose of their trip, education, everyday needs, religious, leisure, or work.

The data was analyzed descriptively by categorizing responses into themes such as existing problems, required improvements, and other perceptions to interpret user response patterns across different routes and gain insights into pedestrian experiences.

4. Results

4.1. Observation-based assessment

The attributes assessed for the four routes using the observation surveys are presented in Table 5. As per the observations the NMT share on the streets range from 68% to 74%. We observed that the none of the routes had a dedicated footpath. Given that the average road width in the lanes of Chhattarpur village is 4 m, we expect the vehicular speeds to be less than 15 to 20 km/hr. In such conditions, pedestrians can walk safely in mixed traffic conditions. Therefore, we have not included footpath availability as one of the attributes for the final assessment. The results show that Route 1 recorded the highest percentage of road width encroached (43.71%) and the highest pedestrian density (70 people/100 m^2). Route 2 had the presence of 1 resting area and 1 dustbin per 100 m, while the other routes recorded none for these attributes. Route 3 showed the greatest building height (9 m) and the highest noise level (62 dB). In terms

Table 5. Attribute data.

S.no.	Dimension	Attribute	R1	R2	R3	R4	Min	Max
1	Safety	Light poles/100 m	4	3	5	5	3	5
2		% of road width encroached	43.71	35	42.3	39.5	35	43.71
3		Potholes/100 m	3	4	2	2	2	4
4		% share of NMT	68	74	67.5	70	67.5	74
5	Comfort	Surface quality (score)	2	1	1	2	1	2
6		Resting areas/100 m	0	1	0	0	0	1
7		Dustbins/100 m	0	1	0	0	0	1
8		Time to traverse 100 m (min)	3	2	3	2	2	3
9		Route diversions	2.5	1	4	2	1	4
10		Building height (m)	6	6	9	7	6	9
11		Walkability satisfaction score	2.5	1	4	1	1	4
12		% covered drains	14	8	16	20	8	20
13	Accessibility	Distance to public transport (m)	500	1000	650	1100	500	1100
14		Effective carriageway width (m)	3	5	3.7	4.3	3	5
15		Distance to amenities	300	400	100	250	100	400
16	Connectivity	Destination type	1	0	0.5	0	0	1
17		Pedestrian density (people/100 m^2)	70	49	49	56	49	70
18		Vehicle density (vehicles/100 m)	37	18	25	28	18	37
19	Environment	Temperature range (°C)	32.38	30	32.64	34.01	30	34.01
20		Relative humidity (%)	51	54	54.27	55	51	55
21		Avg noise level (dB)	54	58	62	56.7	54	62

Source: Author (2024).

of accessibility, Route 1 had the shortest distance to public transport (500 m) and amenities (300 m), whereas Route 4 had the longest distances for both (1100 m and 250 m respectively).

We estimated dimension-wise scores for each route using normalized scores for each attribute incorporating equal weightage method (Table 6 and Figure 5). Route 1 had the highest score in connectivity (4.0), due to high value for destination type and pedestrian density. The route had a high dimension score in accessibility (1.0), primarily due to shorter distances to public transport and amenities. The route received higher comfort score (3.5), due to high values of surface quality and less number of route diversions. Route 1 had the lowest environment score (0.59), due to less favourable environmental conditions in terms of temperature, humidity, and noise levels.

Route 2 had the highest score in accessibility (3.0), due to better proximity to public transport, more carriageway width, and better access to amenities. However, the route had a less connectivity score of zero, due to limited integration with important destinations. In terms of comfort (3.0), the route showed balanced scores across surface quality and travel time but scored lesser in resting areas and dustbins. In terms of the environment dimension (1.26) the route scored lesser compared to other routes, though still higher than Route 1.

Table 6. Route-wise dimension scores

Dimension	Route 1	Route 2	Route 3	Route 4
Safety	1.33	2	2.49	3
Comfort	3.5	3	3.67	3
Accessibility	1	3	0.83	1.84
Connectivity	4	0	1.33	0.83
Environment	0.59	1.26	2.47	2.33

Source: Author (2024).

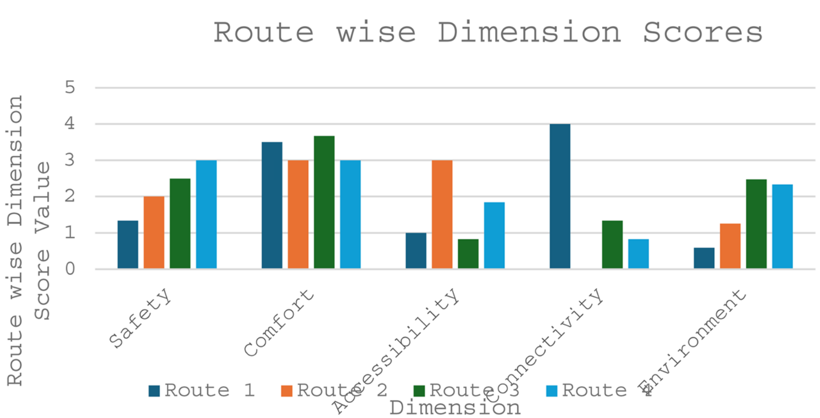

Figure 5. Route-wise dimension scores. *Source:* Author (2024).

Route 3 showed the highest score in comfort (3.67), motivated by attributes such as building height, perceived walkability satisfaction, and shorter travel time. It also had the highest environment score (2.47), suggesting more favourable conditions in terms of temperature, humidity, and noise. However, its accessibility score (0.83) was lower due to increased distance to amenities and public transport. The connectivity score (1.33) indicated limitations in pedestrian movement and access to important destinations.

Route 4 had the highest safety score (3.0), due to the optimal presence of light poles, minimal potholes, and a balanced share of non-motorized transport. While the route scored highest in safety dimension, it scored lesser in connectivity (0.83) and accessibility (1.84). The comfort score (3.0) was lower than other routes, influenced by the absence of resting areas and dustbins. The environment score (2.33) was higher than Route 1 but lower than Route 3.

These findings highlight the need for a balanced performance across all walkability dimensions. While Route 1 scored higher in connectivity, its lower environmental score detracted from its overall walkability score. Similarly, Route 2 scored high in accessibility but scored lesser in connectivity. Route 3 strengths in comfort and environment were offset by accessibility challenges. Route 4, despite scoring high in safety, scored lesser in connectivity and accessibility. These observations suggest that a comprehensive approach, addressing multiple walkability dimensions, is essential to improving the overall walking experience.

We further aggregated the five dimension-wise scores to determine route-level overall walk scores (OWS) that varies from 9.4 to 11.0 (Figure 6). The highest OWS is observed for Route 4, followed by Route 3. The least OWS is measured for Route 2. These variations are related to dimension-specific scores. Route 4

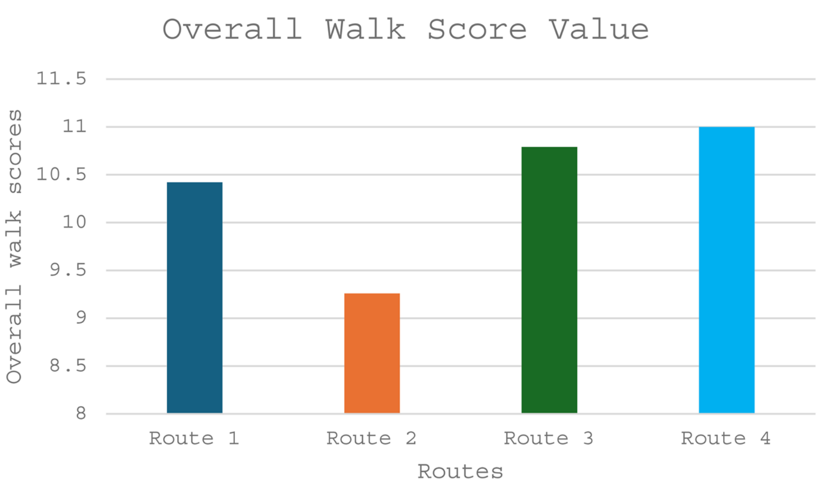

Figure 6. Overall walk scores for all routes. *Source:* Author (2024).

scores better in terms of safety, comfort and environment. Whereas, route 2 performs better in terms of comfort and accessibility. This underscores the necessity of achieving balanced performance across all walkability dimensions, rather than performing well in individual aspects.

4.2. Perception-based assessment

We conducted a street users' perception survey with 100 users on all four routes. The demographic characteristics of the respondents surveyed along Routes 1 to 4 are summarized in Table 7, detailing the number of participants by gender, resident/tenant status, and categorized age groups.

Of the total 21 attributes, we collected responses for 14 attributes. All attributes, except for 13) distance to public transport and 8) time to travel 100 m, were measured using Likert scale ratings. Table 8 and Figure 7 present the average results for these attributes, which have been categorized under 'Existing Problems,' 'Change Required,' and 'Others'.

Route 1 had a higher number of older participants (4 respondents aged 60+ and several aged 50–59), which directly influenced their perception of distance to public transport. The average perceived distance was 847.8 m, which is significantly higher than the actual measured distance of 500 m. Older participants tend to perceive distances as longer due to reduced mobility and physical limitations. Similarly, older participants rated street lighting (mean = 3.65) and resting areas (mean = 4.04) higher than other routes, reflecting their greater need for infrastructure that supports their mobility needs.

On Route 2, the majority of participants were younger, particularly in the 20–29 age range (6 respondents). These younger participants perceived the distance to public transport as 800 m, which is closer than the perception on Route 1. Younger respondents typically experience fewer mobility constraints, which explains their less critical view of infrastructure issues such as potholes (mean = 2.44) and encroachments (mean = 2.64), compared to older respondents on Route 1. They were also less likely to rate street lighting and resting areas as needing significant improvement.

Route 3 had a balanced age distribution with a significant number of participants aged 20–29 (11 respondents), which corresponds to the faster walking speeds observed in the time to travel 100 m. The perceived average travel time was consistent with the observed time of 1–2 minutes, reflecting the general physical capability of younger participants to walk faster. The higher number of residents on this route likely led to more critical views on walkability satisfaction (mean = 2.57), as residents are more familiar with local infrastructure issues and thus more attuned to deficiencies in the walking environment.

On Route 4, the demographic profile was predominantly male (18 out of 27) and included a significant portion of middle-aged participants (9 aged 50–59).

Table 7. Demographic profile of survey participants by route.

Route	Total participants	Males	Females	Residents	Tenants	Age 0–19	Age 20–29	Age 30–39	Age 40–49	Age 50–59	Age 60+
Route 1	23	8	15	13	10	4	3	4	3	4	4
Route 2	22	12	10	13	9	2	6	7	2	2	3
Route 3	28	15	13	14	14	4	11	6	6	7	8
Route 4	27	18	9	14	13	0	7	5	2	9	4

Source: Author (2024).

Table 8. Route-wise mean results for perception survey.

S.no.	Category	Attribute	Route 1	Route 2	Route 3	Route 4
1	Existing problems	2) encroachments	3.26	2.636	2.428	2.407
2		3) potholes	3.51	2.443	3.576	2.768
3		5) surface quality	4.521	4.363	4.428	4.555
4		12) covered drains	4.60	4.45	4.46	4.25
5		19) temperature	2.869	3.181	3.285	3.407
6		21) noise levels	3.26	3.636	3.75	3.85
7	Change required	1) street lighting	3.652	3.636	3.607	3.654
8		6) resting areas	4.043	3.818	3.857	3.836
9		7) dustbins	3	3.817	3.107	3.109
10	Others	8) time to travel 100 m	1.5	1.3	1.5	1.5
11		11) walkability satisfaction score	2.434	2.59	2.571	2.555
12		13) distance to public transport	847.8	800	750	750
13		15) distance to amenities	3.782	4	4.142	4
14		16) destination type	3	5	5	1

Source: Author (2024).

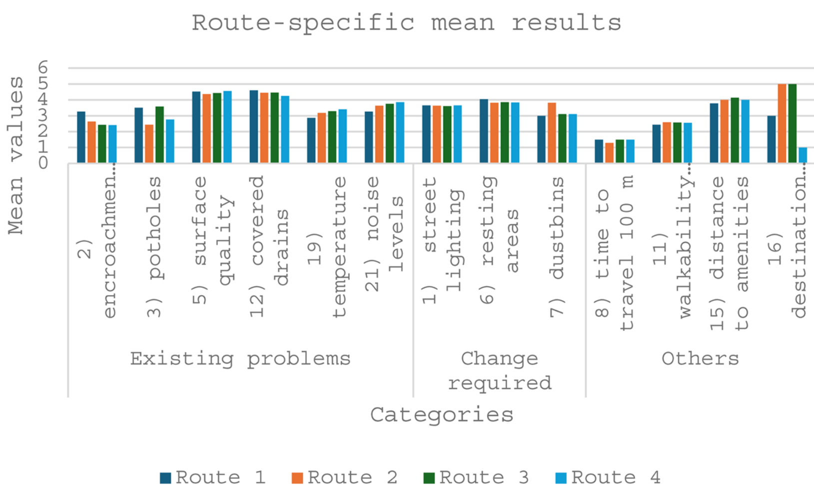

Figure 7. Route-specific mean results. *Source:* Author (2024).

These factors contributed to the lower concerns about noise levels (mean = 3.85) compared to Route 3, where noise was perceived more negatively (mean = 3.75). the predominantly male participants were less concerned with the need for resting areas (mean = 3.83), likely due to their higher physical mobility compared to female or older participants.

For attribute 13) distance to public transport, the user perception results report that the average distance on Route 1 is approximately 850 m, on Route 2 it is 800 m, and on Routes 3 and 4, it is 750 m each. In contrast, the observational findings show that the distances to public transport are 500 m for Route 1, 1000 m for Route 2, 650 m for Route 3, and 1100 m for Route 4. The observed distance for Route 1 in the perception survey is higher than in the observational data, while the distance for Route 2 is lower. For attribute 8) time to travel 100 m, the user perception results indicate that the average travel time ranges between 1 to 2 minutes for all routes. The observational data, however, shows a travel time of 3 minutes for Route 1, 2 minutes for Route 2, 3 minutes for Route 3, and 2 minutes for Route 4. These results suggest that the travel times reported in the user perception survey are generally shorter than those observed, particularly for Route 1 and Route 3, where the difference is most pronounced.

Based on the survey responses from the participants across the five dimensions of safety, comfort, accessibility, connectivity, and environment, we sought to understand both the positive and negative viewpoints expressed by the respondents. This allowed us to analyze the extent to which participants viewed each attribute favourably or unfavourably. The results reflect a division between the positive and negative perceptions of each attribute, as shown in Figure 8. By categorizing the responses into positive and negative comments, we gained insights into the specific areas where the infrastructure is performing well and where improvements are needed.

In Route 1 we observed moderate user satisfaction in terms of the Safety dimension, with significant concerns related to attributes like potholes per 100 m (5 positive vs. 10 negative) and percentage of road width encroached (8 positive vs. 7 negative). In terms of the Comfort dimension we observed positive responses, particularly with respect to surface quality (13 positive vs. 2 negative). In the dimension of Accessibility, distance to public transport (12 positive vs. 3 negative) received positive feedback, although percentage of covered drains (9 positive vs. 6 negative) was a point of concern.

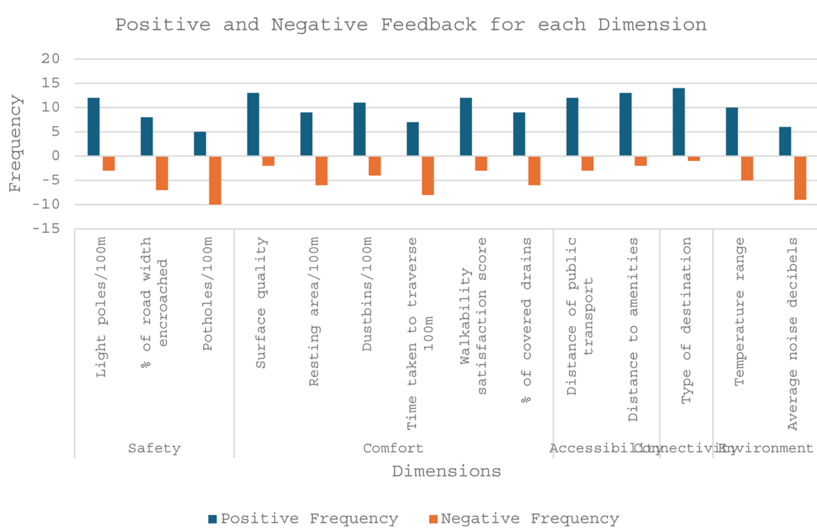

Figure 8. User feedback on walkability dimensions, *Source:* Author (2024).

In Route 2 we observed significant issues within the Safety dimension, especially with potholes per 100 m (2 positive vs. 13 negative) and percentage of road width encroached (5 positive vs. 10 negative). In terms of the Comfort dimension the route displayed challenges with resting areas per 100 m (4 positive vs. 6 negative) and route diversions (6 positive vs. 9 negative). In the dimension of Accessibility, distance to amenities (13 positive vs. 2 negative) was rated positively.

In Route 3 we observed significant challenges in the Safety dimension, particularly regarding potholes per 100 m (3 positive vs. 12 negative) and percentage of road width encroached (5 positive vs. 10 negative). Despite these issues on the route, in terms of Comfort, the route had positive responses, especially for surface quality (13 positive vs. 2 negative). We observed route diversions (6 positive vs. 9 negative) to be a major concern on this route. In terms of Accessibility we observed positive responses, especially with respect to distance to public transport (12 positive vs. 3 negative).

In Route 4 we observed lesser concerns in Safety compared to the other routes, although potholes per 100 m (2 positive vs. 13 negative) and percentage of road width encroached (7 positive vs. 8 negative) included negative responses. In terms of Comfort dimension, positive responses were observed, particularly with surface quality (14 positive vs. 1 negative). In terms of route diversions (6 positive vs. 9 negative) the responses were negative. For the Accessibility dimension, distance to amenities (13 positive vs. 2 negative) had positive responses whereas distance to public transport received more negative responses as compared to other routes.

5. Discussions

The research based on existing literature started with the premise that the relationship between the built, street, and the natural environment is imperative to define walkability. The study adopted an empirical approach to explore these associations across four lanes in Chattarpur village, each exhibiting distinct characteristics. A total of 21 attributes were identified and categorized under five key dimensions: safety, comfort, accessibility, connectivity, and environment. These attributes were evaluated through both observation-based assessments (all 21 attributes) and perception-based assessments (14 selected attributes). The observation-based evaluation yielded dimension-wise scores for each route, along with an overall walkability score. In doing so, it was then identified that there are certain peculiarities based on which any intervention should be identified in these lanes; a few lanes that were high on safety ranking, rank lower in environment and accessibility score; similarly, the lanes with the highest environment score rank lower on safety score. This variation across dimensions underscores the complexity of walkability assessment, as it is influenced by a combination of diverse attributes rather than being dominated by a single dimension. The perception-based assessment further revealed that significant attributes influencing walkability were present across all five dimensions for each route. These findings carry important implications for both policy and practice, emphasizing that improvements in walkability within Chattarpur and similar urban village contexts must address all dimensions holistically. Focusing on a single dimension is insufficient, as overall walkability is shaped by the combined influence of safety, comfort, accessibility, connectivity, and environmental dimensions.

5.1. Limitations of the study

The study, while presenting a comprehensive mixed-methods framework for assessing walkability in the lanes of Chattarpur village, is subject to several limitations that should be acknowledged. A primary limitation is the reliance on subjective self-reported data collected through public perception surveys and interviews, which can introduce biases arising from personal experiences, habituation to local conditions, or the desire to provide socially acceptable responses (social desirability bias). The sample size of 100 pedestrians, selected using purposive sampling, may not fully capture the diversity of user experiences or represent all demographic groups within the area, potentially limiting the generalizability of the findings. In this study, the researcher also acted as the observer, making it difficult to establish inter-dependency between the researcher, observer, and street user; however, the study offers a framework that can potentially be scaled up by independently assigning these roles in future research. The observational assessment conducted by limited number of researchers introduces a possibility of observer bias, as the subjective judgement of a small group may not fully capture the variability of on-ground conditions. Also the observational and environmental data were collected during specific time frames and may not reflect variations across different times of day, seasons, or special events, which can significantly influence pedestrian behaviour and walkability conditions. The normalization and aggregation of scores, especially for attributes where lower values are preferable, could be sensitive to outliers and may oversimplify the complex, multidimensional nature of pedestrian experience. The absence of specific design guidelines for narrow urban village lanes in existing regulatory frameworks, such as those from the Indian Road Congress, constrains the ability to benchmark findings or propose universally applicable standards. Future research should address these limitations by incorporating larger and more representative samples, collecting data across varied temporal contexts, integrating additional objective and subjective measures, and testing the framework in diverse urban settings to enhance its robustness and transferability.

5.2. Recommendations

Based on the analysis and significant findings from the study, the recommendations were grouped into street, built and natural environments (refer Table 4). These strategies are directly informed by the results discussed in Section 4.

The street environment requires urgent upgrades to physical infrastructure, with surface quality and safety emerging as critical concerns. Observation-based assessment showed that open drains, encroachments and uneven surfaces were primary deterrents to walking, related to low safety scores (1.33–3) and moderate comfort scores (3–3.67). To mitigate this, regular maintenance programs should prioritize pothole repairs and debris clearance, aligning with IRC:86-2018 standards for local streets. Installing covered drains and dustbins every 200 m would address hygiene concerns. Lighting infrastructure could be enhanced by installing light poles every 30–50 m to improve nighttime visibility, a factor directly tied to user satisfaction scores.

In terms of the built environment, a village-level master plan could integrate mixed-use zoning to enhance connectivity between residential clusters and amenities, aligning with the objectives of Delhi Master Plan 2021. Formulating lane design guidelines under the Indian Road Congress (IRC) framework is critical for standardizing infrastructure in narrow lanes, which currently lack tailored guidance. Enforcement of bylaws to reclaim encroached spaces and relocating parking to peripheral zones would improve the overall carriageway width, a strategy validated by the Nizamuddin Basti Renewal project in Delhi. Upgrading basic infrastructure such as adding resting areas, could further improve walkability, addressing resident complaints about the absence of such facilities.

In terms of natural environment, noise pollution (65–75 dB) and microclimatic variables (32–38 °C, 55–70% humidity) significantly degrade walkability, with environmental scores ranging from 0.50 to 2.47. Temporary solutions like projected awnings and shade structures can mitigate heat exposure. Community involvement could include strategies of working closely with the community in identifying peripheral parking areas thus limiting vehicular access within Chhatarpur. Community, through its representatives may also work in collaboration with various institutes in employing sound-absorbing materials to reduce noise pollution. Neighbourhood committees could be formed which could work along with DPCC (Delhi Pollution Control Committee) and are tasked to enforce noise pollution control measures. Collaborations with the Delhi Pollution Control Committee (DPCC) to enforce noise regulations and deploy sound-absorbing materials (e.g. green walls) are essential, drawing on models from Paris's noise-mapping programs. Integrating street trees into multi-utility zones (MUZ) could also lower ambient temperatures, aligning with recommendations from IRC:103 for climate-resilient street design.

By harmonizing street, built, and natural environment strategies, Chhatarpur can transform its lanes into safer, cleaner, and more inclusive pedestrian networks, serving as a model for urban villages across India and beyond.

6. Conclusions

This research highlights the urgency of formulating a localized framework for lanes in urban villages like Chattarpur. In doing so, it offers a route-based assessment framework consisting of two main steps: observational-based assessment done for all 21 attributes and perception-based assessment done for 14 out of 21 attributes. The observation-based assessment is further structured into sub-steps, including the identification and categorization of attributes, data collection, and analysis. This includes the calculation of normalized scores to enable comparison across diverse attributes, followed by the computation of route-based dimension scores and an overall walk score, using 21 attributes grouped under the five dimensions of safety, comfort, accessibility, connectivity, and environment. This study revealed important results: routes scoring high in one dimension (Route 4 for safety) often scored lower in others (connectivity and accessibility) underscoring the need for context-specific interventions. It was revealed that the overall walk score was influenced by the aggregate performance across all five dimensions, rather than being driven by any single dimension or attribute alone. The research contributes to the field of pedestrian safety, particularly in the context of Chattarpur village. Unlike uniform road hierarchies and zoning regulations seen in planned colonies of Delhi, urban villages like Chattarpur display a high degree of variability in built form, encroachments, and informal land use patterns. Studies focusing on walkability in areas such as Connaught Place or Lutyens' Delhi often highlight challenges that differ substantially from those in unplanned settlements. This study has sought to bridge existing research gaps by developing a context-sensitive framework that addresses the unique challenges of urban villages. The proposed methodology can be adapted for similar contexts, with appropriate modifications to reflect local attributes and dimensions. By focusing on a relatively underexplored area and offering practical, implementable strategies, this research lays the groundwork for future studies and policy interventions aimed at improving walkability conditions in urban villages of Delhi and beyond.

Acknowledgements

We wish to extend our utmost appreciation to all the participants who donated their precious time and understanding to this study. It would not have been possible without their invaluable contributions. We also profoundly thank our supervisor Prof. Deepty Jain for her unwavering guidance, encouragement, and constructive feedback throughout the whole process of this work. We also acknowledge help from the Transportation Research and Injury Prevention Centre (TRIPC) IIT Delhi, which provided us with the necessary tools and facilities to complete this research work effectively. Their help has been important in helping us succeed in this investigation. We are finally grateful to our colleagues and all those who have indirectly contributed to this research through their constant support and encouragement. Authors acknowledge the opportunity to present their paper at the first World Symposium on Sustainable Transport and Liveability (WSSTL-2025) as well as publish it in this journal.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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Appendix

Survey Questionnaire:

1. Gender:
   ☐ Male ☐ Female ☐ Other: ___________
2. Age: _______________
3. Route:
   ☐ 1 ☐ 2 ☐ 3 ☐ 4
4. Whom do you usually travel with?
   ☐ Alone ☐ Group of Friends ☐ Family
5. Are you a resident or a tenant?
   ☐ Resident ☐ Tenant
6. How long have you been staying here? ___________
7. What is the perceived comfortable walking distance for you?
   ☐ Less than 500 m
   ☐ 500 m to 1 km
   ☐ 1 km to 2 km
   ☐ More than 2 km
8. How much time is required by you to walk 500 m?
   ☐ 0–5 mins ☐ 5–10 mins ☐ 10–15 mins ☐ >15 mins
9. Do you use walking as your primary mode of transportation for everyday travel?
   ☐ Yes ☐ No
10. If yes, what is your main destination?
    ☐ Education ☐ Everyday Needs ☐ Religious Purpose ☐ Leisure
    ☐ Work
11. Type of destination (Please specify): ___________
12. What kind of assistances or amenities would make walking more comfortable and enjoyable for you? Rate according to priority.

Amenity	1 (Not a priority)	2	3	4	5 (Essential)
a) Street Lighting	☐	☐	☐	☐	☐
b) Resting Areas	☐	☐	☐	☐	☐
c) Dustbins	☐	☐	☐	☐	☐

13. At what distance do you find public transport?
    ☐ 0–500 m ☐ 500 m–1 km ☐ 1–1.5 km ☐ >1.5 km
14. What are other alternate routes you take?
15. If you use alternate routes, what factors influence your decision? (Select all that apply)
    ☐ Safety ☐ Comfort ☐ Accessibility ☐ Connectivity
    ☐ Environment
16. Extent to which noisy environments pose a challenge to walkability
    ☐ 1 – Not at all ☐ 2 – Minor ☐ 3 – Moderate ☐ 4 – Significant
    ☐ 5 – Serious
17. Extent to which quality of roads pose a challenge to walkability:
    ☐ 1 – Not at all ☐ 2 – Minor ☐ 3 – Moderate ☐ 4 – Significant
    ☐ 5 – Serious
18. Extent to which open drains pose a challenge to walkability:
    ☐ 1 – Not at all ☐ 2 – Minor ☐ 3 – Moderate ☐ 4 – Significant
    ☐ 5 – Serious

19. Extent to which encroached areas pose a challenge to walkability:
☐ 1 – Not at all ☐ 2 – Minor ☐ 3 – Moderate ☐ 4 – Significant ☐ 5 – Serious
20. Extent to which potholes pose a challenge to walkability:
☐ 1 – Not at all ☐ 2 – Minor ☐ 3 – Moderate ☐ 4 – Significant ☐ 5 – Serious
21. Extent to which heat/heat stress/hot weather pose a challenge to walkability
☐ 1 – Not at all ☐ 2 – Minor ☐ 3 – Moderate ☐ 4 – Significant ☐ 5 – Serious
22. Accessibility of basic amenities (grocery, school, healthcare, etc.):
☐ Not at all ☐ Not accessible ☐ Somewhat accessible ☐ Accessible ☐ Very accessible
23. Overall satisfaction with walking experience on Chattarpur Lane:
☐ Very dissatisfied ☐ Dissatisfied ☐ Neutral ☐ Satisfied ☐ Very satisfied
24. Suggestions for improving walking experience on Chattarpur Lane: ____________