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Enhancing at Crosswalks and Sidewalks: A Case Study of Kathmandu Metropolitan City

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Abstract

This study evaluates pedestrian safety and walkability in Kathmandu Metropolitan City by developing and applying two indices: the Sidewalk Condition Index (SCI) and the Crosswalk Condition Index (CCI). Through a comprehensive literature review, 16 sidewalk and 11 crosswalk attributes were identified. Expert consultations using the Analytical Hierarchy Process (AHP) provided relative weights for each attribute, while a user perception survey (n = 420) captured the experiences of pedestrians. This combined approach ensured both technical priorities and community perspectives were reflected in the assessment. Six urban road sections with the highest pedestrian fatality records were analyzed. Results show that effective signal control (weight = 0.50), zebra crossings (0.47), and sidewalk lighting (0.38) are the most influential factors. SCI values ranged from –0.04 to 1.10, and CCI values from –0.08 to 0.62, identifying S4 (Gongabu – Sarkaridhara) as the least safe section and S6 (Narayan Gopal Chowk – T.U. Teaching Hospital) as the most walkable. The study recommends prioritizing improvements such as enhanced signal timing with pedestrian phases, installation of zebra crossings and refuge islands at high-risk intersections, and regular sidewalk maintenance to ensure continuity and safety. These findings offer a transferable framework for enhancing pedestrian infrastructure in Kathmandu and other similar South Asian urban contexts.

Keywords: *Pedestrian Safety; Walkability; Sidewalks; Crosswalks; Condition index*

1. Introduction

Kathmandu Metropolitan City (KMC) faces significant challenges regarding pedestrian safety and walkability, issues that are exacerbated by rapid urbanization and increasing motorization. More than 70% of urban roads lack essential pedestrian amenities such as continuous sidewalks and marked crosswalks, forcing pedestrians to share road space with vehicles and thereby increasing exposure to crashes (Kathmandu Valley Traffic Police Office [KVTPO], 2024). National statistics also highlight the vulnerability of pedestrians: in Nepal, pedestrians account for approximately 23% of road traffic fatalities, a proportion consistent with South Asian trends where vulnerable road users constitute more than half of total crash victims (WHO, 2023).

Sidewalks and crosswalks are vital elements of an urban transport system that directly influence pedestrian safety and comfort (Sisiopiku & Akin, 2003). In KMC, however, sidewalks are often narrow, discontinuous, encroached upon, or poorly maintained, while over 80% of roads lack designated pedestrian crossings (KVTPO, 2024). These deficiencies not only discourage walking but also increase the risk of crashes for pedestrians. Despite such pressing issues, no standardized framework currently exists in Nepal to systematically evaluate sidewalk and crosswalk conditions.

This study addresses this gap by introducing two indices, the Sidewalk Condition Index (SCI) and Crosswalk Condition Index (CCI), to provide a quantitative, data-driven assessment of pedestrian facilities. The indices are derived through the Analytical Hierarchy Process (AHP), which assigns weights to key attributes based on expert judgment, combined with large-scale user perception surveys to capture public experience. By integrating expert and user perspectives, SCI and CCI go beyond merely identifying the lack of infrastructure; they allow policymakers to compare, rank, and prioritize pedestrian facilities, thereby providing a structured framework to inform targeted improvements.

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Six urban road sections with the highest pedestrian crash histories over the last three years were selected for detailed analysis ≥5 pedestrian fatalities each, as recorded by KVTPO, 2024). Field surveys, traffic and pedestrian counts, and structured questionnaires were conducted to calculate SCI and CCI values. For instance, low CCI scores in sections S2 and S4 reflect inadequate visibility and the absence of safe crossings, directly supporting the recommendation for installing zebra crossings and refuge islands at those locations.

By linking crash data, infrastructure conditions, and user perceptions into a single evaluation framework, this sstudy not only identifies critical deficiencies but also demonstrates how evidence-based interventions, such as improved signal phasing, enhanced lighting, and the introduction of pedestrian-specific crossings, can improve safety and walkability. The findings provide valuable guidance for urban planners and policymakers in KMC and offer a replicable approach for other South Asian cities facing similar challenges.

2. Literature Review

Pedestrian safety and walkability have emerged as critical concerns in rapidly urbanizing cities, particularly in South Asia, where vulnerable road users account for more than half of crash-related fatalities (WHO, 2023). In Nepal, pedestrians represent nearly one-quarter of road traffic deaths, underscoring the urgent need for systematic evaluation of pedestrian facilities (KVTPO, 2024). International studies consistently demonstrate that well-designed sidewalks, crosswalks, and curb ramps reduce pedestrian-vehicle conflicts and improve safety (Mukherjee & Mitra, 2020; Kadi et al., 2021). Conversely, inadequate pedestrian infrastructure in developing cities has been strongly linked to higher crash risks, particularly at intersections and mid-block crossings where vehicle speed and volume are significant factors (Eluru et al., 2008; Marisamynathan & Vedagiri, 2018).

Walkability, defined as the extent to which the built environment supports safe and comfortable pedestrian movement (Southworth, 2005), directly affects public health, accessibility, and sustainable urban development. The “complete streets” approach emphasizes multimodal design, while urban design scholars highlight safety, comfort, and connectivity as key elements for encouraging walking (Deb, 2005; Speck, 2018). Empirical studies confirm that features such as continuous sidewalks, effective crossings, pedestrian lighting, and traffic calming are essential for creating walkable spaces (Sisiopiku & Akin, 2003; Nag et al., 2020).

Several methodological approaches have been developed to evaluate pedestrian facilities. Level of Service (LOS) frameworks provide subjective measures of comfort and capacity (Mori & Tsukaguchi, 1987), while more recent studies have advanced condition indices to incorporate both safety and serviceability. For example, Bari et al. (2018) applied an SCI in Dhaka, while Patil et al. (2021) developed an SCI and CCI for Indian cities, using expert-derived weights for crash-prone locations. Majumdar et al. (2021) emphasized satisfaction-based prioritization, showing the value of user perceptions in identifying critical attributes. Similarly, Rashidi et al. (2016) and Muhammad et al. (2022) demonstrated that composite indices effectively highlight deficiencies and support targeted interventions.

The AHP has frequently been employed to derive attribute weights in transport studies due to its ability to structure complex decisions (Saaty, 1980; Piantanakulchai & Saengkhao, 2003). Prior research primarily relied on expert input for weighting, but critics have noted that excluding pedestrian perspectives may overlook contextual challenges (Oswald Beiler & Phillips, 2016). This study addresses that gap by combining expert-assigned AHP weights with user perception surveys, thereby bridging technical evaluation with community experience.

3. Study Area

The research was conducted in KMC, Nepal’s largest urban center, located at 27°42′14″N and 85°18′32″E. KMC has experienced rapid urbanization and motorization in recent decades, yet more than 70% of its roads lack essential pedestrian amenities, resulting in elevated pedestrian crash risks (KVTPO, 2024).

For this study, six road sections were selected from an initial pool of fourteen based on two criteria: (i) high pedestrian activity, and (ii) a minimum of five pedestrian fatalities recorded between 2021 and 2024, as reported by the KVTPO. This ensured that the analysis focused on crash-prone corridors with significant exposure, thereby maximizing the relevance of the findings for pedestrian safety improvements.

The selected sections represent diverse urban contexts within KMC, including mixed land-use neighborhoods, institutional areas, and commercial corridors connected to the ring road and central business districts. Fatality records and exposure data for these corridors were obtained from KVTPO (2021–2024), supplemented by field observations and survey data collected during this study. Table 1 summarizes the characteristics of the six study sections.

Table 1. Selected study sections in KMC

Section	Location (from–to)	Length (m)	Key land use	Fatalities (last 3 years)	Notes on pedestrian environment
S1	Balaju Chowk – Naya Bazar	847	Mixed land-use	9	Discontinuous sidewalks, poor crosswalk visibility
S2	Balkhu Chowk – Kuleshwor Ganeshthan Temple	580	Commercial	10	Narrow sidewalks, limited amenities
S3	Gaushala Chowk – Old Baneshwor Chowk	730	Institutional/market	7	Maintained sidewalks, inadequate street furniture
S4	Gongabu Chowk – Sarkaridhara Chowk	815	Mixed commercial	13	Poorly maintained sidewalks, frequent waterlogging
S5	Jadibuti Chowk – Ward Office 32	743	Residential/commercial	11	Wide sidewalks, affected by waterlogging
S6	Narayan Gopal Chowk – T.U. Teaching Hospital	774	Institutional/healthcare	6	Well-marked crosswalks, tactile tiles, adequate lighting

4. Methodology

This study adopted a mixed-methods approach, combining both primary and secondary data, to evaluate the safety and walkability of pedestrian infrastructure in KMC. The methodology was designed to integrate expert judgment, user perceptions, and field-based assessments, ensuring a comprehensive analysis of sidewalk and crosswalk conditions.

4.1 Research Design

The research design followed sequential steps: identification of key attributes through literature review, collection of expert and user perceptions, field-based inventory surveys, and analytical modeling using the AHP and weighted sum methods. This enabled the systematic formulation of the SCI and CCI.

4.2 Data Collection

4.2.1 *Primary Data*

Primary data were obtained through expert surveys, user perception surveys, field observations, and key informant interviews. Twenty-five professionals in transportation engineering, urban planning, and road safety completed AHP-based pairwise comparison questionnaires, with reliability confirmed using a consistency ratio (CR < 0.10; Sinha & Labi, 2011). A structured user survey, designed with Cochran's formula (Cochran, 1977), gathered 420 valid responses from 384 participants across six sites, using a Likert scale to assess factors such as safety, lighting, cleanliness, aesthetics, surface condition, and accessibility; reliability was confirmed with Cronbach's Alpha ($\alpha > 0.70$). Field observations and videographic surveys captured traffic speeds, volumes, and pedestrian flows at the selected sections, while eight key informant interviews with residents, engineers, and safety specialists provided contextual insights.

4.2.2 *Secondary Data*

Secondary data comprised pedestrian crash and fatality records from the Kathmandu Valley Traffic Police Office (2021–2024), along with relevant literature, manuals, and guidelines, including the Nepal Road Standard (2013), Nepal Urban Road Standard (2019), and prior studies such as Patil et al. (2021) and Mukherjee & Mitra (2020).

4.3 Attribute Selection

Drawing from existing literature and national guidelines, a total of 16 sidewalk-specific and 11 crosswalk-specific attributes were identified as critical determinants of pedestrian safety and walkability. The sidewalk attributes were grouped under four categories: facilities and security, aesthetics and surface quality, physical characteristics, and traffic interaction, while crosswalk attributes were classified into two categories, namely geometric and operational characteristics and traffic-related factors. The complete list of attributes and their sources is presented in Tables 2 and 3.

Table 2. List of attributes for crosswalk elements

Crosswalk Elements	Attributes	Source
Crosswalk Characteristics	• Conflicts with traffic • Refuge Island • Signage and road marking • Dropped kerb • Zebra crossing • Lighting at the crossing	Zainol et al, (2014); Sisiopiku and Akin (2003), Majumdar et al. (2021); Galanis and Eliou (2011); Ahmed et al. (2021); NRS (2013); NURS (2019)
Traffic Characteristics	• Traffic speed • Traffic volume • Signal Control • Delay for pedestrians • Pedestrian flow	Mukherjee and Mitra (2020); Fabian et al. (2010); Kadali and Vedagiri (2015); Marisamynathan and Vedagiri (2018); NRS (2013); NURS (2019)

Table 3. List of attributes for sidewalk elements

Sidewalk Elements	**Attributes**	**Source**
Sidewalk facilities and security	• Security from crime • Sidewalk Lighting • Ramps in the sidewalk • Tactile paving • Sidewalk Amenities	Nepal and Lal (2021); Muhammad et al. (2022); Abaya et al. (2011); Rahman et al. (2022); Galanis and Eliou (2011); Zainol et al, (2014); NRS (2013); NURS (2019)
Aesthetics and Footpath Quality	• Aesthetic • Cleanliness • Surface Condition • Raised Curb	Nepal (2021); Majumdar et al. (2021); Abaya et al. (2011); Zainol et al, (2014); NRS (2013); NURS (2019)
Physical Characteristics	• Sidewalk Width • Sidewalk continuity • Physical separation from traffic • Obstruction	Kim et al. (2024); Sisiopiku and Akin (2003); Banerjee et al. (2018); Majumdar et al. (2021); NRS (2013); NURS (2019)

Traffic Characteristics	• Traffic Speed • Traffic Volume • Pedestrian Volume	Mukherjee and Mitra (2020); Banerjee et al. (2018); Fabian et al. (2010); NRS (2013); NURS (2019)

4.4 Analytical Methods

4.4.1 *AHP*

Expert responses were analyzed using AHP through paired comparison questionnaires on sidewalk and crosswalk attributes. The CR was used to validate responses, and 15 of the 25 surveys with CR < 0.10 were retained. Final weights were computed using Super Decision V3.2, providing an objective evaluation of the most influential factors.

4.4.2 *Weighted Sum Method*

SCI and CCI were computed as weighted sums of attribute values using AHP-derived weights:

$$SCI_j = \sum_{a-1}^{n} \quad w_a X_{aij} \tag{1}$$

$$CCI_j = \sum_{b-1}^{m} \quad w_b Y_{bij} \tag{2}$$

Where,

SCI_j , CCI_j: $indices\ for\ the\ j^{th}$sidewalk/ crosswalk

w_a, w_b : weight of attributes derived from AHP

$\mathrm{X}a_{ij}, Yb_{ij}$: normalized score of the b^{th} or a^{th}attribute at the j^{th} location

n, m: total number of sidewalk and crosswalk attributes

4.5 Statistical Analysis

User perception data were analyzed using SPSS for descriptive and inferential statistics. Reliability of scales was confirmed with Cronbach's Alpha, and thematic analysis was applied to KII data for qualitative insights

5. **Results and Discussion**

5.1. Calculation from AHP

The AHP analysis identified signal control (0.50) and zebra crossings (0.47) as the most influential crosswalk attributes, while physical separation from traffic (0.56), sidewalk lighting (0.38), and cleanliness (0.41) were most critical for sidewalks. These results highlight the need for regulated crossings, speed management, and well-maintained pedestrian spaces in KMC. Table 4 presents the relative weights of all attributes.

Table 4. Relative weights of crosswalk and sidewalk attributes

Category	Attributes	Relative weight	Category	Attributes	Relative weight
Crosswalks	Conflicts with traffic	0.19	Sidewalks	Sidewalk amenities	0.19
	Refuge island	0.05		Sidewalk lighting	0.38
	Dropped kerb	0.04		Ramp in sidewalk	0.11
	Lighting at the crossing	0.16		Security from crime	0.25
	Signage & markings	0.09		Tactile paving	0.06
	Zebra crossing	0.47		Aesthetic	0.37
	Delay for pedestrians	0.04		Cleanliness	0.41
	Pedestrian flow	0.07		Raised kerb	0.04
	Signal control	0.5		Surface condition	0.17
	Traffic speed	0.25		Sidewalk continuity	0.24
	Traffic volume	0.14		Obstruction	0.12

	Physical separation from traffic	0.56
	Sidewalk width	0.08
	Pedestrian volume	0.06
	Traffic speed	0.6
	Traffic volume	0.35

5.2. User's Perception

A structured questionnaire survey was administered to pedestrians along the six selected road sections of KMC, yielding 420 valid responses. The survey captured demographic profiles, walking behavior, perceived safety, and user ratings of specific attributes influencing pedestrian safety and walkability. These attributes were evaluated on a five-point Likert scale (1 = Very Poor, 5 = Excellent) and later categorized for condition rating to support the calculation of the SCI and CCI. Table 5 summarizes user demographics, behavior, safety perceptions, and issues, while Tables 6 and 7 present crosswalk and sidewalk attributes with their justifications for inclusion in the CCI and SCI.

Table 5. Summary of user perception survey results

Variable	Key Findings	Sectional Highlights
Gender	Males outnumbered females in all sections.	Highest male share: S2 (81.7%); highest female share: S6 (43.5%).
Age	Majority are in 20–40 years; seniors <5%.	S3 & S4: mostly 30–40 yrs; S2: dominated by 20–30 yrs.
Employment	Predominantly employed, notable student, and self-employed groups.	Students: S1 (27.4%), S5 (18.8%); Self-employed: S6 (30.4%).
Walking frequency	Most walked daily or weekly.	Daily: highest in S2 (60.6%); infrequent: S1 & S5.
Purpose of walking	Shopping, leisure, and access to public transport.	Shopping: S1–S3; Leisure: S5–S6; Transport: S5–S6.
Perceived safety	Varied across sections.	Highest in S6 (71%); lowest in S4 (70.8%); 50% unsafe in S2.
Common issues	Traffic congestion, poor sidewalks, inadequate crossings, and lighting.	Congestion: S3 (54.4%); Poor sidewalks: S2 (49.3%), S4 (41.7%); Inadequate crossings: S1 (42.5%); Lighting: S4 (27.8%), S5 (32.8%).

Table 6. Crosswalk Attributes Rated by Users

Attribute	Description	Justification
Zebra crossing visibility	Clarity and maintenance of markings	Enhances conspicuity and reduces conflicts
Presence of signals	Availability of pedestrian signals	Improves compliance and crossing safety
Waiting time	Average delay experienced at the crossing	Directly affects pedestrian compliance and satisfaction
Crosswalk lighting	Adequacy of lighting at night	Reduces accident risk, increases perceived security
sConflicts with vehicles	Frequency of conflicts with turning/through vehicles	High predictor of pedestrian crashes
Dropped kerbs	Accessibility for wheelchair users, the elderly, and prams	Critical for inclusive mobility
Tactile paving	Presence/quality of tactile surfaces	Assists visually impaired pedestrians

Refuge islands	Median spaces for safe two-stage crossing	Especially useful on wide roads

Table 7. Sidewalk Attributes Rated by Users

Attribute	Description	Justification
Width	Usable walking width of sidewalk	Narrow widths reduce capacity and comfort
Surface quality	Smoothness, absence of cracks/potholes	Poor surfaces discourage use, increase risk
Continuity	Uninterrupted walking path	Discontinuity leads to unsafe detours
Lighting	Adequacy of illumination	Enhances safety and nighttime walkability
Cleanliness	Absence of litter/obstacles	Directly tied to user comfort and hygiene
Trees/greenery	Shading, environmental comfort	Improves aesthetics, reduces heat exposure
Seating/amenities	Benches, bins, shading structures	Encourages longer, safer pedestrian stays
Separation from traffic	Physical buffer from roadway	Reduces exposure to vehicles
Accessibility	Suitability for the elderly/disabled	Ensures equity and inclusiveness

5.3. Traffic and Pedestrian Data

Traffic and pedestrian counts were conducted during three daily peak periods (09:30–10:30, 13:00–14:00, and 16:30–17:30) to capture representative flow conditions across the six study sections. The observed traffic volumes ranged from 4,044 PCU/hr in Section S4 to 6,911 PCU/hr in Section S1, while average vehicular speeds varied between 24.28 km/h (S1) and 35.37 km/h (S5). Correspondingly, pedestrian flows at crosswalks ranged from 308 ped/hr (S3) to 598 ped/hr (S1), and sidewalk pedestrian volumes varied from 881 ped/hr (S3) to 1,707 ped/hr (S1). The detailed figures for each section are summarized in Table 8, which provides a comprehensive overview of traffic volumes, pedestrian flows, and vehicular speeds across the study corridors.

For comparative analysis and integration into the condition indices, these traffic-related parameters were normalized and classified into three risk categories: low, moderate, and high. The thresholds applied are consistent with international safety benchmarks (WHO, 2023; Patil et al., 2021), which highlight the exponential rise in pedestrian crash severity above 30 km/h, as well as with walkability assessments (Nepal & Lal, 2021) that emphasize traffic speed, exposure, and pedestrian demand as key determinants of walkability. This categorization framework ensures methodological robustness and allows for systematic ranking of road sections in terms of both exposure risk (traffic volume), operational safety (speed), and infrastructure demand (pedestrian flow). This categorization framework, presented in Table 9, Categorization of Traffic-Related Parameters for Condition Rating.

Table 8. Summary of the traffic and pedestrian data

Road Sections	**Average Traffic Volume (PCU/hr)**	**Average Traffic Speed (km/hr)**	**Average Pedestrian Volume (Ped/hr)**	
			Crosswalk	Sidewalk
S1	6911	24.28	598	1707
S2	5160	27.9	462	1319
S3	6142	31.3	308	881
S4	4044	25.49	512	1464
S5	6756	35.37	402	1017
S6	5341	26.8	551	1573

Table 9. Categorization of Traffic-Related Parameters for Condition Rating

Parameter	Range	Interpretation
Traffic Speed (km/h)	<25 (Low), 25–35 (Moderate), >35 (High)	Low speeds are safer; above 30 km/h, fatality risk rises sharply
Traffic Volume (PCU/hr)	<4,500 (Low), 4,500–6,000 (Moderate), >6,000 (High)	High volumes increase exposure risk and conflicts
Pedestrian Volume (ped/hr)	<500 (Low), 500–1,000 (Moderate), >1,000 (High)	High volumes highlight demand and the need for infrastructure

5.4. CCI and SCI Calculation

Using normalized attribute values, the explicit formulations applied were developed to combine the weighted contribution of each attribute into a single index score. Normalization ensured that all survey and field data were scaled to a comparable range (0–1), avoiding bias from differing measurement units. This allowed the attributes with higher AHP-derived weights to exert proportionally greater influence on the overall index value. The final equations for CCI and SCI are expressed as follows:

$$SCI_j = (0.19 * X_{amenities}) + (0.38 * X_{lighting}) + (0.11 * X_{ramp}) + (0.25 * X_{security}) + (0.06 * X_{tactile}) + (0.37 * X_{aesthetic}) + (0.41 * X_{cleanliness}) + (0.04 * X_{kerb}) + (0.17 * X_{surface}) + (0.24 * X_{continuity}) + (-0.12 * X_{obstruction}) + (0.56 * X_{separation}) + (0.08 * X_{width}) + (-0.06 * X_{p.volume}) + (-0.60 * X_{speed}) + (-0.35 * X_{t.volume}) \quad (3)$$

$$CCI_j = (-0.19 * Y_{conflict}) + (0.05 * Y_{island}) + (0.04 * Y_{kerb}) + (0.16 * Y_{lighting}) + (0.09 * Y_{signage}) + (0.47 * Y_{zebra\ crossing}) + (-0.04 * Y_{delay}) + (-0.07 * Y_{flow}) + (0.50 * Y_{signal}) + (-0.25 * Y_{speed}) + (-0.14 * Y_{volume}) \quad (4)$$

Both indices range from negative to positive values, where lower or negative scores reflect unsafe and inconvenient pedestrian environments caused by traffic conflicts, poor infrastructure, and inadequate maintenance, while higher scores indicate safer, more functional, and walkable spaces. This approach is consistent with international applications of SCI and CCI, which are widely used to evaluate pedestrian facilities and guide infrastructure priorities (Patil et al., 2021; Mukherjee & Mitra, 2020; Banerjee & Maurya, 2018).

The CCI and SCI values offer a clear numerical representation of crosswalk and sidewalk conditions. Lower scores identify locations in urgent need of intervention, while higher scores suggest lower priority. By normalizing survey and field data, the indices allow consistent ranking of study sections, as shown in Table 10. This systematic, data-driven method helps authorities allocate resources effectively, focusing improvements on the most critical areas to enhance safety and walkability (Patil et al., 2021; Rashidi et al., 2016; Oswald Beiler & Phillips, 2016).

Table 10. CCI and SCI with the ranking of the selected road section

Road section	Crosswalks		Sidewalks	
	CCI	Ranking	SCI	Ranking
S1	0.06	2nd	0.43	3rd
S2	0.11	3rd	0.17	2nd
S3	0.37	4th	0.99	5th
S4	-0.08	1st	-0.04	1st
S5	0.54	5th	0.81	4th
S6	0.62	6th	1.1	6th

5.5. Performance Analysis of Crosswalks and Sidewalks

5.5.1. *Crosswalk Performance*

The calculated CCI values (Table 10) demonstrate varying crosswalk performance across six study sections. The lowest performance was recorded at S4 (CCI = -0.08, Rank 1), indicating severe deficiencies such as high traffic conflicts, lack of signage, and uncontrolled vehicle speeds. Moderate performance was observed at S1 (0.06, Rank 2) and S2 (0.11, Rank 3), where crosswalks suffered from frequent conflicts and insufficient lighting. S3 (0.37, Rank 4) showed improvement, benefiting from better refuge facilities and reduced conflicts. The best performance was seen at S5 (0.54, Rank 5) and S6 (0.62, Rank 6), supported by effective signalization and zebra crossings, though traffic conflicts still pose risks. Overall, the analysis confirms that traffic-related attributes such as speed and volume exert a strong negative influence on crosswalk safety, while signal control and zebra crossings emerge as the most critical determinants of safer conditions. The Nepal-specific practice of implementing signals and zebra crossings together also explains their dominant influence, in contrast to international contexts where these measures are usually independent.

5.5.2. *Sidewalk Performance*

SCI scores revealed substantial variation in pedestrian space quality across the study sections. The lowest performance was found in S4 (SCI = -0.04, Rank 1), marked by discontinuity, obstructions, poor aesthetics, and inadequate amenities. Moderate scores at S1 (0.43, Rank 3) and S2 (0.17, Rank 2) reflected deficits in lighting, security, and sidewalk amenities. S5 (0.81, Rank 4) benefited from wider sidewalks but continued to face challenges related to cleanliness and safety. The highest performance was observed in S3 (0.99, Rank 5) and S6 (1.10, Rank 6), where improved cleanliness, adequate lighting, and physical separation from traffic contributed to safer and more walkable conditions. These results highlight that, similar to crosswalks, traffic speed and volume have the strongest negative effect on sidewalk usability, while factors such as lighting, cleanliness, and separation from traffic are the most influential in creating positive pedestrian environments.

5.6. Improvements for Crosswalks and Sidewalks Based on SCI and CCI Scores

Based on the SCI and CCI scores, targeted improvements are recommended for each road section to enhance pedestrian safety, walkability, and infrastructure quality.

1. S1 (Balaju Chowk to Naya Bazar). The priority should be reducing pedestrian–vehicle conflicts through refuge islands at wide crossings and improving high-visibility signage and road markings. Enhancing sidewalk lighting and providing better security measures will address safety concerns identified by low SCI scores.
2. S2 (Balkhu Chowk to Kuleshwor Ganeshthan Temple). Wider crosswalks and improved dropped kerbs are essential to reduce conflicts and enhance accessibility. Additional lighting, improved aesthetics, and obstruction-free sidewalks will directly improve SCI ratings.
3. S3 (Gaushala Chowk to Old Baneshwor Chowk). Optimized signal control and better lighting at crossings are required to reduce delays and improve safety, consistent with its moderate CCI performance. On sidewalks, ramps for universal access and strategic placement of amenities without causing obstructions are critical. Regular cleaning will maintain high SCI conditions.
4. S4 (Gongabu Chowk to Sarkaridhara Chowk). This section scored lowest in both indices, demanding urgent intervention. High-visibility zebra crossings, reflective markings, improved lighting, and signal optimization should be prioritized to address conflicts and delays. For sidewalks, raised curbs, obstruction removal, and aesthetic upgrades will be essential to raise walkability standards.
5. S5 (Jadibuti Chowk to Ward Office). Installing zebra crossings at critical points and improving signage are needed to support favorable CCI scores. Enhanced lighting, ramp installation, and ensuring sidewalk continuity will improve accessibility and pedestrian comfort.
6. S6 (Narayan Gopal Chowk to T.U. Teaching Hospital). Already performing best in both indices, this section should focus on consolidating gains. Design refinements to further reduce conflicts, along with upgraded lighting, tactile paving, and added security, will ensure inclusivity and sustainability of walkability gains.

6. Conclusion and Recommendation

6.1. Conclusion

This study developed and applied the Sidewalk Condition Index (SCI) and Crosswalk Condition Index (CCI) to assess pedestrian infrastructure in Kathmandu Metropolitan City (KMC). The findings reveal significant deficiencies in sections with high pedestrian crash histories, with S4 performing the worst (CCI = -0.08; SCI = -0.04) due to conflicts, poor signage, and weak infrastructure, while S6 scored highest (CCI = 0.62; SCI = 1.10) with better lighting, signalization, and sidewalk quality. Key attributes such as signal control, zebra crossings, and sidewalk lighting were identified as the strongest determinants of safety and walkability, while traffic speed and volume consistently reduced scores**.**

6.2. Recommendation

The study recommends a priority-based improvement program where low-performing sections, such as S4 and S2, are upgraded first through measures like improved signage, optimized signals, and zebra crossings, while higher-performing sections, like S6, focus on consolidating gains. Policy-level actions include integrating SCI and CCI into walkability maps, enforcing pedestrian right-of-way, and redesigning signal timings at crash-prone locations. For long-term impact, authorities should implement regular maintenance programs, ensure accessibility through universal design, and adopt traffic calming strategies in pedestrian-heavy areas. Future research should extend these methods city-wide, test their applicability in well-designed corridors, and incorporate socioeconomic and behavioral dimensions to capture broader determinants of pedestrian safety and walkability.

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