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Review Article

Big Data and AI in Urban Planning: Advancing Pedestrian -Oriented Development in India – "Challenges, Strategies, and Future Directions"

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Abstract

The integration of big data and artificial intelligence (AI) in pedestrian-oriented urban planning presents transformative potential for sustainable cities, yet implementation in developing nations like India remains constrained. This study examines global applications of big data and AI in pedestrian planning, focusing on India's emerging but limited adoption through a systematic literature review of 76 publications (2014–2025). While advanced economies leverage AI for walkability assessments, pedestrian safety, and infrastructure optimization using multi-source data (GPS, IoT, computer vision). India's efforts are predominantly restricted to vehicular safety projects like iRASTE and BATCS. Key barriers include fragmented data ecosystems, reliance on manual methods, and inadequate pedestrian-centric datasets in platforms like NUDM and IUDX. Challenges such as temporal-spatial data misalignment, privacy concerns, and algorithmic biases further hinder progress. The study proposes a three-pronged framework for India: ethical data governance models balancing innovation and privacy; hybrid methodologies combining AI tools (e.g. dashcam analytics, UAV surveys) with traditional surveys; and public-private partnerships to build local capacity. Successful case studies from Nagpur and Bengaluru demonstrate scalable opportunities, while global benchmarks highlight the need for context-sensitive adaptations. A novel crowdsourced GPS-camera system is suggested to capture pedestrian perspectives, addressing critical data gaps. Findings emphasize that AI adoption in pedestrian planning transcends technological advancement—it necessitates institutional collaboration, policy standardization, and equity-focused solutions aligned with SDG 11. Strategic recommendations include longitudinal pilot studies, regulatory reforms, and integrated data hubs to bridge the gap between India's smart city initiatives and inclusive pedestrian infrastructure. The study positions India to lead Global South nations in human-centric urban innovation through responsible AI deployment.

Keywords: Big data, Artificial intelligence, Pedestrian planning, Walkability, Urban infrastructure, SDG 11

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Highlights

- Technological-Implementation Gap: While India has successfully deployed AI solutions like iRASTE and BATCS for vehicular safety, pedestrian-centric applications remain underdeveloped due to data scarcity, governance fragmentation, and cultural resistance to technological adoption.
- Strategic Imperatives for Inclusive Urbanism: India must prioritize ethical data frameworks, pilot AI implementation studies, and foster public-private collaborations to transform urban mobility—aligning technological innovation with SDG 11's vision of walkable, equitable cities.
- Future-Ready Solutions: Developing integrated data hubs and context-sensitive AI models can bridge current gaps, enabling evidence-based pedestrian planning through multi-stakeholder collaboration and scalable, privacy-conscious frameworks.

1 Introduction

Big data and AI are being used in various sectors such as e-commerce, ride-hailing, transportation, and planning (Chaffey, D., 2022; Chen, T., & Zhang, S., 2021; Wang, K., et al., 2022). In particular big data and AI plays a pivotal role in optimizing urban infrastructure systems (Ogunkanand. D.V., &.Ogunkan, S.K., 2025). The "Forward-thinking organizations are harnessing the transformative power of AI-driven geospatial data to revolutionize transportation planning and make data-informed decisions that are shaping the future of our communities"(Ecopia, 2025). "While 75% of organizations acknowledge that cultural readiness is critical for AI integration, many struggle with leadership alignment and employee adoption" (ai, 2024a). Huge volumes of big data and the use of artificial intelligence (AI) tools in urban planning enabled innovative analysis techniques which were impossible earlier due to data scarcity (Kamrowska-Załuska, 2021). For example, sensor networks embedded in roads, buildings, and utilities generate big data, offering real-time insights into traffic flow, air quality, and energy consumption. Such information facilitates immediate adjustments to optimize efficiency and reduce environmental impact. This allows for rapid adjustments to enhance efficiency and environmental quality. Usage of big data and AI in pedestrian planning in research and application remains largely limited to pedestrian detection and safety; crowd flow optimization; monitor footpath conditions (Zhang et al., 2022); AI powered traffic management adjusts signals in real time to ease the pedestrian density and studied the pedestrian vehicular interaction and safety (Alfikri; Kulhandjian *et al.*, 2024; Yin *et al.*, 2023). Even though there are studies using big data on walkability, most of the studies were limited to use Google street view images (Aschwanden *et al.*, 2019; Bader *et al.*, 2016; Blečić *et al.*, 2018; Glaeser, 2015; Guo and Loo, 2013; Koo *et al.*, 2021; Liu *et al.*, 2017; Sevtsuk *et al.*, 2021; Sevtsuk *et al.*, 2024; Shao *et al.*, 2023; Yang *et al.*, 2021; Yin and Wang, 2016; Yussif *et al.*, 2024; Zhang *et al.*, 2025; Zhou *et al.*, 2019). Although several studies have utilized AI and Big Data, it is important to focus on how these technologies advance pedestrian planning and development to support modal choice decisions. In global contexts such as Australia, Italy, the USA, and the UK, the use of big data in pedestrian planning has significantly advanced both research and practical solutions to social challenges. These countries benefit from well-developed planning frameworks and street networks, which facilitate easier data procurement for evidence-based decision-making and optimization. In contrast, the use of big data and AI remains limited in developing countries like India (Isaacson et al., 2015; Yenisetky & Bahadure, 2020) across urban planning domains—including pedestrian infrastructure design, development, and transport network planning. This is attributed to several barriers: lack of enabling data ecosystems, low AI research intensity, inadequate availability of expertise and training opportunities, high resource costs, limited awareness of AI adoption in business processes, ambiguous privacy and ethical regulations, and an unattractive intellectual property regime that fails to incentivize AI research and implementation (NITI Aayog, 2018). However, several Indian planning agencies now utilize AI and big data in pedestrian infrastructure planning, particularly for smart city projects (Ministry of Urban Development, 2021). Although few Indian planning agencies have implemented pilot projects using AI and big data for pedestrian design, scaling these solutions remains constrained by persistent data procurement challenges (Isaacson et al., 2015). In general researchers, planners and statutory agencies are using Google street view (GSV) images, GPS data, Eye-tracking glasses, data from open street map (OSM), Bluetooth sensors, data from social media and Machine learning (ML) algorithms in solving specific research problems related to pedestrian oriented development (Angel *et al.*, 2024; Angel and Plaut, 2024; Aparicio *et al.*, 2024; Arribas-Bel *et al.*, 2015; Basu *et al.*, 2024; Droin *et al.*, 2024; Fernández-Arango *et al.*, 2024; Gerogiannis and Bode, 2024; Guo and Loo, 2013; Jehle *et al.*, 2024; Nourian *et al.*, 2018; Sevtsuk *et al.*, 2024; van Beek *et al.*, 2024; Yang *et al.*, 2021; Yussif *et al.*, 2024). But Street view data often lack the reflection of quality of street and pedestrian perspective; data of point of interest (POI) can be obtained from open street map and due to the complexity of built environment variables, challenge in data categorization; persisting difficulties in getting pedestrian consent in using GPS data; understanding the data from social media is difficult and there exists a sample bias as offline users are ignored (Yang *et al.*, 2024). Although developed nations like Australia, Italy, the USA and the UK face similar challenges, India's unique position warrants special examination of both its existing pedestrian infrastructure and the current application of big data/AI in urban planning. Comprehensively documenting the problems and issues for pedestrian planning using big data and AI in advancing pedestrian development for modal choice decisions, this examines the global application of big data and AI in pedestrian planning, with particular focus on India's emerging yet constrained adoption. While developed nations leverage these technologies for advanced urban solutions, developing countries face systemic barriers to implementation. This research identifies critical gaps in current pedestrian planning methodologies—particularly the over-reliance on limited data sources (e.g., Google Street View) and lack of contextual adaptability—and proposes an integrated framework to address these limitations. By synthesizing Challenges (data scarcity, technological barriers), Strategies (multi-source data integration, AI-driven contextual analysis), and Future Directions (scalable models for developing economies), the study advances holistic, equity-focused approaches to pedestrian-oriented urban development".

2 Methodology

To understand the landscape of big data and AI in advancing pedestrian design and development, and to characterize strategies for data integration in the planning decision process—as well as to facilitate users' modal choice decisions—a systematic literature review was conducted, as illustrated in Figure 1. Based on the research question - how Big data and AI advance pedestrian planning, design and development that align to transits nodes to support modal choice decisions?, along with the key words "Pedestrians, Big data, Artificial intelligence, Walkability, Built environment, Modal choice" using boolean operators from Scopus database and relevant web pages. The results underwent a screening process by selecting the research articles, news articles, blogs, articles from websites which are relevant to pedestrians, big data and AI as shown in Figure 2 which shows the detailed literature search procedure.

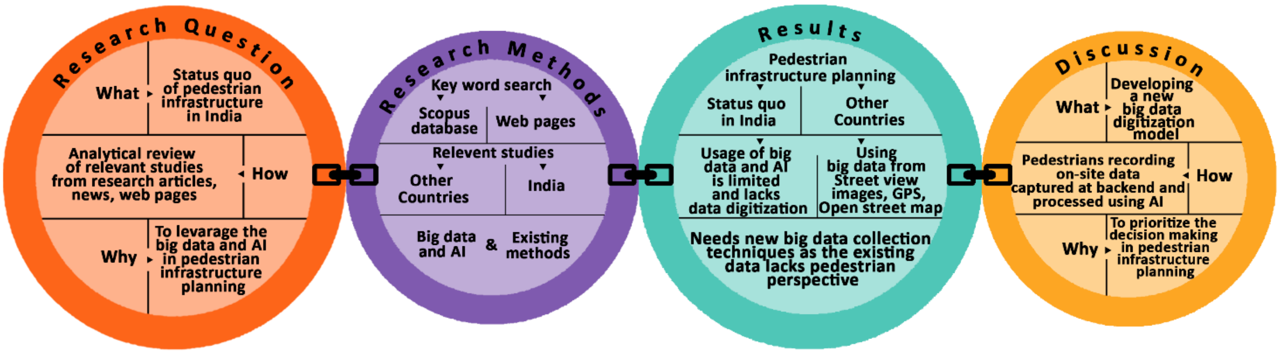

Figure 1. Methodological process of the study

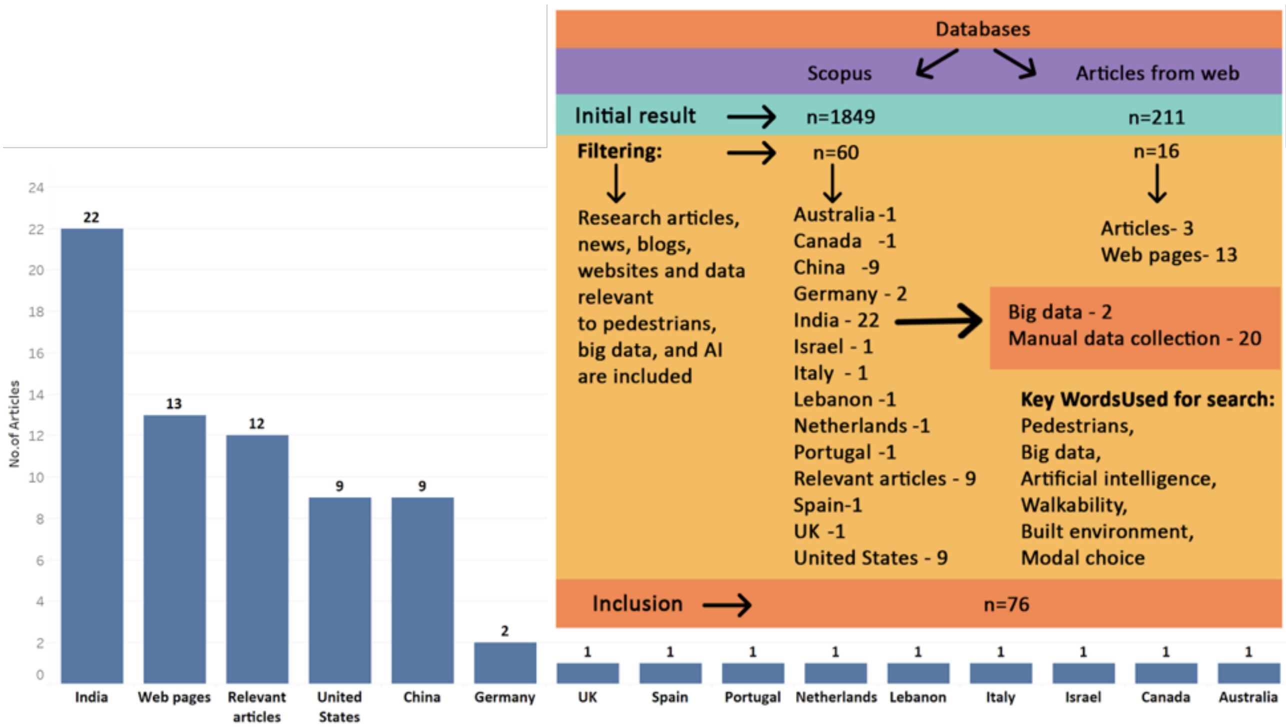

Figure 2: Literature selection process and distribution of published works by country (2014–2025)

With a total of 76 articles included in this study, there are studies from Australia, Canada, China, Germany, Israel, Italy, Lebanon, Netherlands, Portugal, Spain UK, United states. China and the United States are mostly using big data whereas in India only two studies were found to be using big data and the remaining studies depended on manual data collection methods. Further, the detailed literature survey reveals that planning experts (academia) in India don't have knowledge about BiG Data and AI Application for Pedestrian modal choice planning, and design decisions.

3 Role of Big data & AI in pedestrian oriented development

Pedestrian-oriented planning and development serve as critical indicators of a city's livability, reflecting its commitment to sustainable urban design, public health, and social equity. Traditional walkability measurement techniques—often reliant on manual audits or static spatial metrics—are now being transformed by advancements in big data and artificial intelligence (AI). As highlighted by

Yang et al. (2024), these technologies enable dynamic, real-time analysis of pedestrian movement patterns, infrastructure utilization, and environmental interactions through sources such as GPS trajectories, IoT sensors, and computer vision. AI-driven models further enhance walkability assessments by predicting pedestrian behavior, optimizing route design, and integrating multimodal transport data, thereby supporting evidence-based policy decisions that prioritize human-centric urban spaces (Papageorgiou, 2017). However, existing studies leveraging big data and AI for walkability research have explored diverse themes, including street-level walkability assessment, pedestrian safety, visual comfort, built environment analysis, neighborhood auditing, modal choice, route preferences, and social inequalities in accessibility. A majority of these studies rely on Google Street View imagery, supplemented by GPS data and OpenStreetMap (Aschwanden et al., 2019; Bader et al., 2016; Cinnamon & Jahiu, 2021; Kim, 2025; Koo et al., 2021; Lian et al., 2024; Liu et al., 2017; Lue & Miller, 2019; Sevtsuk et al., 2021; Shao et al., 2023; Taş et al., 2025; Tribby et al., 2016; Yin & Wang, 2016; Zhang et al., 2025; Zhou et al., 2019), as illustrated in Figure 3 that the data underscores the uneven global adoption of big data in pedestrian research, highlighting opportunities for expanded studies—especially in underrepresented regions—using scalable tools like GPS and open-source maps (OSM). Street view imagery provides valuable insights for assessing built environment characteristics, while point-of-interest (POI) data enhances the understanding of correlations between urban design variables. GPS tracking enables detailed analysis of pedestrian movement patterns in relation to the built environment. Additionally, the vast volume of multi-modal social media data—including images, text, and videos—offers diverse perspectives on pedestrian experiences and spatial interactions (Yang et al., 2024). Recent international research demonstrates diverse applications of artificial intelligence in pedestrian planning. OpenStreetMap (OSM) data has been effectively utilized to examine pedestrian accessibility (Jehle et al., 2024; Yenisetty & Bahadure, 2020) and mobility patterns (Droin et al., 2024; Fernández-Arango et al., 2024; Sevtsuk et al., 2024). GPS tracking data has provided insights into pedestrian movement dynamics (Nourian et al., 2018) and route selection behavior (Basu et al., 2024; Guo & Loo, 2013). Advanced computer vision techniques, including YOLOv8, have been employed for crosswalk segmentation to optimize pedestrian pathways (Fernández-Arango et al., 2024). Machine learning approaches such as Random Forest models (Yang et al., 2021) and Decision Tree Regressors (Angel et al., 2024) have contributed to understanding walkability for older adults and built environment characteristics, respectively. While these international studies showcase the potential of AI in pedestrian infrastructure planning, our review of Indian literature reveals a notable research gap. Although AI applications have been documented in Indian traffic and road safety studies, no comparable studies were identified that specifically apply AI methodologies to pedestrian infrastructure planning in the Indian context. To process big data Python, a programming language for machine learning, was used to identify sidewalk defect detection using Google street view images and in-person data through smartphone cameras (Yussif *et al.*, 2024). This data primarily comes from three sources: location-aware devices carried by individuals, businesses transitioning some activities to digital platforms, and governments increasingly releasing data in open formats" (Arribas-Bel, 2014).

Machine learning (ML) algorithms are increasingly used to model pedestrian movement and modal choice (e.g., walking, cycling, or public transport) by analyzing data ranging from simple movement patterns to complex travel behavior sequences. These data-driven machine learning models generate critical insights to inform urban planning decisions, infrastructure investments, and transportation policies (Jordan, 2015). Specifically, ML applications enable the prediction of pedestrian traffic patterns, the identification of high-use pedestrian corridors, and the evaluation of how street design modifications affect mode choice behavior. However, the reliability and generalizability of these models face significant methodological challenges. First, data fidelity issues arise from inherent limitations in GPS positioning accuracy (e.g., signal multipath errors in urban canyons) and spatial-temporal gaps in pedestrian detection systems. Second, data scarcity constraints emerge due to restricted access to proprietary mobility datasets (e.g., commercial ride-hailing APIs or location-based service data), creating barriers to comprehensive model training and validation. The collection and utilization of pedestrian mobility data present critical privacy challenges, as individual trajectory tracking raises substantial concerns regarding personal data protection under frameworks like GDPR (General Data Protection Regulation Act, European Union) and CCPA (California Consumer Privacy Act). This necessitates robust ethical review protocols and strict compliance with data anonymization standards. Furthermore, inherent sampling biases in training datasets—particularly the overrepresentation of privileged demographic groups or high-income urban areas—introduce systematic distortions in model outputs. Such biases risk perpetuating spatial inequities through flawed policy prescriptions that fail to address underserved populations". Furthermore, algorithmic biases emerge when training datasets exhibit demographic or geographic sampling imbalances, systematically distorting model outputs and generating inequitable policy recommendations that disproportionately disadvantage underrepresented populations. Compounding these challenges are: (1) technical capacity limitations in municipal planning departments to effectively interpret ML-derived insights; (2) data harmonization issues arising from incompatible collection methodologies across sources (e.g., IoT sensor networks versus traditional travel surveys); and (3) physical infrastructure limitations that constrain practical implementation (Arribas-Bel et al., 2015; Cinnamon & Gaffney, 2021; Jordan, 2015; Kim, 2025; Lian et al., 2024; Shao et al., 2023; Yang et al., 2024; Zhang et al., 2025). Addressing these challenges requires establishing an integrated policy-methodological framework to ensure machine learning applications yield equitable, empirically-validated outcomes for pedestrian infrastructure and multimodal transportation systems. This imperative aligns with recent global efforts to institutionalize ethical AI governance, as evidenced by the inaugural UK AI Safety Summit (2023), Seoul Summit (2024), and forthcoming Paris AI Action Summit. India's prospective hosting of the fourth Global AI Safety Summit (Agrawal, 2025) presents a strategic opportunity to: Democratize AI accessibility for Global South nations; Establish transnational governance protocols for algorithmic equity; and Develop context-sensitive implementation models for emerging economies. Such multilateral cooperation provides critical scaffolding for developing standardized evaluation metrics, bias mitigation methodologies, and infrastructure-sensitive deployment protocols in urban mobility analytics. Therefore, a unified policy-methodological framework is urgently needed to standardize data practices, mitigate biases, and align AI applications with equitable urban planning goals, ensuring pedestrian infrastructure advances both technological innovation and social inclusion.

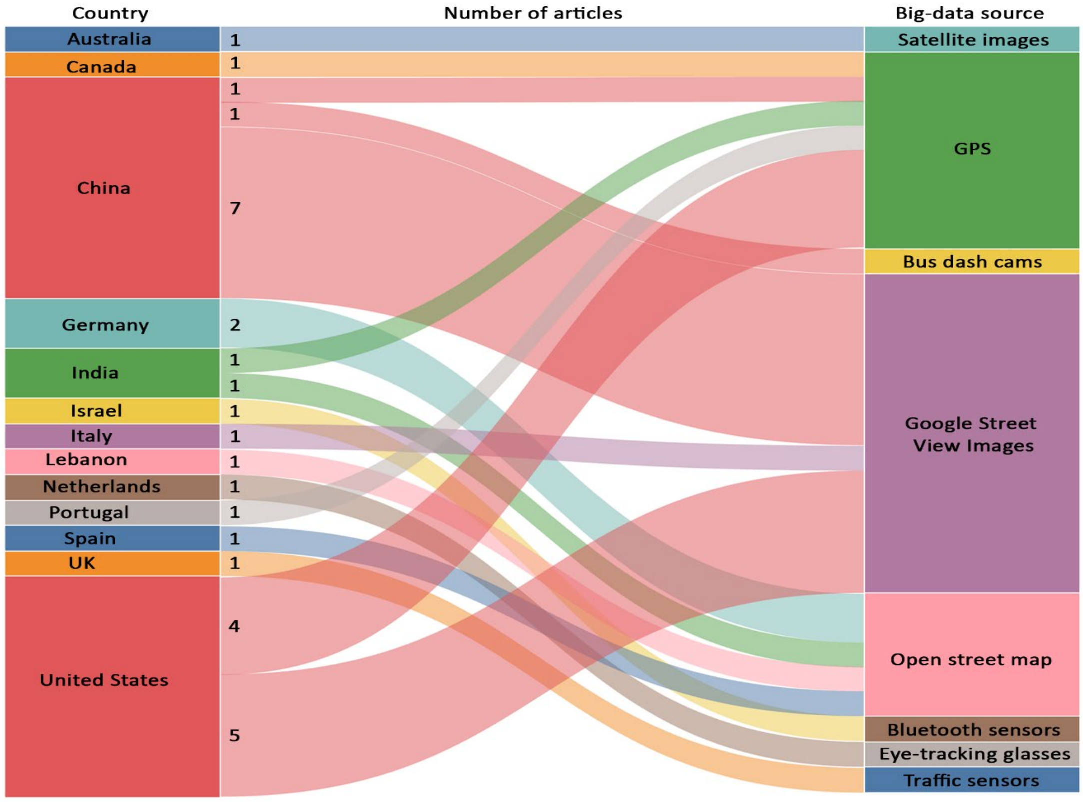

Figure 3. Spatial Concentration of Big Data Sources for Pedestrian Studies by Country

3.1 Leveraging Big Data and AI for Pedestrian -Centric Planning in India

Research leveraging big data and AI for pedestrian-oriented development in India remains limited, with most studies relying on conventional manual data collection methods—such as surveys, videographic analysis, and field observations (Khatoon *et al.*, 2013; Mohanty *et al.*, 2017; Bivina et al., 2019, 2020; Kadali & Vedagiri, 2016, 2020; Mukherjee & Mitra, 2020a; Roy et al., 2024;). These approaches, while valuable, are often labor-intensive, time-consuming, and resource-constrained, limiting scalability and real-time insights. A smaller subset of Indian studies has adopted emerging technologies, including OpenStreetMap (OSM) and GPS-based tracking (Isaacson et al., 2015; Yenisetty & Bahadure, 2020), to analyze pedestrian accessibility and movement patterns. However, advanced AI applications—such as computer vision for automated pedestrian detection or machine learning for predictive modeling—are conspicuously absent in the Indian context, despite their growing use in global pedestrian research. However, India has successfully integrated big data and AI technologies into urban infrastructure projects across several cities, including Nagpur, Bengaluru, and Pune, though primarily with a focus on road safety rather than pedestrian-oriented development. In Nagpur, the iRASTE project utilizes AI-powered cameras installed on 150 buses operating in urban and peri-urban areas to analyze real-time data and provide drivers with collision warnings at least 2.5 seconds before potential incidents, significantly enhancing pedestrian safety (360, 2024). Bengaluru's Adaptive Traffic Control System (BATCS) employs AI to dynamically adjust traffic signal timings based on real-time conditions, improving vehicular flow while holding potential for future adaptation to pedestrian needs (INDIA, 2024). Similarly, Pune's Intelligent Traffic Management System (ITMS) leverages AI for traffic violation detection and pattern analysis to bolster road safety (Presswire, 2025). While these initiatives demonstrate India's growing technological capabilities in urban mobility solutions, they reveal a notable gap in direct applications of big data and AI for pedestrian infrastructure planning. The current emphasis remains predominantly on vehicular safety and traffic management, underscoring the need for dedicated technological interventions targeting pedestrian-oriented urban development to create more walkable and inclusive cities. This technological disparity highlights an opportunity to expand smart city initiatives to incorporate pedestrian-centric AI solutions, aligning with global sustainable development goal practices-11.

Table I. Challenges and strategies of big data sources

Data source	Challenges	Strategies
Bus dash cam videos (Lian *et al.*, 2024)	Temporal misalignment of data sources as the data was collected at different times and conditions. Reliability on this data can be affected by speed of the bus and number of observations at particular space and time.	Data needs to be collected in more time periods for comprehensive validation. Strategic sampling approach is required to optimize the resource utilization while procession the data. Multi source approach like data from CCTV cameras, Google street view images, Unmanned aerial vehicles (UAVs) is advantageous.
Google street view images (Aschwanden *et al.*, 2019; Blečić *et al.*, 2018; Glaeser, 2015; Koo *et al.*, 2021; Liu *et al.*, 2017; Sevtsuk *et al.*, 2021; Shao *et al.*, 2023; Yin and Wang, 2016; Zhang *et al.*, 2025; Zhou *et al.*, 2019)	Data availability and accuracy is a challenge. Spatial distribution of the imagery is uneven. Low resolution of the images results in capturing spatial quality. The images captured from the perspective of vehicles overlooked the pedestrian perspective.	With the advancement in technology more open data environments could help in get more precise data. Combining on-site data and geo-big data helps in comprehensive understanding.
GPS (Lue and Miller, 2019; Sevtsuk *et al.*, 2021; Tribby *et al.*, 2016)	Variables like age, gender, trip purpose, user type are unobserved. Signal loss in dense environments may affect the results.	Distribution of auxiliary signal transmitters in the environment with weak signals or unavailability of signals can mitigate this problem.

The lack of master plans in 65% of India's urban settlements reflects systemic challenges in urban governance, including data fragmentation, outdated development regulations, and limited grassroots expert engagement (International, 2023). The efficacy of AI-driven urban solutions hinges critically on data quality, as inferior datasets compromise analytical accuracy (AI, 2024a), while their enduring utility underscores the imperative for systematic digitization (AI, 2024b). Although India has established digital infrastructure through initiatives like the National Urban Digital Mission (NUDM) and India Urban Data Exchange (IUDX) – hosting datasets on demographics, crime, waste management, and transportation – progress remains sluggish, with pedestrian-centric data notably absent. These platforms, designed as unified data repositories for stakeholders (urban local bodies, transportation agencies, and private entities), are undermined by inadequate data collection methodologies, resulting in interagency coordination failures and resource inefficiencies. Globally, even technologically advanced nations (e.g., U.S., Canada, Australia) face similar big data utilization challenges (Table 1), suggesting India could adopt proven strategies like dashcam networks, CCTV analytics, and UAV-based surveys. However, such implementations require robust regulatory frameworks to address ethical and privacy concerns, mirroring approaches in the U.S., EU, and China. This dual focus on technological adoption and governance reform is essential for transforming India's urban data ecosystem into a foundation for pedestrian-inclusive AI applications. To advance pedestrian-inclusive urban development in India, a strategic integration of hybrid methodologies—combining traditional surveys with AI-powered tools—should be adopted, alongside context-sensitive adaptations of global models tailored to India's urban morphology. Establishing ethical frameworks for pedestrian data collection and conducting longitudinal studies on AI implementation in pilot cities will ensure sustainable and equitable outcomes. This approach aligns with SDG 11 by transforming vehicle-centric planning into pedestrian-friendly smart cities, leveraging both global best practices and localized solutions to bridge existing gaps through innovation and governance reform.

4 Discussion

The application of big data and AI in India's infrastructure development remains limited, with traditional manual data collection methods still dominating due to insufficient data digitization. While some progress has been observed in cities like Nagpur, Bangalore, and Pune, the use of big data has been largely restricted to road safety initiatives. In the context of pedestrian infrastructure, only a few research studies have leveraged open-source tools such as OpenStreetMap and GPS for data collection. However, there is little evidence of real-time big data and AI applications, primarily due to challenges related to data availability and cultural resistance to adopting new technologies. These limitations are not unique to India; even technologically advanced nations such as the U.S., Canada, Italy, Australia, and China face difficulties in effectively utilizing big data, as illustrated in Table I. To overcome these barriers, studies have proposed strategies such as deploying dash cams, CCTV cameras, and unmanned aerial vehicles (UAVs) for data collection. However, a key challenge persists—the lack of a pedestrian-centric perspective in the collected data, which restricts comprehensive infrastructure planning. Addressing these gaps will require not only technological advancements but also policy interventions and public awareness to foster greater acceptance of data-driven approaches in urban development.

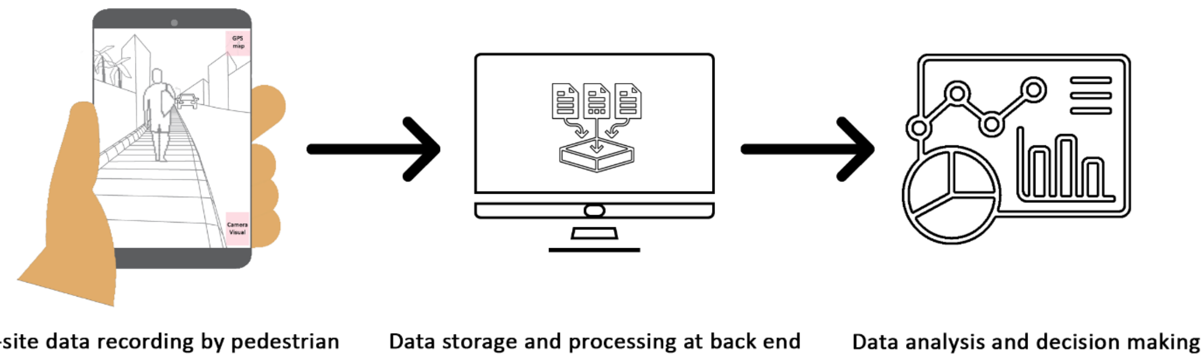

Figure 4. Conceptual framework of data digitization method

To overcome the existing challenges in pedestrian infrastructure planning, innovative methods for data digitization must be developed, with pedestrians themselves serving as key data sources. A potential solution involves integrating GPS and camera-based systems, wherein pedestrians can voluntarily record their walking routes via GPS while simultaneously capturing street-level visuals through video. This approach, illustrated in Figure 3, would provide real-time, ground-level insights into pedestrian infrastructure conditions, enabling evidence-based prioritization of development efforts. However, the success of such a system depends on public participation, necessitating awareness campaigns and incentives—such as free bus fares—to encourage engagement. While crowdsourced data collection could reduce government expenditure on manual surveys, ethical and privacy concerns must be addressed through robust regulatory frameworks, similar to those implemented in the U.S., Japan, France, the U.K., and China (Ayog, 2018). AI can play a crucial role in validating the collected data, filtering inconsistencies, and analyzing patterns to identify infrastructural gaps. By leveraging big data and AI in this manner, urban planners can make informed decisions that align with Sustainable Development Goal (SDG) 11—creating sustainable cities and communities—where pedestrian-friendly infrastructure is a critical indicator. Thus, adopting such participatory and technology-driven approaches could accelerate inclusive urban development while optimizing resource utilization.

The application of big data and AI in pedestrian-oriented urban planning represents a significant yet underutilized opportunity for India's sustainable development. While countries like the U.S. and China have made strides in leveraging computer vision, machine learning, and multi-source data integration for pedestrian infrastructure (Yang et al., 2024; Fernández-Arango et al., 2024), India's current initiatives—such as iRASTE and BATCS—remain largely confined to vehicular safety (360, 2024; INDIA, 2024). This discrepancy highlights a pressing need to reorient AI infrastructure toward pedestrian-centric solutions, especially given that 65% of Indian cities lack comprehensive master plans and suffer from fragmented urban data systems (International, 2023). The exclusion of standardized pedestrian datasets in platforms like the National Urban Digital Mission (NUDM) and Indian Urban Data Exchange (IUDX) further restricts the scalability of AI-driven interventions, despite the availability of underutilized technologies such as GPS tracking and OpenStreetMap (Isaacson et al., 2015; Yenisetty & Bahadure, 2020). Methodological barriers, as outlined in Table-I, present additional challenges to effective data utilization. Issues such as temporal inconsistencies in bus dashcam footage, uneven coverage of Google Street View imagery, and GPS signal disruptions in high-density areas (Lian et al., 2024; Sevtsuk et al., 2021) are exacerbated by systemic governance gaps, including outdated policies and weak interdepartmental coordination. Nevertheless, India's growing involvement in global AI governance, including its potential role in hosting the 2025 AI Safety Summit (Agrawal, 2025), offers a strategic avenue to address these limitations. Hybrid approaches that merge conventional survey methods with AI tools—such as adapting iRASTE's collision detection algorithms for pedestrian movement analysis or expanding BATCS to incorporate walkability-focused traffic signals—could help reconcile road safety and pedestrian-priority objectives. By tailoring global best practices to India's unique urban fabric, cities can overcome existing data constraints while fostering contextually appropriate, inclusive infrastructure development. This shift would not only align with India's commitments to Sustainable Development Goal (SDG) 11 but also demonstrate the transformative potential of AI in creating safer, more walkable cities. However, success hinges on addressing ethical, privacy, and governance challenges through robust regulatory frameworks and participatory data collection models, ensuring that technological advancements translate into equitable urban progress.

To realize pedestrian-inclusive smart cities aligned with SDG 11, India must adopt a multi-pronged approach that combines ethical governance, evidence-based implementation, and collaborative capacity-building. First, the nation should develop robust ethical frameworks for pedestrian data collection, drawing lessons from both EU's privacy-centric models and China's scalable implementation strategies, ensuring innovation doesn't compromise individual rights. Second, targeted longitudinal studies in select cities should assess AI implementation outcomes using integrated data streams from CCTVs, UAVs, and mobile sensors, creating an evidence base for nationwide scaling. Third, strategic public-private partnerships must be cultivated to develop local technical expertise and sustainable implementation models. Crucially, these efforts require unified policy-methodological frameworks that standardize data practices, address algorithmic biases, and guarantee equitable urban outcomes. Global precedents (Aschwanden et al., 2019; Zhang et al., 2025) demonstrate that integrating big data and AI in pedestrian planning represents more than technological advancement—it signifies a fundamental shift toward human-centric urbanism. For India, embracing this paradigm is not optional but imperative to resolve its escalating urban mobility crises while fulfilling its sustainable development commitments. The time for incremental approaches has passed; what's needed now is systemic transformation anchored in ethical innovation, empirical validation, and institutional collaboration.

5 Conclusion

The integration of big data and AI in pedestrian-oriented urban planning presents a transformative opportunity for India, yet significant gaps persist between technological potential and on-ground implementation. While global research demonstrates advanced applications of AI and multi-source data integration for pedestrian infrastructure, India's efforts remain largely confined to vehicular safety initiatives like iRASTE and BATCS, with limited focus on walkability and pedestrian-centric design. The absence of standardized pedestrian datasets in platforms such as NUDM and IUDX, coupled with systemic challenges in data digitization, governance fragmentation, and cultural resistance to technological adoption, hinders scalable AI solutions. Methodological barriers—including temporal misalignment in dashcam footage, uneven spatial distribution of Google Street View imagery, and GPS signal limitations—further complicate data reliability. However, India's participation in global AI governance forums and its prospective role in hosting the 2025 AI Safety Summit offer strategic opportunities to bridge these gaps. Hybrid approaches that combine traditional surveys with AI-driven tools, such as repurposing collision detection algorithms for pedestrian flow analysis or integrating multi-source data from CCTVs, UAVs, and crowdsourced GPS-camera systems, can provide real-time, contextually relevant insights. To realize pedestrian-inclusive smart cities aligned with SDG 11, India must prioritize three key imperatives: (1) establishing ethical frameworks for data collection that balance innovation with privacy protections; (2) piloting longitudinal AI implementation studies in select cities to validate scalable models; and (3) fostering public-private partnerships to build local technical capacity. These efforts must be underpinned by unified policy-methodological frameworks that standardize data practices, mitigate algorithmic biases, and ensure equitable urban outcomes. Global precedents underscore that leveraging big data and AI for pedestrian planning is not merely a technological upgrade but a paradigm shift toward human-centric cities. For India, systemic transformation—anchored in participatory data collection, regulatory clarity, and institutional collaboration—is essential to address urban mobility challenges and create inclusive, walkable communities. The path forward demands urgent action: embracing ethical innovation, validating solutions through empirical research, and aligning technological adoption with sustainable development goals to ensure equitable progress for all urban stakeholders. This study highlights the need for future research to expand beyond its current resource limitations by developing integrated data systems that consolidate pedestrian infrastructure information into a unified hub. Such a platform would streamline stakeholder collaboration, optimize resource efficiency, and enhance evidence-based decision-making for walkable urban development. The findings underscore the urgency for Indian researchers and policymakers to pioneer new AI-driven methodologies through multi-stakeholder partnerships, advancing pedestrian-oriented planning while addressing data gaps and ethical considerations. These efforts are critical for achieving SDG 11's vision of sustainable, inclusive cities, positioning India at the forefront of human-centric urban innovation through collaborative, technology-enabled solutions.

Conflicts of Interest

The authors declare no conflicts of interest related to the research, data collection, analysis, or publication of this work. All data collection methods, analytical processes, and writing decisions were made solely based on academic and scientific considerations, with no external parties involved in directing the research conclusions or publication choices.

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