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Review TTEA

A Critical Review on Measuring Accessibility of Multimodal Transport Systems in Indian Cities

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Abstract

Measuring accessibility is crucial for evaluating the performance of multimodal transport systems in Indian cities. This review paper examines the methodologies, indicators, and applications of accessibility measurement in the context of developing countries, focusing on Indian urban areas. The paper discusses the challenges posed by data limitations, informal transport modes, and socioeconomic disparities, and highlights the need for adapting accessibility measures to the Indian context. Case studies from major Indian cities are presented to illustrate the application of accessibility analysis in multimodal transport planning. The review emphasizes the importance of considering accessibility in decision-making processes and provides recommendations for improving accessibility through multimodal integration, equity considerations, and capacity building. The findings contribute to the growing body of knowledge on accessibility-based planning in developing countries and offer insights for enhancing sustainable urban mobility in Indian cities.

Keywords: Accessibility, multimodal transport, Indian cities, sustainable urban mobility, transport planning

INTRODUCTION

This section presents the introduction on accessibility urbanization and transportation challenges in Indian cities of multimodal transport system and lists the objectives and scope of this study.

Urbanization and Transportation Challenges in Indian Cities

Indian cities have experienced rapid urbanization in recent decades, with the urban population growing from 286 million in 2001 to 377 million in 2011 [1]. This rapid growth has led to numerous transportation challenges, including congestion, air pollution, and inadequate public transport infrastructure [2]. The increasing demand for mobility has put immense pressure on the existing transport systems, leading to a decline in accessibility and quality of life for urban residents [3].

The Role of Multimodal Transport Systems in Enhancing Accessibility

Multimodal transport systems, which integrate various modes such as walking, cycling, public transit, and private vehicles, have the potential to enhance accessibility and promote sustainable urban mobility [4]. By providing diverse travel options and facilitating seamless connectivity, multimodal transport systems can improve access to opportunities, reduce travel times, and enhance overall transportation efficiency [5]. In the context of Indian cities, multimodal integration is particularly crucial given the high dependence on public transport and the presence of diverse travel modes, including informal transport services [6].

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Objectives and Scope of the Review

Measuring accessibility is essential for understanding the performance of multimodal

transport systems and guiding transport planning decisions in Indian cities. However, existing accessibility measures often fail to capture the unique challenges and characteristics of urban mobility in developing countries [7]. This review paper aims to bridge this gap by synthesizing the literature on measuring accessibility of multimodal transport systems in Indian cities. The objectives of the review are threefold: (1) to examine the methodological approaches and indicators used for measuring accessibility in the Indian context; (2) to discuss the challenges and opportunities for improving accessibility in Indian cities; and (3) to provide policy implications and recommendations for accessibility-based planning. The review focuses on peer-reviewed articles, conference proceedings, and gray literature published between 2000 and 2021, covering case studies from major Indian cities.

REVIEW ON ACCESSIBILITY IN THE CONTEXT OF INDIAN CITIES

This section presents the definition of accessibility in developing countries like India and factors influencing, equity and social inclusion considerations on accessibility for India cities.

Defining Accessibility in Developing Country Contexts

Accessibility is a multifaceted concept that encompasses the ease with which individuals can reach desired destinations and opportunities, such as employment, education, healthcare, and social activities [8]. In the context of developing countries, accessibility is often influenced by various factors, including land use patterns, transport infrastructure, and socio-economic conditions [9]. The unique challenges faced by Indian cities, such as high population density, informal settlements, and diverse travel modes, necessitate a context-specific understanding of accessibility [10]. Researchers have emphasized the need to adapt accessibility measures to capture the realities of urban mobility in developing countries, considering factors such as affordability, safety, and reliability [11].

Factors Influencing Accessibility in Indian Cities

Several factors influence accessibility in Indian cities, including land use patterns, transport infrastructure, and socio-economic conditions. The rapid urbanization experienced by Indian cities has led to the development of sprawling and fragmented land use patterns, characterized by the separation of residential areas from employment centers and other essential services [12]. This spatial mismatch contributes to longer travel distances and increased reliance on motorized transport, which can negatively impact accessibility [13]. Additionally, the inadequate coverage and quality of transport infrastructure, particularly for non-motorized and public transport modes, pose significant barriers to accessibility in Indian cities [14]. Socioeconomic factors, such as income, gender, and age, also play a crucial role in shaping accessibility, with vulnerable groups often facing disproportionate challenges in accessing opportunities [15].

Equity and Social Inclusion Considerations

Equity and social inclusion are critical considerations in the context of accessibility in Indian cities. The uneven distribution of transport infrastructure and services often leads to disparities in accessibility, with low-income and marginalized communities experiencing lower levels of access to opportunities [16]. Women, in particular, face unique accessibility challenges due to safety concerns, social norms, and limited access to resources [17]. Addressing these equity issues requires a comprehensive approach that prioritizes the needs of vulnerable groups and ensures the provision of affordable, safe, and reliable transport options [18]. Inclusive planning processes that engage diverse stakeholders and consider the distributional impacts of transport interventions are essential for promoting equitable accessibility in Indian cities.

REVIEW ON METHODOLOGIES FOR MEASURING ACCESSIBILITY IN INDIAN CITIES

This section presents a review on methodologies for measuring accessibility, data availability and limitations, adaption of location-based measures, application of person-based measures, network-based measures for multimodal transport systems for accessibility of multimodal transport system in Indian cities.

Data Availability and Limitations

Measuring accessibility in Indian cities is often hindered by the availability and quality of data. Comprehensive and reliable data on land use patterns, transport networks, and travel behavior are essential for accurate accessibility assessments [19]. However, Indian cities often lack detailed and up-to-date spatial data, particularly for informal settlements and transport services [20]. Additionally, the absence of standardized data collection methods and the limited integration of data across different agencies pose challenges for accessibility analysis [21].

Adaptation of Location-Based Measures

Location-based measures, such as cumulative opportunities and gravity-based measures, have been widely used to assess accessibility in Indian cities. These measures consider the spatial distribution of opportunities and the impedance between locations, typically based on travel time or distance [22]. However, the application of location-based measures in the Indian context requires adaptations to account for the unique characteristics of urban mobility, such as the prevalence of non-motorized transport and the influence of socioeconomic factors on travel behavior [23].

Application of Person-Based Measures

Person-based measures, such as space-time accessibility and utility-based measures, have gained prominence in accessibility research in Indian cities [24]. These measures focus on individual-level accessibility, considering factors such as personal characteristics, time constraints, and activity patterns [25]. Person-based measures are particularly relevant in the Indian context, where socioeconomic disparities and gender-based differences significantly influence accessibility [26]. However, the application of person-based measures is often limited by the availability of detailed individual-level data, which can be costly and time-consuming to collect [27].

Network-Based Measures for Multimodal Transport Systems

Network-based measures, such as centrality and connectivity measures, are increasingly being used to assess accessibility in multimodal transport systems in Indian cities [28]. These measures capture the properties of transport networks and the ease of movement between different modes [29]. In the context of Indian cities, network-based measures are particularly useful for evaluating the integration of public transport systems, such as bus rapid transit (BRT) and metro rail, with other modes like walking and cycling [30]. However, the application of network-based measures requires detailed data on multimodal transport networks, which may not always be readily available in Indian cities [31].

REVIEW ON KEY INDICATORS FOR ACCESSIBILITY MEASUREMENT IN INDIAN CITIES

This section presents the key indicators for accessibility measurement, socioeconomic and demographic indicators, land use and built environment indicators, performance indicators and what is the effect on accessibility of multimodal transport system in Indian cities.

Socioeconomic and Demographic Indicators

Socioeconomic and demographic indicators play a crucial role in shaping accessibility in Indian cities. Factors such as income, education, employment status, age, and gender significantly influence an individual's ability to access opportunities. Low-income households and marginalized communities often face disproportionate accessibility challenges due to limited resources and social exclusion. Additionally, demographic characteristics, such as age and gender, can impact travel behavior and accessibility needs [32]. Incorporating socio-economic and demographic indicators in accessibility assessments is essential for understanding the distributional impacts of transport policies and interventions [33].

Land Use and Built Environment Indicators

Land use and built environment indicators are key determinants of accessibility in Indian cities. The spatial distribution of residential areas, employment centers, and other essential services significantly

influences travel patterns and accessibility levels. Factors such as land use density, diversity, and design can impact the ease of reaching destinations. In Indian cities, the rapid urbanization and unplanned growth have led to the development of sprawling and fragmented land use patterns, which can negatively affect accessibility. Measuring land use and built environment indicators, such as the density of opportunities, land use mix, and street connectivity, is crucial for understanding the relationship between urban form and accessibility [34].

Transportation System Performance Indicators

Transportation system performance indicators are essential for evaluating the efficiency and effectiveness of multimodal transport systems in Indian cities. These indicators capture various aspects of transport supply and service quality, such as travel time, reliability, comfort, and safety [35]. In the context of Indian cities, indicators related to public transport accessibility, such as network coverage, frequency, and affordability, are particularly important [36]. Additionally, measuring the performance of non-motorized transport infrastructure, such as the availability and quality of sidewalks and cycle lanes, is crucial for assessing accessibility for vulnerable road users [37].

Informal Transport Modes and Their Impact on Accessibility

Informal transport modes, such as shared auto-rickshaws, cycle-rickshaws, and private buses, play a significant role in providing accessibility in Indian cities, particularly in areas underserved by formal public transport [38]. These modes offer flexible and affordable travel options, especially for low-income and marginalized communities [39]. However, the informal nature of these services often leads to challenges in terms of safety, reliability, and integration with other transport modes [40]. Assessing the impact of informal transport modes on accessibility requires innovative data collection methods and indicators that capture their unique characteristics and contributions to urban mobility [41].

REVIEW ON CASE STUDIES OF ACCESSIBILITY MEASUREMENT IN INDIAN CITIES

This section presents the review on the case studies on accessibility measurement in various Indian cities.

Accessibility analysis in Mumbai, being one of the most populous cities in India, faces unique accessibility challenges. A study by Shirgaokar [42] analyzed the accessibility of jobs and educational opportunities in Mumbai using a gravity-based measure. The results highlighted the spatial disparities in accessibility, with central and western parts of the city having higher accessibility compared to the eastern suburbs [42]. Another study by Basu and Bhattacharyya [43] assessed the impact of the Mumbai Metro on accessibility, finding that the metro system improved access to employment centers and reduced travel times for commuters [43].

Evaluating the impact of metro systems on accessibility in Delhi, the capital city of India, has witnessed significant investments in metro rail systems to enhance accessibility. Goel and Tiwari [44] evaluated the accessibility impacts of the Delhi Metro using a combination of location-based and person-based measures. The study found that the metro system improved accessibility to jobs and education, particularly for low-income households [44]. Another study by Joshi and Sharma [45] used a gravity-based measure to assess the impact of the Delhi Metro on the accessibility of health facilities, highlighting the positive influence of the metro on healthcare access.

Assessing the accessibility of bus rapid transit systems in Ahmedabad, a city in the western state of Gujarat, has implemented a successful bus rapid transit (BRT) system. Adhvaryu et al. [46] assessed the accessibility benefits of the Ahmedabad BRT using a network-based measure, considering factors such as travel time, frequency, and connectivity. The study found that the BRT system significantly improved accessibility to jobs and education, especially for low-income populations residing along the BRT corridors [46]. Another study by Shah and Adhvaryu [47] used a person-based measure to evaluate the accessibility impacts of the BRT system on women, highlighting the importance of considering gender-specific travel patterns and needs [47].

Measuring accessibility for non-motorized transport in Pune, a city in the western state of Maharashtra, has been promoting non-motorized transport through infrastructure improvements and policy interventions. Puntambekar et al. [48] measured the accessibility of non-motorized transport in Pune using a network-based measure, considering factors such as the availability and quality of sidewalks, cycle lanes, and street lighting. The study identified areas with poor non-motorized transport accessibility and provided recommendations for infrastructure improvements [48]. Another study by Joshi et al. [49] used a person-based measure to assess the accessibility of non-motorized transport for different age groups in Pune, emphasizing the need for age-friendly non-motorized transport infrastructure and policies [49].

REVIEW ON CHALLENGES AND OPPORTUNITIES FOR IMPROVING ACCESSIBILITY IN INDIAN CITIES

This section presents the review on what are the challenges and opportunities for improving accessibility for various Indian cities.

Institutional and Governance Challenges

Improving accessibility in Indian cities faces significant institutional and governance challenges. The fragmented nature of urban transport governance, with multiple agencies involved in planning and implementation, often leads to a lack of coordination and integrated decision-making [50]. Additionally, the limited capacity and expertise of local authorities in accessibility planning and assessment hinder the effective implementation of accessibility-enhancing measures [51]. Addressing these challenges requires institutional reforms, capacity building, and the establishment of dedicated accessibility planning units within local governments.

Financing and Investment in Multimodal Transport

Infrastructure adequate financing and investment in multimodal transport infrastructure are crucial for improving accessibility in Indian cities. However, the current funding mechanisms for urban transport projects often prioritize large-scale infrastructure investments, such as flyovers and expressways, over more affordable and accessible modes like public transport and non-motorized transport [52]. Securing sustainable funding sources, such as value capture mechanisms and public-private partnerships, can help in financing accessibility-enhancing projects [53]. Additionally, prioritizing investments in multimodal integration, such as interchanges and last-mile connectivity, can significantly improve the overall accessibility of the transport system [54].

Integration of Land Use and Transport Planning

The integration of land use and transport planning is essential for creating accessible and sustainable urban environments. However, Indian cities often face challenges in coordinating land use and transport decisions, leading to a disconnect between the location of housing, jobs, and other essential services. Encouraging mixed-use development, transit-oriented development, and compact urban growth can help in reducing travel distances and improving accessibility [55]. Moreover, incorporating accessibility considerations into land use planning processes, such as master plans and zoning regulations, can ensure that the built environment supports sustainable and equitable access to opportunities [56].

Leveraging Technology and Innovation for Accessibility

Measurement technology and innovation offer significant opportunities for enhancing accessibility measurement in Indian cities. The increasing availability of digital data sources, such as mobile phone data, GPS (global positioning system) data, and smart card data, can provide valuable insights into travel patterns and accessibility levels [57]. Leveraging these data sources through advanced analytics and visualization tools can enable more accurate and real-time accessibility assessments [58]. Additionally, the development of user-friendly accessibility mapping tools and platforms can support evidence-based decision-making and public engagement in accessibility planning [59]. However, ensuring data privacy, security, and transparency is crucial when leveraging technology for accessibility measurement [60].

REVIEW ON POLICY IMPLICATIONS AND RECOMMENDATIONS

This section presents a review on policy implications and recommendation for the researchers and planners in the field in multimodal transport system.

Prioritizing Accessibility in Transport Planning and Decision-Making

To create inclusive and sustainable urban transport systems, it is essential to prioritize accessibility in transport planning and decision-making processes. This requires a paradigm shift from mobility-based planning, which focuses on increasing travel speeds and reducing congestion, to accessibility-based planning, which emphasizes the ease of reaching desired destinations [61]. Incorporating accessibility indicators and metrics into transport project appraisal and evaluation can help in assessing the distributional impacts of transport investments and prioritizing projects that enhance accessibility for all [62]. Moreover, setting accessibility-based performance targets and monitoring progress can ensure that transport policies and investments align with the goal of improving access to opportunities [63].

Promoting Multimodal Integration and Seamless Connectivity

Promoting multimodal integration and seamless connectivity is crucial for enhancing accessibility in Indian cities. This involves developing an integrated network of public transport services, including buses, metro systems, and paratransit, with efficient interchanges and last-mile connectivity [64]. Implementing integrated ticketing systems, such as smart cards and mobile ticketing, can facilitate seamless transfers between modes and reduce travel costs for users]. Additionally, improving the accessibility and safety of walking and cycling infrastructure can encourage the use of non-motorized transport modes and enhance first- and last-mile connectivity [65].

Addressing the Needs of Vulnerable and Marginalized Groups

Transport policies and interventions should prioritize the needs of vulnerable and marginalized groups, such as low-income households, women, children, the elderly, and persons with disabilities. Conducting accessibility assessments that consider the specific travel patterns and constraints faced by these groups can help in identifying accessibility gaps and designing targeted interventions [66]. Providing affordable and accessible transport options, such as concessionary fares and demand-responsive services, can improve the mobility and accessibility of vulnerable populations [67]. Moreover, promoting universal design principles in transport infrastructure and services can ensure that the transport system is inclusive and accessible for all users.

Capacity Building and Stakeholder Engagement

Capacity building and stakeholder engagement are essential for the effective implementation of accessibility-based planning and policies. Providing training and resources to transport planners, policymakers, and practitioners can enhance their understanding of accessibility concepts, measurement techniques, and best practices [68]. Encouraging collaboration and knowledge sharing among different stakeholders, including government agencies, academic institutions, civil society organizations, and the private sector, can foster innovation and promote the adoption of accessibility-based approaches [69]. Moreover, engaging the public and local communities in transport planning processes through participatory methods, such as workshops, surveys, and online platforms, can ensure that the transport system reflects the diverse needs and preferences of users [70–75].

CONCLUSION

The important conclusions drawn on based of this study are summaries as follows:

Summary of key findings: This review paper has explored the challenges and opportunities for measuring accessibility of multimodal transport systems in Indian cities. The key findings highlight the importance of adopting context-specific approaches to accessibility measurement, considering the unique characteristics of urban mobility in developing countries. The case studies from Mumbai, Delhi, Ahmedabad, and Pune demonstrate the application of various accessibility measures and their

potential to inform transport planning and decision-making. The paper also emphasizes the need for addressing institutional, financial, and technical barriers to implementing accessibility-based planning in Indian cities.

The Way Forward for Accessibility-Based Planning in Indian Cities

To promote accessibility-based planning in Indian cities, a paradigm shift is required from mobility-oriented to accessibility-oriented approaches. This involves prioritizing investments in multimodal transport infrastructure, integrating land use and transport planning, and addressing the needs of vulnerable and marginalized groups. Strengthening institutional capacity, securing sustainable funding sources, and leveraging technology and innovation are crucial for the effective implementation of accessibility-based planning. Moreover, engaging stakeholders and fostering collaboration among different sectors can help in building a shared vision for accessible and sustainable urban transport systems [82].

Future research directions and knowledge gaps while this review paper has provided insights into the current state of accessibility measurement in Indian cities, several research gaps and future directions have been identified. These include the need for developing standardized accessibility indicators and benchmarks, exploring the potential of big data and advanced analytics for accessibility assessment, and evaluating the long-term impacts of accessibility-enhancing interventions on social equity and environmental sustainability [83]. Additionally, future research should focus on understanding the behavioral aspects of travel decision-making and their influence on accessibility, as well as examining the distributional effects of transport policies on different population segments [84].

In summary, the review paper highlights the need for a paradigm shift from mobility-oriented to accessibility-oriented planning approaches in Indian cities. It emphasizes the importance of developing standardized accessibility indicators, exploring advanced data analytics, and evaluating the long-term impacts of accessibility-enhancing interventions on social equity and environmental sustainability. The paper also identifies future research directions and knowledge gaps, including the need for understanding behavioral aspects of travel decision-making and examining the distributional effects of transport policies on different population segments.

Overall, this review paper contributes to the growing body of knowledge on accessibility measurement in developing countries and provides valuable insights for researchers, planners, and policymakers working towards creating inclusive and sustainable urban transport systems in Indian cities.

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