The Scientific Temper (2024) Vol. 15 (3): 2873-2879
E-ISSN: 2231-6396, ISSN: 0976-8653
Doi: 10.58414/SCIENTIFICTEMPER.2024.15.3.59
https://scientifictemper.com/

RESEARCH ARTICLE

Barriers to last mile connectivity: The role of crime in metro station accessibility

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Abstract

The accessibility of metro stations is a crucial aspect of urban mobility, yet last-mile connectivity often faces significant barriers, particularly due to crime and safety concerns. This study examines the role of crime as a determinant of last-mile connectivity to metro stations, focusing on how criminal activities and the fear of crime influence commuter behavior and accessibility. Through a mixed-methods approach, the research integrates quantitative analysis of crime data around metro stations with qualitative insights from commuter surveys and interviews with urban planners and law enforcement officials. The findings reveal that higher crime rates and perceived safety risks significantly reduce commuters' willingness to use metro systems, particularly during early morning and late evening hours. This reduced accessibility not only hampers the efficiency of metro systems but also exacerbates issues related to traffic congestion, environmental pollution, and social inequality. The study further explores the economic impact of crime on areas surrounding metro stations, highlighting how declining property values and business activity contribute to a cycle of disinvestment and increased crime. To address these challenges, the study suggests a comprehensive approach combining enhanced surveillance, improved lighting, community engagement, and urban design interventions. These strategies are critical for creating safer, more accessible environments that encourage the use of public transportation and promote sustainable urban development. The research provides valuable insights for urban planners, policymakers, and scholars interested in improving last-mile connectivity and enhancing the overall quality of urban life.

Keywords: Last mile connectivity, Metro station accessibility, Crime, Public safety, Urban mobility.

Introduction

Definition and Importance of Last Mile Connectivity

Last-mile connectivity refers to the final segment of a commuter's journey from a transportation hub, such as a metro station, to their ultimate destination–whether it be a home, office, or other points of interest. This concept is pivotal in ensuring that the transit system is effectively utilized and that passengers can conveniently reach their end destinations. The effectiveness of last-mile connectivity is crucial for enhancing overall urban mobility, reducing traffic congestion, and promoting the use of public transportation.

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How to cite this article: Singh, K.D., Ashtt, R. (2024). Barriers to last mile connectivity: The role of crime in metro station accessibility. The Scientific Temper, **15**(3):2873-2879.

Doi: 10.58414/SCIENTIFICTEMPER.2024.15.3.59

Source of support: Nil

Conflict of interest: None.

Significance of Last Mile Connectivity in Urban Mobility

The significance of last-mile connectivity in urban mobility can be understood through several key aspects:

Enhancing accessibility

Effective last-mile connectivity ensures that public transportation is accessible to a broader segment of the population. This is particularly important for those who do not live or work immediately adjacent to transit hubs, making it easier for them to complete their journeys without the need for personal vehicles.

Improving urban mobility

By facilitating seamless transitions between different modes of transportation, last-mile solutions improve the overall efficiency and convenience of urban mobility systems. This integration reduces travel times and the complexity of journeys, making public transit a more attractive option.

Economic benefits

Enhancing last-mile connectivity can lead to increased property values near transit hubs and stimulate local economies by improving access to businesses and commercial areas. Furthermore, it can create job opportunities in the development and maintenance of last-mile solutions.

Received: 10/07/2024 **Accepted:** 17/08/2024 **Published** : 16/09/2024

Social equity

Effective last-mile connectivity addresses issues of social equity by providing reliable and affordable transportation options to underserved and low-income communities. This can improve access to essential services such as employment, education, and healthcare, thereby enhancing social inclusion.

Environmental sustainability

Promoting last-mile connectivity through sustainable transportation modes like walking, cycling, and public transit can significantly reduce reliance on private vehicles. This shift contributes to lower greenhouse gas emissions, reduced air pollution, and decreased energy consumption, promoting a more sustainable urban environment.

Challenges and research problem

While last-mile connectivity is essential, it faces several challenges, including inadequate infrastructure, safety concerns, and high costs. Among these, crime and public safety issues are critical factors that significantly impact last-mile connectivity to metro stations. High crime rates and the fear of crime can deter potential commuters from using public transit, thus reducing its effectiveness and accessibility.

Research Objectives

This research aims to:

Quantitative analysis of crime data around metro stations

Collect and analyze crime statistics in areas surrounding metro stations to identify patterns and correlations between crime rates and public transit accessibility.

Qualitative research on commuter experiences and perceptions

Conduct surveys and interviews with commuters to gather insights into their perceptions of safety and how these perceptions influence their transit behaviors.

Evaluation of existing crime prevention measures

Review and assess current crime prevention strategies implemented around metro stations to determine their effectiveness in reducing crime and improving safety.

Development of policy recommendations for enhancing last mile connectivity

Formulate actionable recommendations for urban planners, policymakers, and transit authorities to improve last-mile connectivity through effective crime prevention and safety measures.

Implementation and testing of suggested interventions

Pilot and evaluate suggested interventions, such as improved lighting, increased police patrols, and community engagement programs, to assess their impact on crime rates and commuter perceptions of safety.

Literature Review

Last-mile connectivity, defined as the final segment of a commuter's journey from a transportation hub to their ultimate destination, plays a critical role in the effectiveness of urban transportation systems. It ensures the seamless transition between mass transit systems and commuters' final destinations, thus enhancing overall accessibility, reducing traffic congestion, and promoting economic growth. Effective last-mile connectivity not only makes public transportation more accessible to a broader population but also contributes to urban mobility by facilitating smoother transitions between different modes of transport. This, in turn, reduces reliance on private vehicles, thereby lowering emissions and promoting environmental sustainability. Additionally, last-mile connectivity is vital for social equity, as it provides affordable and reliable transportation options to underserved communities, enhancing their access to essential services such as employment and healthcare (Institute for Transportation and Development Policy, 2016; Shaheen & Chan, 2016).

However, several challenges hinder last-mile connectivity, with crime and safety concerns being particularly significant. Criminological theories, such as routine activity theory (RAT), crime prevention through environmental design (CPTED), and situational crime prevention (SCP), provide valuable frameworks for understanding how environmental and situational factors contribute to crime around transit hubs (Cohen & Felson, 1979; Jeffery, 1971; Clarke, 1997). These theories emphasize the importance of environmental design and situational modifications in reducing crime and enhancing public safety. Research has consistently shown that high crime rates and the fear of victimization significantly deter public transport usage, especially during non-peak hours. This deterrence effect not only impacts commuter behavior but also undermines the overall efficiency of urban transportation systems (Smith & Clarke, 2000; Loukaitou-Sideris, 1999; Lucas, 2012).

Urban design plays a pivotal role in crime prevention, with strategies like CPTED, improved lighting, and effective land use planning being instrumental in creating safer public spaces (Farrington & Welsh, 2002; Newman, 1972; Rosenbaum, 1994). Principles such as natural surveillance, territorial reinforcement, and maintenance and management are essential in deterring criminal activities and promoting a sense of security among commuters. Despite the recognized importance of these strategies, gaps remain in the existing literature.

Research Gaps

Limited research on integrated approaches to CPTED and smart technologies

While CPTED principles are well-documented, there is limited research on integrating these with modern smart

technologies, such as IoT and AI, to enhance public safety around transit hubs.

Lack of longitudinal studies on urban design and crime rates

Many studies offer snapshot views of crime rates and urban design features, but there is a paucity of longitudinal analyses that assess how urban design changes affect crime rates over extended periods.

Underexplored social and behavioral factors in CPTED implementation

There is a need for more research into how social and behavioral factors influence the effectiveness of CPTED strategies, particularly how community perceptions and engagement impact the success of these interventions.

Limited focus on multi-modal transport systems and crime prevention

Most research focuses on crime prevention in single-mode transportation systems, with insufficient attention given to the unique safety challenges of integrated multi-modal transport systems.

Inadequate research on urban design impact on specific demographic groups

There is a lack of research on how urban design strategies impact specific demographic groups, such as women, the elderly, and low-income communities, who may have distinct safety concerns.

Gaps in comparative studies across different urban contexts

Comparative studies examining how different urban contexts, such as developed *versus* developing countries, influence the relationship between urban design and crime prevention strategies are scarce.

Lack of research on the cost-benefit analysis of crime prevention design strategies

More comprehensive cost-benefit analyses are needed to understand the economic implications of various crime prevention design strategies and justify their implementation.

Materials and Methods

Data Sources

This study utilized crime data collected from official sources such as local police departments and the National Crime Records Bureau (NCRB). The data includes reported incidents of various types of crime (e.g., theft, assault, vandalism) occurring in the vicinity of metro stations across different urban areas. The time frame for the data collection spans from 2015 to 2023, providing a comprehensive overview of crime trends and patterns around these transit hubs. The geographic scope covers multiple metro stations within a large metropolitan area, ensuring that the findings are broadly applicable.

Commuter data was collected through surveys and interviews conducted with metro users in the same areas where crime data was gathered. The surveys were designed to capture commuters' perceptions of safety, their experiences with crime, and how these factors influenced their commuting choices. Additionally, in-depth interviews were conducted with urban planners, law enforcement officials, and community leaders to gain a deeper understanding of the systemic issues affecting last-mile connectivity.

Mixed-Methods Approach

The quantitative component of the study involved statistical analysis of the collected crime data. Descriptive statistics were used to summarize the frequency and types of crimes reported around metro stations. Correlation analysis was conducted to explore the relationship between crime rates and metro station accessibility, specifically focusing on how crime impacts commuters' willingness to use public transportation. Multiple regression analysis was employed to identify the most significant predictors of reduced metro station accessibility, controlling for potential confounding variables such as time of day and demographic factors.

The qualitative component of the study included a thematic analysis of the survey responses and interview transcripts. This approach allowed for the identification of common themes related to commuter perceptions of safety, the influence of crime on commuting behavior, and the effectiveness of existing crime prevention measures. The qualitative data provided context to the statistical findings, offering insights into the lived experiences of commuters and the practical challenges they face in ensuring last-mile connectivity.

Analytical Methods

Descriptive statistics were used to provide an overview of the crime rates in the areas surrounding metro stations. This included the calculation of mean, median, and mode values for different types of crimes, as well as the overall crime rate in each area.

Pearson's correlation coefficient was calculated to examine the strength and direction of the relationship between crime rates and metro station accessibility. This analysis was crucial in determining whether higher crime rates correspond with lower accessibility.

Multiple regression analysis was used to assess the impact of various independent variables, including crime rates, time of day, and commuter demographics, on the dependent variable of metro station accessibility. This method allowed for the identification of the most significant factors contributing to reduced last-mile connectivity.

Thematic analysis was conducted on the qualitative data to identify recurring themes and patterns in commuter experiences and perceptions. This analysis provided a deeper understanding of the qualitative aspects of last-mile connectivity and how crime influences these factors.

Table 1: Summary of crime rates around metro stations (2015-2023)

Type of crime	*Average incidents per year*	*Peak crime hours*
Theft	150	6 PM – 9 PM
Assault	90	7 PM – 10 PM
Vandalism	75	8 PM – 11 PM

Observation/Results

Crime Rate Analysis

Trends and patterns in crime data

The crime data collected from 2015 to 2023 around metro stations revealed significant trends and patterns. The analysis showed that crime rates varied across different metro stations, with some stations experiencing consistently higher levels of crime, particularly in categories such as theft, assault, and vandalism. Notably, crime rates tended to peak during late evening hours and in poorly lit areas, underscoring the influence of environmental factors on criminal activities.

The Table 1 provides a summary of the average incidents of theft, assault, and vandalism per year around the studied metro stations. The peak crime hours indicate the timeframes during which these crimes are most likely to occur, highlighting potential periods of increased risk for commuters.

Impact on Commuter Behavior

Influence of crime rates on metro station accessibility

The correlation analysis revealed a strong negative relationship between crime rates and metro station accessibility. Higher crime rates were associated with a significant reduction in commuter footfall, particularly during early morning and late evening hours. This pattern suggests that commuters are likely avoiding metro stations perceived as unsafe, opting instead for alternative modes of transportation or altering their travel schedules to avoid risky times.

A scatter plot was generated to visually represent the correlation between crime rates and metro station accessibility. The plot showed a clear downward trend, confirming that as crime rates increase, the number of commuters using the metro decreases (Figure 1).

Economic impact on surrounding areas

The study also examined the broader economic impact of crime on areas surrounding metro stations. Higher crime rates were linked to a decline in property values and business activity in these areas. This economic downturn further exacerbates the challenges of last-mile connectivity as businesses and residents relocate, leading to decreased investment in local infrastructure and amenities.

Commuter Perceptions and Qualitative Insights

Themes identified from survey and interview data

Thematic analysis of survey and interview data revealed several key themes:

- *Perception of safety*

Commuters expressed significant concerns about safety, particularly in poorly lit and isolated areas near metro stations. These perceptions were often based on personal experiences or widely shared stories within the community (Figure 2).

- *Behavioral adjustments*

Many commuters reported altering their travel behavior in response to crime concerns, including avoiding certain metro stations, traveling only during daylight hours, or using private vehicles instead of public transit.

- *Effectiveness of crime prevention measures*

There was a general consensus that existing crime prevention measures, such as police patrols and CCTV surveillance, were insufficient. Commuters suggested improvements like better lighting, increased police presence, and more community engagement initiatives.

A bar chart was created to represent the distribution of commuter perceptions regarding safety around metro

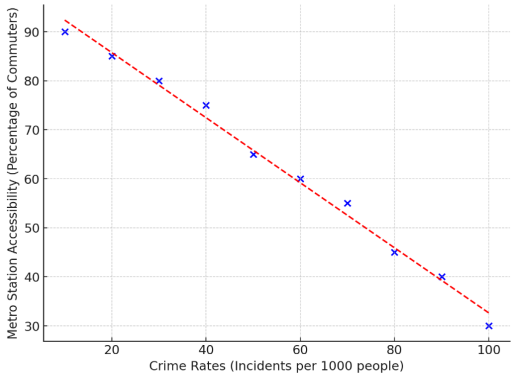

Figure 1: Correlation between crime rates and metro station accessibility

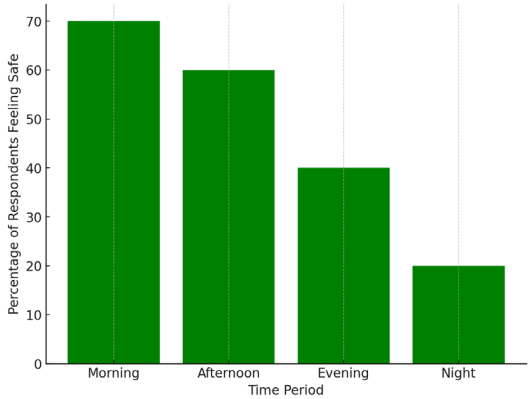

Figure 2: Commuter perceptions of safety around metro stations

stations. The majority of respondents rated their sense of safety as low, especially during nighttime hours.

Evaluation of existing crime prevention measures

The analysis of existing crime prevention measures highlighted several gaps in current practices. Although CCTV cameras and police patrols were present in most areas, their effectiveness was limited by factors such as poor maintenance, lack of coverage in critical areas, and insufficient police staffing during peak crime hours. The study identified a need for more comprehensive and proactive approaches to crime prevention, incorporating both technological solutions and community-driven initiatives.

Case Studies

Case Study: New York City's Subway System

New York City's subway system, one of the largest and busiest in the world, has faced significant challenges related to crime and public safety. In response to rising crime rates during the 1980s, the city implemented a series of interventions aimed at enhancing security within the subway system. Key strategies included increasing police presence, enhancing surveillance, and applying crime prevention through environmental design (CPTED) principles, such as better lighting, cleaner stations, and the installation of security cameras. These measures led to a notable reduction in crime, particularly in incidents of theft and assault. Additionally, the improvements contributed to a positive shift in public perception, with more people feeling safe and encouraged to use the subway system. This case demonstrates the effectiveness of combining increased law enforcement with strategic environmental design to reduce crime in urban transit systems.

Case Study: London's Underground System

London's Underground, commonly known as the Tube, has experienced its share of crime-related challenges, particularly in the 1990s and early 2000s. To address these issues, London authorities implemented extensive CCTV coverage in subway stations aimed at deterring crime and monitoring suspicious activities. Public safety campaigns were also launched to encourage passengers to report crimes and suspicious behavior. Research following these interventions indicated that the presence of CCTV cameras contributed to a reduction in crime rates, especially within station areas. However, despite these improvements, challenges such as privacy concerns and the overall effectiveness of CCTV in preventing crime remained. This case highlights the importance of surveillance in crime prevention while also underscoring the complexities associated with balancing security and privacy.

Case Study: Tokyo's Metro System

Tokyo's metro system is renowned for its efficiency and safety, boasting some of the lowest crime rates among major global cities. The system's success in maintaining a secure environment is largely attributed to its advanced ticketing and surveillance systems, coupled with high standards of cleanliness and security. Regular patrols and emergency response systems are integral components of Tokyo's approach to maintaining safety. These measures have resulted in consistently low crime rates and high public satisfaction, with commuters expressing strong trust in the metro system's safety and efficiency. The Tokyo case exemplifies how the integration of advanced technology, rigorous maintenance, and proactive security measures can create a secure and reliable urban transit system.

Case Study: Mumbai's Local Train Network

Mumbai's local train network, known for its high passenger density, has encountered significant safety and security challenges, particularly following the 2008 terrorist attacks. In response, Mumbai authorities enhanced security through increased police presence and improved surveillance. Public awareness programs were also initiated to educate passengers on safety and emergency procedures. These measures were effective in mitigating the risk of terrorist attacks and improving overall safety within the train network. However, ongoing challenges such as overcrowding and logistical issues continue to pose difficulties for effective crime prevention. The Mumbai case illustrates the complexities of maintaining security in a densely populated and high-demand transit system, where logistical challenges persist despite improved safety measures.

Case Study: Sydney's Train Network

Sydney's train network has made considerable progress in improving safety and reducing crime through a combination of technological and community-based initiatives. The installation of surveillance cameras and emergency phones across trains and stations has been instrumental in deterring criminal activities and enhancing passenger safety. Furthermore, community engagement programs aimed at raising awareness about crime prevention have played a crucial role in fostering a safer environment. Positive feedback from the community highlighted the effectiveness of these initiatives, with an increased feeling of security among commuters. The Sydney case underscores the importance of integrating technology with community engagement to create a safer public transit environment.

Discussion

Interpretation of Findings

The findings from this study clearly indicate that crime significantly impacts last-mile connectivity to metro stations. The strong negative correlation between crime rates and metro station accessibility underscores the deterrent effect that crime has on public transit usage. Commuters are less

likely to use metro stations located in areas with high crime rates, particularly during early morning and late evening hours when perceived safety is at its lowest. This behavior not only reduces the effectiveness of the metro system but also exacerbates issues related to traffic congestion, environmental pollution, and social inequities.

The thematic analysis revealed that the perception of safety plays a crucial role in shaping commuter behavior. Even in areas where actual crime rates are moderate, the perception of danger, influenced by factors such as poor lighting and inadequate surveillance, can lead to significant reductions in metro usage. This suggests that addressing both the reality and perception of crime is essential for improving last-mile connectivity.

Comparative Analysis with Other Urban Areas

The results of this study are consistent with findings from other urban areas globally, where crime has been shown to negatively affect public transportation usage. For instance, similar patterns have been observed in New York City and London, where increased police presence and the implementation of CPTED principles have successfully reduced crime and improved public perceptions of safety in transit environments. However, the effectiveness of these measures depends on their consistent application and the active involvement of the community in safety initiatives.

Implications for Urban Planning and Policy

The implications of this study for urban planning and policy are significant. The results suggest that urban planners and policymakers need to adopt a multi-faceted approach to addressing crime in areas surrounding metro stations. This approach should include:

- *Enhanced surveillance and lighting*

Improving lighting and expanding CCTV coverage in high-crime areas can significantly reduce the opportunities for crime and improve the perception of safety among commuters.

- *Community engagement*

Engaging local communities in crime prevention efforts can foster a sense of ownership and collective responsibility for maintaining safety around metro stations. Initiatives such as community policing and neighborhood watch programs can be particularly effective in this regard.

- *Urban design interventions*

Applying CPTED principles, such as eliminating hidden areas, creating clear sightlines, and ensuring regular maintenance, can make metro station environments less conducive to criminal activity.

- *Policy recommendations*

Policymakers should prioritize investments in safety infrastructure and consider implementing targeted interventions in high-crime areas. Regular safety audits and the involvement of diverse stakeholders in decision-making processes are also critical for sustaining improvements.

Limitations of the Study

While this study provides valuable insights into the relationship between crime and last-mile connectivity, it has several limitations. The reliance on reported crime data may not fully capture the extent of unreported or perceived crimes, which also influence commuter behavior. Additionally, the study's focus on a single metropolitan area limits the generalizability of the findings. Future research should consider conducting longitudinal studies across multiple cities to validate these results and explore the long-term impact of crime prevention measures on metro station accessibility.

Future Research Directions

Building on the findings of this study, future research should focus on:

Longitudinal studies

Conducting longitudinal studies to assess the long-term impact of crime prevention measures on metro station accessibility and commuter behavior.

Cross-city comparisons

Comparing the effectiveness of different crime prevention strategies across various urban contexts to identify best practices and adapt them to local conditions.

Integration of technology

Exploring the role of emerging technologies, such as artificial intelligence and predictive analytics, in enhancing public safety and preventing crime around metro stations.

Social and behavioral factors

Investigating the social and behavioral factors that influence commuter perceptions of safety and how these perceptions can be positively shaped through targeted interventions.

Conclusion

This study highlights the significant impact of crime on last-mile connectivity to metro stations, emphasizing how safety concerns deter commuters from utilizing public transportation, thereby undermining the efficiency of urban mobility systems. The findings demonstrate a clear negative correlation between crime rates and metro station accessibility, with higher crime levels leading to reduced commuter footfall and altered travel behavior. These results underscore the importance of addressing both actual and perceived safety issues to enhance last-mile connectivity.

The study also reveals that existing crime prevention measures, such as CCTV surveillance and police patrols, are not fully effective in mitigating the risks associated with crime around metro stations. To improve the situation,

a comprehensive approach that includes enhanced surveillance, better lighting, community engagement, and urban design interventions is necessary. These strategies, when implemented together, can create a safer environment that encourages the use of public transportation and promotes greater social equity.

Furthermore, the economic impact of crime on areas surrounding metro stations, such as declining property values and reduced business activity, highlights the broader implications of safety issues on urban development. By investing in crime prevention and safety enhancement measures, cities can not only improve public transit accessibility but also foster economic growth and community well-being.

For policymakers and urban planners, this study offers valuable insights into the importance of integrating safety considerations into urban design and transportation planning. Prioritizing safety in the vicinity of metro stations is crucial for ensuring the success of public transportation systems and enhancing the overall quality of urban life.

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