

INFLUENCE OF WALKING INFRASTRUCTURE ON PEDESTRIAN SAFETY PERCEPTION AND ROUTE CHOICE

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by

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Certificate

This is to certify the thesis entitled “**Influence of walking infrastructure on pedestrian safety perception and route choice**”, submitted by **Ms. Neba C Tony**, to the Indian Institute of Technology Delhi, for the award of the degree of **Doctor of Philosophy**, is a bonafide record of the research work carried out by her under our supervision and guidance.

To the best of my knowledge, the thesis has reached the requisite standard. The material contained in this thesis has not been submitted, in part or in full to any other University or Institute for the award of any degree or diploma.

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Abstract

The travel demand market is directly related to an individual's ability to pay. As a result, traditional transport planning models allocate resources and amenities to meet the needs of an 'average' trip maker, who typically belong to middle- or high-income populations that can afford these services. This approach overlooks the transportation needs of people who are differentiated by income, gender, employment status or physical ability. Due to the high cost of motorised transport and low incomes, even minor changes in fares or services can significantly affect the mobility of low income people. As a result, these individuals are termed captive pedestrians. They rely on walking for the entire route.

Apart from affordability, a major issue faced by captive pedestrians is safety. Despite walking accounting for the largest share of short trips in low- and middle-income countries, where captive pedestrians are mostly found, their needs remain largely ignored. They are more exposed to unsafe travel conditions than any other road user, making them particularly vulnerable to crashes. Transport safety literature has primarily relied on crash data to understand the nature and causes of crashes, often overlooking the fact that pedestrians have a keen sense of recognising potential safety risks (termed safety perceptions). Studying safety from their perspective can aid in proactive planning. Additionally, these studies overlook how walking infrastructure along the route influences pedestrian decisions, such as route choice risk perceptions and walking patterns. Understanding this interaction not only improves pedestrian safety but also encourages walking.

Despite the significant presence of captive pedestrians, urban planning has largely overlooked their need for safe, affordable, accessible, and well-connected walking infrastructure. This thesis aims to address this neglect by analysing how walking infrastructure characteristics

influence pedestrian safety perceptions and route choice decisions, with a special focus on captive pedestrians.

This research investigated the influence of safety and walking infrastructure on route choice behaviour, with the primary study conducted in New Delhi, India. A comparative study was conducted between New Delhi and London (United Kingdom) to examine pedestrian safety perceptions for different walking and crossing safety scenarios. An intercept survey was conducted which sought details on pedestrian route, measurement of safety perception, perceived route selection criteria, and socio-demographics. The sample size consisted of 409 pedestrians in Delhi and 348 pedestrians in London. 240 pedestrians in Delhi, who revealed their routes, were accurately mapped on ArcGIS. These routes were divided into series of nodes and links and 20 walking infrastructure variables were collected for each node separately. Virtual audits were conducted along each reported route and their alternatives using Google Street View. The data was then aggregated from link level to route level for further analysis.

Safety perceptions of pedestrians in Delhi and London were assessed using Rasch analysis. While pedestrians in both cities recognise certain crossing activities as unsafe, they still engage in risky behaviours due to factors like time urgency and infrastructure availability. Differences in perceptions between the two cities reflect variations in traffic conditions and urban environments, highlighting the need for context-specific pedestrian policies.

The study compared pedestrians' perceived and actual route safety using route perception and crash data, respectively. Findings revealed a notable gap between perception and reality, with pedestrians often misjudging safety risks. While walking infrastructure features, such as footpath buffers, and security measures, such as surveillance cameras, influenced both actual and perceived safety, traffic speed—a major crash factor—was not perceived as a significant

risk. This places the responsibility of making the routes genuinely safer on transport planners and road designers.

Perceived route criteria indicated that route length and safety were the most important factors. Two conditional logit models with a path size factor were used to identify route choice determinants of the shortest and safest routes. Route length emerged as the most significant factor. Although comfort and convenience ranked lower in perceived route selection, they significantly influenced route choices, highlighting their dual role in shaping both perceived safety and route appeal. The findings suggest that pedestrians do not exclusively look for the shortest, safest, or most comfortable path, but rather a combination of these factors.

Finally, the study uniquely explored the concept of pedestrian captivity by analysing trip characteristics, safety perceptions, and route preferences in the context of Delhi. Captive pedestrians—including children, women, and low-income workers—walked daily for work or education. Findings revealed that captive pedestrians walked longer distances than choice pedestrians and prioritised shorter, more direct routes to minimize time and energy. They exhibited distinct safety perceptions and route choices, favouring routes with street vendors and surveillance, highlighting their preference for passive security measures. These differences in travel behaviour underscore the need to integrate captive pedestrians into transport modelling frameworks to ensure equitable and inclusive urban mobility.

सार

यात्रा मांग का परिदृश्य सीधे तौर पर व्यक्ति की भुगतान करने की क्षमता से जुड़ा हुआ है। नतीजतन, पारंपरिक परिवहन नियोजन मॉडल एक 'औसत' यात्रा करने वाले की जरूरतों को पूरा करने के लिए संसाधनों और सुविधाओं का आवंटन करते हैं, जो आम तौर पर मध्यम या उच्च आय वाली आबादी से संबंधित होते हैं जो इन सेवाओं का खर्च उठा सकते हैं। यह दृष्टिकोण उन लोगों की परिवहन आवश्यकताओं को अनदेखा करता है जो आय, लिंग, रोजगार की स्थिति या शारीरिक क्षमता के आधार पर अलग-अलग होते हैं। मोटर चालित परिवहन की उच्च लागत और कम आय के कारण, किराए या सेवाओं में मामूली बदलाव भी कम आय वाले लोगों की गतिशीलता को काफी प्रभावित कर सकते हैं। नतीजतन, इन व्यक्तियों को बंदी पैदल यात्री कहा जाता है। वे पूरे मार्ग के लिए पैदल चलने पर निर्भर हैं। सामर्थ्य के अलावा, बाध्य पैदल यात्रियों के सामने एक प्रमुख मुद्दा सुरक्षा का है। निम्न और मध्यम आय वाले देशों में, जहां बाध्य पैदल यात्री ज्यादातर पाए जाते हैं, छोटी यात्राओं का सबसे बड़ा हिस्सा पैदल चलने के बावजूद, उनकी जरूरतों को बड़े पैमाने पर नजरअंदाज किया जाता है। वे किसी भी अन्य सड़क उपयोगकर्ता की तुलना में असुरक्षित यात्रा स्थितियों के संपर्क में अधिक आते हैं, जिससे वे विशेष रूप से दुर्घटनाओं के प्रति असुरक्षित हो जाते हैं। परिवहन सुरक्षा साहित्य मुख्य रूप से दुर्घटनाओं की प्रकृति और कारणों को समझने के लिए दुर्घटना के आंकड़ों पर निर्भर करता है, अक्सर इस तथ्य को नजरअंदाज कर दिया जाता है कि पैदल यात्रियों में संभावित सुरक्षा जोखिमों को पहचानने की गहरी समझ होती है। उनके दृष्टिकोण से सुरक्षा का अध्ययन सक्रिय योजना बनाने में सहायता कर सकता है। इसके अतिरिक्त, ये अध्ययन इस बात की अनदेखी करते हैं कि मार्ग के साथ चलने का बुनियादी ढांचा पैदल यात्रियों के निर्णयों को कैसे प्रभावित करता है, जैसे मार्ग चुनने के जोखिम की धारणा और चलने के प्रतिरूप।

बाध्य पैदल यात्रियों की महत्वपूर्ण उपस्थिति के बावजूद, शहरी नियोजन ने सुरक्षित, किफायती, सुलभ और अच्छी तरह से जुड़े पैदल चलने के बुनियादी ढांचे की उनकी ज़रूरत को काफी हद तक अनदेखा

कर दिया है। इस शोध का उद्देश्य पैदल चलने के बुनियादी ढांचे की विशेषताओं का विश्लेषण करके इस उपेक्षा को दूर करना है कि पैदल चलने वालों की सुरक्षा धारणाओं और मार्ग चयन निर्णयों पर किस तरह से असर पड़ता है, जिसमें बाध्य पैदल यात्रियों पर विशेष ध्यान दिया गया है।

इस शोध ने मार्ग चयन व्यवहार पर सुरक्षा और पैदल चलने के बुनियादी ढांचे के प्रभाव की जांच की, जिसका प्राथमिक अध्ययन नई दिल्ली, भारत में किया गया। विभिन्न पैदल चलने और पार करने के सुरक्षा परिदृश्यों के लिए पैदल यात्री सुरक्षा धारणाओं की जांच करने के लिए नई दिल्ली और लंदन (यूनाइटेड किंगडम) के बीच एक तुलनात्मक अध्ययन किया गया। एक इंटरसेप्ट सर्वेक्षण किया गया जिसमें पैदल यात्री मार्ग, सुरक्षा धारणा का मापन, कथित मार्ग चयन मानदंड और सामाजिक-जनसांख्यिकी के बारे में विवरण मांगा गया। दिल्ली में 409 पैदल यात्री और लंदन में 348 पैदल यात्री शामिल थे। दिल्ली में 240 पैदल यात्री, जिन्होंने अपने मार्ग बताए, को आर्कजीआईएस पर सटीक रूप से मैप किया गया था। इन मार्गों को नोड्स और लिंक की श्रृंखला में विभाजित किया गया था और प्रत्येक नोड के लिए अलग से 20 पैदल चलने के बुनियादी ढांचे चर एकत्र किए गए थे।

दिल्ली और लंदन में पैदल यात्रियों की सुरक्षा धारणाओं का मूल्यांकन रैश विश्लेषण का उपयोग करके किया गया। जबकि दोनों शहरों में पैदल यात्री कुछ क्रॉसिंग गतिविधियों को असुरक्षित मानते हैं, फिर भी वे समय की तात्कालिकता और बुनियादी ढांचे की उपलब्धता जैसे कारकों के कारण जोखिम भरे व्यवहार में संलग्न होते हैं। दोनों शहरों के बीच धारणाओं में अंतर यातायात की स्थिति और शहरी वातावरण में भिन्नता को दर्शाता है, जो संदर्भ-विशिष्ट पैदल यात्री नीतियों की आवश्यकता को उजागर करता है।

अध्ययन में पैदल यात्रियों की कथित और वास्तविक मार्ग सुरक्षा की तुलना क्रमशः मार्ग धारणा और दुर्घटना डेटा का उपयोग करके की गई। निष्कर्षों से धारणा और वास्तविकता के बीच उल्लेखनीय अंतर का पता चला, जिसमें पैदल यात्री अक्सर सुरक्षा जोखिमों का गलत आकलन करते हैं। जबकि पैदल चलने के बुनियादी ढांचे की विशेषताएं, जैसे कि फुटपाथ बफर, और सुरक्षा उपाय, जैसे कि निगरानी कैमरे,

वास्तविक और कथित सुरक्षा दोनों को प्रभावित करते हैं, यातायात की गति - एक प्रमुख दुर्घटना कारक - को एक महत्वपूर्ण जोखिम के रूप में नहीं माना जाता है। यह मार्गों को वास्तव में सुरक्षित बनाने की जिम्मेदारी परिवहन योजनाकारों और सड़क डिजाइनरों पर डालता है।

लोगों द्वारा अनुभव किए गए मार्ग के चयन ने संकेत दिया कि मार्ग की लंबाई और सुरक्षा सबसे महत्वपूर्ण कारक थे। सबसे छोटे और सबसे सुरक्षित मार्गों के मार्ग चयन निर्धारकों की पहचान करने के लिए पथ आकार कारक वाले दो सशर्त लॉजिट मॉडल का उपयोग किया गया था। मार्ग की लंबाई सबसे महत्वपूर्ण कारक के रूप में उभरी। हालाँकि आराम और सुविधा कथित मार्ग चयन में निचले स्थान पर थी, लेकिन उन्होंने मार्ग विकल्पों को महत्वपूर्ण रूप से प्रभावित किया, जिससे कथित सुरक्षा और मार्ग अपील दोनों को आकार देने में उनकी दोहरी भूमिका पर प्रकाश डाला गया। निष्कर्ष बताते हैं कि पैदल यात्री केवल सबसे छोटे, सबसे सुरक्षित या सबसे आरामदायक मार्ग की तलाश नहीं करते हैं, बल्कि इन कारकों के संयोजन की तलाश करते हैं।

अंत में, अध्ययन ने दिल्ली के संदर्भ में यात्रा की विशेषताओं, सुरक्षा धारणाओं और मार्ग वरीयताओं का विश्लेषण करके पैदल यात्रियों की कैद की अवधारणा का अनोखे ढंग से पता लगाया। बच्चों, महिलाओं और कम आय वाले श्रमिकों सहित बाध्य पैदल यात्री रोज़ाना काम या शिक्षा के लिए पैदल चलते थे। निष्कर्षों से पता चला कि बाध्य पैदल यात्री पसंदीदा पैदल यात्रियों की तुलना में लंबी दूरी तक पैदल चलते थे और समय और ऊर्जा को कम करने के लिए छोटे, अधिक सीधे मार्गों को प्राथमिकता देते थे। उन्होंने अलग-अलग सुरक्षा धारणाओं और मार्ग विकल्पों का प्रदर्शन किया, सड़क विक्रेताओं और निगरानी वाले मार्गों को प्राथमिकता दी, जिससे अक्रिय सुरक्षा उपायों के लिए उनकी प्राथमिकता पर प्रकाश डाला गया। यात्रा व्यवहार में ये अंतर समान और समावेशी शहरी गतिशीलता सुनिश्चित करने के लिए परिवहन मॉडलिंग ढांचे में बाध्य पैदल यात्रियों को एकीकृत करने की आवश्यकता को रेखांकित करते हैं।

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List of Abbreviations

API	Application Programming Interface
AQI	Air Quality Index
BE	Built Environment
CCTV	Closed Circuit Television
CTT	Classical Test Theory
CV	Coefficient of Variation
DIF	Differential Item Functioning
DOF	Degrees of Freedom
FIR	First Information Report
GIS	Geographical Information System
GPS	Global Positioning System
HHI	Herfindahl-Hirschman Index
IDE	Integrated Development Environment
IRC	Indian Roads Congress
IRT	Item Response Theory
JJ	Jhuggie Jhopries
LL	Log Likelihood
LR	Likelihood Ratio
MNSQ	Mean Square fit
N/A	Not Applicable
NB	Negative Binomial
NDMC	New Delhi Municipal Corporation
OLR	Ordered Logistic Regression
ONS	Office of National Statistics

OSM	Open Street Maps
PAZ	Pedestrian Analysis Zones
PCA	Principal Component Analysis
PCM	Partial Credit Model
QoL	Quality-of-Life
RSM	Rating Scale Model
SE	Standard Error
UT	Union Territory
VIF	Variance Inflation Factor
WHO	World Health Organisation