

**A STUDY ON THE EFFECTS OF BUILT ENVIRONMENT MEASURES
ON VEHICLE OWNERSHIP AND TRAVEL BEHAVIOR: THE
CONTEXT OF TWIN CITIES IN INDIA**

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April 2022

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CONTEXT OF TWIN CITIES IN INDIA**

by

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Submitted

in fulfilment of the requirements of the degree of Doctor of Philosophy
to the



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CERTIFICATE

This is to certify that the thesis entitled “**A study on the effects of built environment measures on vehicle ownership and travel behavior: the context of twin cities in India**”, is being submitted by **Mr. Chetan Nagesh Doddamani** to the Indian Institute of Technology Delhi, for the award of the degree of Doctor of Philosophy. This is a record of the research work and is entirely carried out by him under my supervision and guidance. The research report presented in this thesis has not been submitted for the award of any other degree or diploma.

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ABSTRACT

Personal vehicle ownership and use have grown worldwide. Governments and policymakers have been striving to mitigate ill-effects of personal vehicle use by transport policies. In many countries, built environment policies, aiming to restricting vehicle ownership and its use to encourage sustainable travel practices, have long been in place. Elements of the built environment, such as density, diversity, distance, accessibility, etc., are reported to affect vehicle ownership and travel demand. Built environment factors like population density, land use diversity, road network configuration, etc., are correlated with sustainable travel practices such as active mode use and reduced private vehicle miles traveled. However, studies have also revealed that built environment interventions (e.g., road network density and transit accessibility) could encourage personal vehicle ownership and undesirable travel practices. Besides, the built environment's association with mobility decisions varies by locations in a city, by different regions of a state, and by countries.

This thesis contributes to the emerging travel behavior literature pertaining to built environment impacts on household vehicle ownership and travel behavior. First, the thesis compares the effects of both subjective and objective built environment measures on household motorcycle and car ownership levels after controlling for travel attitudes. An important contribution of the study is the investigation of the impacts of subjective and objective built environment measures on motorcycle ownership levels after controlling for travel attitudes. By this way, the study also addresses self-selection issues related to built environment impacts on motorcycle ownership. Second, the thesis presents a quasi-longitudinal analysis of built environment impacts on vehicle ownership changes and travel behavior in an integrated framework. The analysis, thus, reveals the ‘causal’ effects of built environment features on vehicle ownership and travel behavior. In both cross-sectional and quasi-longitudinal analysis, the study also controls for social aspects of built environment such as neighborhoods’ support to women and children’s travel friendliness. Third, the study identifies the geographical scales of residential relocation and investigates how the spatial scales of relocation are linked to household motorcycle and car ownership levels and use after controlling for land use measures. Fourth, the thesis also contributes to the travel satisfaction literature by identifying the role of mode shift behavior in the linkages between land use changes and travel satisfaction changes. Finally, the study also compares built environment associations with vehicle ownership and travel behavior decisions in two adjacent urban areas of a developing economy India and

contributes to the travel behavior literature of emerging economies and variations in built environment effects across different urban areas.

Vehicle ownership and travel behavior information collected from a sample of residential movers in Hubli-Dharwad cities, two adjacent urban areas, in India are utilized for the research. Both cities' data were gathered through a primary survey. Subjective built environment information was also collected through the primary survey. Objective built environment details were derived from secondary sources. The study finds that objective built environment features strongly correlate with motorcycle ownership than car ownership levels in the cross-sectional analysis. Travel attitude variables remained significant in motorcycle ownership models for Dharwad city, suggesting motorcycle ownership due to travel attitudes and built environment features. The quasi-longitudinal analysis did not confirm self-selection effects due to travel attitudes. The latent factor related to women-travel friendliness was found to impact vehicle ownership decisions significantly. The thesis identified three geographic scales of residential mobility – within wards, between wards, and between cities. Families that moved within or between wards are observed to increase their two-wheeler fleet from holding two vehicles at their previous home location. The statistical model for vehicle ownership implied that families that moved between cities are less likely to procure personal vehicles and are more likely to abandon the existing fleet. Finally, the thesis finds that mode shifting behavior mediates the impacts of built environment changes on travel satisfaction changes. It was noted that the changes in neighborhood social factors have a significant role in travel satisfaction changes. The thesis also identifies the broad implications of the research findings for transport planning and policy.

Keywords: Twin city, Residential mobility, motorcycle and car ownership, Travel behavior, India

सार

निजी वाहन का स्वामित्व और उपयोग दुनिया भर में बढ़ा है। सरकार और नीति निर्माता, परिवहन नीतियों द्वारा निजी वाहन के उपयोग के दुष्प्रभावों को कम करने का प्रयास कर रहे हैं। कई देशों में, निर्मित पर्यावरण नीतियां, वाहन के स्वामित्व को प्रतिबंधित करने और स्थायी यात्रा अभ्यासों को प्रोत्साहित करने और उपयोग करने के लिए लंबे समय से लागू हैं। निर्मित पर्यावरण के तत्व, जैसे घनत्व, विविधता, दूरी, पहुंच, आदि, तत्व निजीवाहन के उपयोग और उनसे यात्रा करने को प्रेरित करते हैं। जनसंख्या घनत्व, भूमि उपयोग विविधता, सड़क नेटवर्क विन्यास आदि, जैसे निर्मित पर्यावरणीय कारक, संबंधित है स्थायी यात्रा अभ्यासों से, उदाहरण के लिए जयादा निजी वाहनों का प्रयोग करना और निजी वाहन दूक से कम दूरी की यात्रा करना। हालांकि, अध्ययनों से यह भी पता चला है कि निर्मित पर्यावरण हस्तक्षेप (जैसे, सड़क नेटवर्क घनत्व और पारगमन पहुंच) व्यक्तिगत वाहन स्वामित्व और अवांछनीय यात्रा प्रथाओं को प्रोत्साहित कर सकते हैं। इसके अलावा, पर्यावरण संघ द्वारा निर्मित गतिशीलता के नियम विभिन्न क्षेत्रों और देशों के अनुसार अलग-अलग होते हैं।

यह थीसिस घरेलू वाहन स्वामित्व और यात्रा व्यवहार पर निर्मित पर्यावरण प्रभावों से संबंधित उभरते यात्रा व्यवहार साहित्य में योगदान देता है। सबसे पहले, थीसिस यात्रा की आदतों को नियंत्रित करने के बाद घरेलू मोटरसाइकिल और कार के स्वामित्व के स्तर पर व्यक्तिपरक और उद्देश्यपूर्ण निर्मित पर्यावरण उपायों दोनों के प्रभावों की तुलना करती है। अध्ययन का एक महत्वपूर्ण योगदान यात्रा की आदतों को नियंत्रित करना और मोटरसाइकिल स्वामित्व के स्तर पर व्यक्तिपरक और उद्देश्य निर्मित पर्यावरण उपायों के प्रभावों की जांच करना है। इस तरह, अध्ययन मोटरसाइकिल के स्वामित्व पर निर्मित पर्यावरण प्रभावों से संबंधित स्व-चयन मुद्दों को भी संबोधित करता है। दूसरा, थीसिस एक एकीकृत ढांचे में वाहन स्वामित्व परिवर्तन और यात्रा व्यवहार पर निर्मित पर्यावरण प्रभावों का अर्ध-अनुदैर्घ्य विश्लेषण प्रस्तुत करता है। इस प्रकार, विश्लेषण से वाहन के स्वामित्व और यात्रा व्यवहार पर निर्मित पर्यावरण सुविधाओं के 'कारण' प्रभावों का पता चलता है। क्रॉस-सेक्शनल और अर्ध-अनुदैर्घ्य विश्लेषण दोनों, अध्ययन निर्मित वातावरण के सामाजिक पहलुओं जैसे कि महिलाओं और बच्चों के लिए अनुकूल यात्रा को भी नियंत्रित करता है।

तीसरा, अध्ययन आवासीय पुनर्वास के भौगोलिक पैमाने की पहचान करता है और जांच करता है कि पुनर्वास का स्थानिक स्तर घरेलू मोटरसाइकिल और कार स्वामित्व के स्तर से कैसे संबंधित है और कितनी जमीन किस काम के लिए उपयोग की जाएगी, उसपर भी निर्भर करता है। चौथा, थीसिस भूमि के उपयोग में परिवर्तन और यात्रा संतुष्टि परिवर्तनों के बीच संबंधों में छोटे वाहन से बड़े वाहन के स्वामित्व के

व्यवहार में स्थानांतरण की भूमिका की पहचान करके यात्रा संतुष्टि साहित्य में भी योगदान देता है। अंत में, यह अध्ययन भारत के विकासशील अर्थव्यवस्था के दो निकटवर्ती शहरी क्षेत्रों में वाहन स्वामित्व और यात्रा व्यवहार निर्णयों के साथ निर्मित पर्यावरण संघों की तुलना करता है और उभरती अर्थव्यवस्थाओं के यात्रा व्यवहार साहित्य और विभिन्न शहरी क्षेत्रों में निर्मित पर्यावरण प्रभावों में भिन्नता में योगदान देता है। भारत के दो निकटवर्ती शहरी क्षेत्रों हुबली-धारवाड़ शहरों में आवासीय मूवर्स के नमूने से एकत्र किए गए वाहन के स्वामित्व और यात्रा व्यवहार की जानकारी का उपयोग अनुसंधान के लिए किया गया है। दोनों जानकारी एक प्राथमिक सर्वेक्षण के माध्यम से एकत्र की गयी है। विषयगत निर्मित पर्यावरण की जानकारी भी प्राथमिक सर्वेक्षण के माध्यम से एकत्र की गई थी। उद्देश्य निर्मित पर्यावरण विवरण द्वितीयक स्रोतों से प्राप्त किए गए थे। अध्ययन में पाया गया है कि क्रॉस-सेक्शनल विश्लेषण में कार स्वामित्व के स्तर की तुलना में मोटरसाइकिल स्वामित्व के साथ वस्तुनिष्ठ निर्मित पर्यावरण विषेषताओं का दृढ़ता से संबंधित हैं। धारवाड़ शहर के लिए मोटरसाइकिल स्वामित्व मॉडल में मोटरसाइकिल के उपयोग की आदतों को प्रभावित करने वाली यात्राएं महत्वपूर्ण हैं, जो यात्रा की आदतों और निर्मित पर्यावरण सुविधाओं के कारण मोटरसाइकिल स्वामित्व का सुझाव देते हैं। अर्ध-अनुदैर्घ्य विश्लेषण ने यात्रा व्यवहार के कारण स्व-चयन प्रभावों की पुष्टि नहीं की। महिला यात्रा अनुकूल वातावरण से संबंधित कारक वाहन स्वामित्व निर्णयों को महत्वपूर्ण रूप से प्रभावित करते पाए गए हैं। थीसिस ने आवासीय गतिशीलता के तीन भौगोलिक पैमानों की पहचान की - वार्डों के भीतर, वार्डों के बीच और शहरों के बीच। जो परिवार वार्ड के भीतर या उनके बीच चले गए हैं, ऐसे परिवारों में यहाँ पाया गया है की वे दो वाहनों के अपने ग्रुप को और बढ़ाने के लिए उत्साहित पाए गए हैं। वाहन स्वामित्व के लिए सांख्यिकीय मॉडल का तात्पर्य है कि जो परिवार शहरों के बीच चले गए हैं, उनके निजी वाहन खरीदने की संभावना कम है और मौजूदा वाहनों की संख्या को घटने की अधिक संभावना है। अंत में, थीसिस में पाया गया है की दोपहिया वाहनों से चार पहिया वाहनों की और अग्रसर होने के व्यवहार में परिवर्तन, यात्रा संतुष्टि परिवर्तनों पर निर्मित, पर्यावरण परिवर्तनों के प्रभावों की मध्यस्थता करता है। यह नोट किया गया था कि यात्रा संतुष्टि परिवर्तनों में पड़ोस के सामाजिक कारकों में परिवर्तन की महत्वपूर्ण भूमिका होती है। थीसिस परिवहन योजना और नीति के लिए शोध निष्कर्षों के व्यापक प्रभावों की भी पहचान करती है।

कीवर्ड: जुड़वां शहर, आवासीय गतिशीलता, मोटरसाइकिल और कार स्वामित्व, यात्रा व्यवहार, भारत

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ABBREVIATIONS AND NOTATIONS

AMRUT	Atal Mission for Rejuvenation and Urban Transformation
AVE	Average Variance Extracted
ANOVA	Analysis of Variance
BRTS	Bus Rapid Transit System
CBD	Central Business District
CFA	Confirmatory Factor Analysis
CMP	Comprehensive Mobility Plan
DWLS	Diagonally Weighted Least Square
EFA	Exploratory Factor Analysis
GDP	Gross Domestic Product
GIS	Geographic Information System
GLM	Generalized Linear Model
HDBRTS	Hubli-Dharwad Bus Rapid Transit System
IID	Independently Identically Distributed
KUIDFC	Karnataka Urban Infrastructure Development and Finance Corporation
LISREL	Linear Structural Relations
ML	Maximum Likelihood
MNL	Multinomial Logit Models
MoRTH	Ministry Of Road Transport and Highways
MoUH	Ministry Of Housing and Urban Affairs
NMT	Non-Motorized Transport
NITI	National Institution for Transforming India
NWKRTC	North Western Karnataka Road Transport Corporation
OECD	Organization For Economic Co-Operation and Development
OICA	International Organization of Motor Vehicle Manufacturers
PDF	Probability Distribution Function
PM	Particulate Matter
RMSEA	Root Mean Square Error of Approximation
SEM	Structural Equations Modelling
TAZ	Traffic Analysis Zone
TOD	Transit Oriented Development
WLS	Weighted Least Square

INR	Indian Rupees
CI	Confidence Interval
df	Degree of Freedom
ϵ	Error
Km	Kilometer
LL	Log-Likelihood
Min	Minutes
N, n	Sample Size

P, q	Proportions
S, d	Standard Deviation
t	t-Statistic
X, x	Independent Variables
Z	Z-Statistic
β	Beta-Parameter Estimate
μ	Population Mean
χ	Chi-Square
Σ	Population Covariance Matrix
θ	Matrix of parameter