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Mapping Informal Mobility: A Comparative Study of GPS Tracking of Motorcycle Taxis to Better Understand Users' Behaviors Between University Campuses in Vietnam

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Abstract

Rapid urbanization in Southeast Asia has intensified pressures on urban transportation systems, with motorcycle taxis emerging as crucial informal transport services in cities especially. This study examines the spatial behavior of informal motorcycle taxi services in Ho Chi Minh City, Vietnam, focusing on the UEH University campus. Using 201 recorded GPS trips, space syntax analysis, and user surveys, the research explores how spatial configuration influences movement across trip types - short (≤2 km), medium (2–5 km), and long (≥5 km). Metrics such as Global Choice, Choice_R2, Choice_R3, Integration_HH, and Connectivity were computed. Findings show that short trips concentrate on highly connected local grids (e.g., campuses, hospitals), medium trips align with neighborhood connectors (e.g., schools, offices), and long trips follow arterial routes toward commercial centers or transport hubs. Nighttime and off-peak trips displayed higher average speeds than daytime trips, especially for longer distances. User behavior insights highlight convenience, flexibility, and traffic avoidance as key motivators. The study reveals a gap between planned urban structure and lived mobility, positioning informal transport as essential for first-last mile access. By combining spatial metrics and behavioral data, the research offers a framework for incorporating informal modes into urban mobility planning to improve accessibility and reduce congestion.

Keywords*:* Motorcycle Taxi; Mix-methods Approach; Spatial Analysis; GPS Tracking Tools; Space Syntax; Smart Cities.

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1. Introduction

1.1 Background and Context

Urbanization accelerates the decline of industrialization and air quality. Substantial emissions of greenhouse gases and toxic pollutants from industrial facilities and power generation plants deteriorate the environment and pose a significant risk of climate change. Urbanization, industrialization, and air pollution collectively need the implementation of sustainable development practices through the use of clean energy, efficient public transportation, and green infrastructure. In Southeast Asia, traffic congestion is one of the most observable and obvious outcomes of rapid urbanization. In Vietnam, particularly, several cities were heavily choked with motorbikes and cars at rush hours, hence regarded as gridlock stretching for miles. This gets worse because of the narrow streets, mixed-traffic conditions, and lack of synchronized traffic lights. According to a study cited by the Asian

Development Bank (ADB, 2021), billions of dollars are put on the cost of traffic congestion to the economy of Vietnam in lost productivity, wasted fuel, and increased air pollution.

The smart city concept and informal mobility such as motorbike taxis offers fresh potential for innovative solutions to the issue of urban mobility in Vietnam. Informal mobility, with their unplanned transport systems, is central to provide the service of cost-effective dynamic transport solutions to deliver the last-mile connectivity to fill the gap of the current formal transport systems like the Vietnamese bus transport systems and the Thai metro transport systems. Motorcycle taxis are a significant mode of urban transportation, enabling efficient and cost-effective movement of individuals across congested cities in both nations. Nonetheless, due to their lack of regulation, they frequently lead to inefficiencies, roadway dangers, and environmental deterioration. In order to yield optimal advantages of informal mobility systems are to engage in GPS tracking of motorcycle taxi operations to analyze user behaviours.

1.2 Problem Statement and Research Gap

Analysis of GPS data on these platforms elucidates customer demand patterns, optimizes routes, and minimizes waiting periods. The device enhances service quality while also alleviating congestion and pollution by eliminating unnecessary journeys. The augmented accessibility of GPS data is also beneficial for urban planners. Identifying regions of elevated demand and peak usage hours for motorbikes enables policymakers to implement targeted interventions, such as exclusive motorcycle lanes or improved traffic signal systems. Consequently, communities might more efficiently address mobility concerns while offering transit alternatives that are safer and more sustainable. In Vietnam, motorbikes are the backbone of urban transport with ease of movement at very minimal rates within highly dense urban areas. The informality of the company is likely to lead to ineptitude, danger, and destruction of the environment.

1.3 Objectives and Hypotheses

This study of "Informal Mobility Mapping" is to research the motorbike taxis' role in the urban transport systems of Vietnam with the specific aim of the potential of GPS tracking to supply information about user behaviours. It is to separate the activity of the motorbike taxis to segment the user patterns of demand that will supply insightful information to urban planning and policy making.

1.4 Significance and Structure of the Paper

The study is expected to generate insights into the behavioral patterns of motorcycle taxi users, highlighting inefficiencies and opportunities for improving urban mobility. Key anticipated outcomes include:

- Identification of peak-hour demand trends and high-traffic zones for informal motorcycle taxis.
- Evidence of operational inefficiencies, such as route redundancies or high waiting times.
- Finding potential short-distance destinations for better traffic management, enhance traffic management, safety, and environmental sustainability through data-driven decision-making.

2. Literature Review

2.1. Motorbike Taxi

Motorcycle taxis in Vietnam, commonly referred to as xe om, are a primary means of transportation in Vietnam. Xe om has been crucial in addressing the issues of urban mobility, particularly in major cities such as Ho Chi Minh and Hanoi, where movement is consistently hindered by congestion and the provision of public transport services is severely limited. The history of xe om illustrates Vietnam's socio-economic development, urbanization trends, and agility in addressing transportation challenges.

Xe om emerged in the late 1980s and early 1990s as a result of the Renovation (Đổi Mới) strategy, which transitioned Vietnam's centrally planned economy to a market-oriented framework. According to Vu and Mateo-Babiano, this age had significant growth and urbanization, resulting in substantial demand for rapid, short-distance travel in cities with limited public transit options (Vu & Mateo-Babiano, 2017). Public buses, the principal mode of formal transportation, experienced significant congestion and adhered to predetermined routes and schedules, hence creating a critical gap in last-mile connectivity (World Bank, 2018). In response, xe om emerged as a solution, providing economical and adaptable transportation. These motorcycle taxis operated informally in communities, near markets and schools, or at transit hubs for people seeking rapid and convenient transportation. Their capacity to navigate tiny streets and alleyways rendered them essential in urban areas where larger vehicles frequently encountered challenges (Nguyen-Phuoc et al., 2019).

The 2010s witnessed a significant transformation in Vietnam's motorcycle taxi sector due to the emergence of technology-driven ride-hailing platforms like Grab and GoJek, formerly known as GoViet. These services included online booking, uniform pricing, and enhanced safety measures, thereby attracting a larger customer base, including middle-class commuters and tourists (Vu & Mateo-Babiano, 2017). In contrast to conventional xe om, which depends on personal bargaining, ride-hailing services employ transparent pricing and cashless transactions, hence enhancing their adoption (Nguyen-Phuoc et al., 2019). Although these platforms have enhanced efficiency and accessibility, they have also posed issues for conventional xe om drivers who cannot compete with the operational benefits of ride-hailing companies. Primarily, they have no alternative but to register with ride-sharing networks; otherwise, their earnings diminish. The scenario has created tensions between modernized and conventional services, necessitating the development of balanced regulatory measures (Truong & Nguyen, 2020).

Despite the obstacles encountered, motorcycle taxis are an essential component of Vietnam's urban mobility environment. Xe om offers essential last-mile connection in metropolitan areas with inadequate public transit infrastructure (World Bank, 2018). Their agility in congested traffic and tight streets guarantees access to areas inaccessible by buses or cars (Nguyen-Phuoc et al., 2019). Motorcycle taxis serve as a crucial economic resource for riders, many of whom rely heavily on this method of transport for their income; their adaptability enables them to coexist with conventional transportation systems. It enhances the buses and upcoming metro within an urban transportation framework (Vu & Mateo-Babiano, 2017).

The continued evolution of xe om services emphasizes the necessity for thoughtful policies regarding urban transportation. Achieving equilibrium between the interests of conventional operators and contemporary ride-hailing platforms is crucial for fostering a level playing field, promoting fair competition, and ensuring sustainable development. The incorporation of motorcycle taxis into urban mobility schemes would significantly improve connectivity and alleviate road congestion in rapidly growing cities in Vietnam (World Bank, 2018). Safety concerns, environmental implications, and equitable regulations will continue to be the primary areas of intervention moving forward. Motorcycle taxis will continue to be a vital element of Vietnam's urban transportation system, contingent upon the implementation of appropriate legislation and technological advancements that facilitate their operation (Nguyen-Phuoc et al., 2019; Truong & Nguyen, 2020).

In light of the current research about motorcycle taxis, little exploration exists about their patterns and behaviors particularly given their uptake and density of motorbikes in Vietnam.

2.2. African Case Studies of GPS Tracking for Motorbike Taxis

In many parts of Africa, informal motorcycle taxis are one of the most affordable and practical ways to get around-especially in areas with bad infrastructure and where the community information systems are not well developed. The sheer number present throughout East Africa has earned them the name

boda-bodas, while West Africans know these as okadas. These have become essential transportation links between and within rural and urban areas. GPS tracking has become an integral part in understanding that strength through the study of operational costs, spatial patterns, and safety. One of the prominent applications of GPS tracking devices is the analysis of motorcycle taxi operation patterns. In Cameroon, for example, a study titled 'Assessment of Motorcycle Taxi Operations in Cameroon Using GPS Devices' used GPS data sets to track the movements of motorcycle taxis in Yaoundé (Kemajou et al., 2019). The results indicate that these taxis mainly serve short trips, with most routes being less than 2 km. GPS data also picked up a high proportion of home visits, with drivers spending more than 50% of their working time waiting for passengers. These insights have been shown to be economically efficient in balancing supply and demand and shed light on the important role of motorcycle taxis in providing last-mile connectivity in underserved areas (Kemajou et al., 2020).

Similarly, GPS tracking devices have mapped the travel patterns of motorcycle taxis among other researches in Kenya to demonstrate how they act as a lifeline in connecting rural communities with markets, health care facilities, and transport hubs. Other studies have concluded that vehicle's understanding often fills in gaps where conventional transportation does not exist, increasing access and economic opportunity among less fortunate populations (Harry K. Bett, 2012). In terms of improving overall road safety, GPS technology also plays a leading role in monitoring drivers' behavior. In Uganda, GPS data identified that risky driving practices-for example, at high speeds and with a large number of stops-were associated with crash risk. Identification of such behavioral practices enables people in training programs or management measures that improve safety standards (Wesolowski et al. 2018). GPS was integrated into a management system in Rwanda that allowed it to track licensed vehicle operators with appropriate assurances given by regulators that safety protocols would be observed, which helped minimize unauthorized operations (World Bank, 2018).

The spatial analysis enabled by GPS is, therefore, essential in urban planning and infrastructure development. For instance, in Cameroon, GPS data identifies high-traffic routes with a high level of detail to determine which roads need improvements or where more transport infrastructure has to be installed. These findings help incorporate the interests of autonomous motorcycle taxis into more general urban transformation processes—and the demands of both drivers and passengers (Kemajou et al., 2020). Moreover, there are many challenges in the tracking drives using GPS. For example, given the scarcity of resources and the need for broad, diffused application, a significant financial investment may be required for GPS devices and data management systems. Drivers may also raise privacy concerns linked to the gathering of personal data and the possibility of the data being misused. In addition, GPS signals may show interference in areas of heavy vegetation or rural settings, compromising data accuracy and making any firm conclusion problematic. Hence, the conditions reinforcing this barrier have to be recognized to ensure insurance planning and stakeholder engagement for maximum benefit from GPS technology (Kemajou et al., 2020; Kaplan & Hegarty, 2005).

GPS tracking devices have transformed the study of informal motorcycle taxis across Africa by offering highly detailed information on operating patterns, spatial coverage, and other safety issues for data-driven insights that could inform installation planning decisions. While much remains to be done, increased integration of GPS technology holds out the prospect for efficiency improvement, safety, and reliability within Africa's informal transportation information systems.

2.3. Smart City - Top Down & Bottom Up Approaches

According to rapid urbanization, smart cities have become one of the best solutions by combining technologies and urbanization (UN, 2020). The result of smart cities is bringing data-driven solutions by top-down approaches to apply technologies to their own citizens, focusing on the enhancement of

public services and citizen performance to increase the quality of life of the people (Human-centric Approach).

The top-down smart city strategy referenced by Breuer et al. (2014) signifies centrally administered large-scale technological solutions implemented by either governmental entities or private corporations. The model highlights the potential for enhanced urban management through the utilization of technology and data, exemplified by infrastructure monitoring, optimized resource management, and superior service delivery. This strategy has faced criticism for prioritizing efficiency and control, hence undermining community engagement and adaptability. (IBM, 2009)

In contrast to a top-down approach, the concept of a smart city from a bottom-up perspective emphasizes the significance of citizens: innovation arises from grassroots initiatives rather than being Imposed, by empowering engaged citizens through self-organization in urban development. Consequently, the outcome frequently manifests as community-driven solutions tailored to local requirements and ingenuity. (Breuer, Walravens, & Balloon, 2014)

According to UN-Habitat true smart cities are people-oriented: “Citizens are a city’s greatest resource as they provide new ideas for innovation, act as the eyes or ears of the city, help monitor conditions on the ground and engage the city more actively in setting priorities. Smart city technologically-based initiatives need to be people-centred and people-driven." (UN-Habitat, 2020)

An important element of this bottom-up strategy is citizen-oriented planning, in which individuals participate in decision-making through participatory platforms. At the same time, local innovations are taking root, with small-scale projects such as urban gardening, community waste management, and local energy systems sprouting from the ground of user feedback. For instance, Amsterdam's Smart Citizen Lab involves citizens in checking air quality, while Barcelona's Decidim platform allows residents to propose and vote on city projects (Cardullo & Kitchin, 2019).

The bottom-up approach helps everyone by showing different community needs and encouraging residents to take charge, which makes projects last longer. It is affordable because projects can start small and successful ones can grow to other places. But there are challenges like possible division, lack of resources, and problems in expanding local solutions to the whole city. The step-by-step way of this approach may also slow down big benefits (Vanolo, 2014).

Both techniques, when integrated, can provide a human-centered model. By integrating top-down infrastructure with grassroots input from inhabitants, a smart city may significantly enhance quality of life, stimulate local entrepreneurship, and advance technical solutions to meet human needs. In this research, combining Smart City Top-Down Approach with Understanding Bottom-Up Behaviors can help a lot in Traffic management in Urban Concept.

2.4. Space Syntax

Space syntax was the culmination of Bill Hillier and Julienne Hanson research that resulted in their work The Social Logic of Space (Hillier & Hanson, 1984). Space syntax was established to overcome the deficiencies of classical urban analysis methodologies that all too frequently had no respect to the way the built environment structures the behavior of individuals. Space syntax eschews the use of aesthetic or geometric considerations to instead consider the relationships between places within a graph theoretical analysis of the networks of the space.

The methodology of space syntax entails the analysis of urban patterns into axial lines (greatest lines of movement and vision), convex areas (direct areas of vision), and segment graphs (based on segments). Space syntax measures them with the aid of measures like connectivity, integration, and choice (betweenness centrality) (Hillier, 1996). It aims to measure the way various spaces are

connected to each other and the way their configuration influences movement patterns. It measures the highest value of integration to indicate that a space is central with a greater chance of attracting movement, while the least value of integration reflects segregation with less accessibility (Hillier, 1999).

One of the main achievements of space syntax is the prediction of movement patterns in urban areas. Research has continually established that highly integrated streets generate more pedestrian and vehicular movement (Hillier, 1999). An analysis of London's street network illustrated that streets with high values of integration had greater pedestrian densities, which made them ideal places for businesses and commercial activities (Penn et al., 1998). Likewise, studies have established that retail outlets in cities like Tokyo and Barcelona are associated with spatial integration, reaffirming the predictive ability of space syntax in urban economic growth (Karimi, 2018).

Space syntax is also important in transport planning through the determination of ideal street patterns for public transport and pedestrian networks. It has been utilized to enhance walkability in densely populated cities through examination of the spatial accessibility of streets (Marshall, 2012). In situations where streets are poorly integrated, urban designers have suggested changes in road networks, pedestrian routes, and public transport lines to enhance connectivity (Vaughan, 2018).

3. Materials and Methods

3.1 Study Design and Setting

As of mid-2024, Ho Chi Minh City (HCMC) has a population of approximately 9.5 million, making it the most populous city in Vietnam and a critical center for studying urban development and mobility patterns (VietnamNet, 2024). The city's student population is substantial, contributing notably to its youthful demographic structure. For instance, Vietnam National University – Ho Chi Minh City alone reported over 37,000 enrolled students in 2024 (EduRank, 2024), while Industrial University of Ho Chi Minh City welcomed more than 9,000 new students in the 2023–2024 academic year (IUH, 2023). With hundreds of thousands more attending other major public and private universities in the city, students form a significant proportion of HCMC's residents. Nationally, youth aged makeup 21.1% of Vietnam's total population, a figure that helps estimate HCMC's youth population at around 2 million people (UNFPA Vietnam, 2023). Therefore, the student population can be seen as a strong representative of the city's youth, especially in research related to urban mobility, such as motorcycle taxi usage, digital service adoption, and behavioral modelling. This makes university campuses like UEH ideal focal points for studying youth-driven transport trends and piloting smart city innovations. Selecting UEH B Campus for this research presents numerous benefits in monitoring the peak movements of students and staff commuting to and from different city locations to the campus and vice versa. It offers a dataset to analyze behavioral knowledge and trends concerning tripping frequency, travel time duration, and favorite travel routes. This is further amplified by the sociodemographic diversity of consumers across varying socioeconomic statuses, facilitating a more comprehensive study of motorcycle taxi utilization among distinct groups.

3.2 Participants or Subjects

For a study into user mobility behavior, with a population at least 5000 to 6000 people working and studying in UEH Campus B, both the sample collection and size have been planned to obtain minimum sample of 38 respondents – according to the sample size calculator by Raosoft, Inc. For a concentrated and workable data corpus, weekday behavior, Monday through Friday, is monitored, with a minimum of one average daily trip collected per participant over five days. Participants will log five trips over the five-day period (on average one trip per day), representing typical weekday movement during daytime hours, during the semester, as opposed to during recess. This yields a minimum of a 200 trips corpus (rounding up 38*5), enough to effectively detail urban mobility behavior. Data collection is focused on GPS tracking, with participants tracking routes using a tracking device or app on their

smartphone. Clear instructions and constant support will be assured for participants in order to record complete and correct data during the study period. Focusing on weekdays, the study exclusively identifies commuting and routine traveling behavior, an important consideration for urban workday-related mobility. By specifically targeting weekdays, a high level of detail can be gained through a closely examined analysis of daily routines, with a balanced and coherent dataset guaranteed. Methodology is underpinned with a high level of statistical robustness, with collected data guaranteed to cover a desired confidence level and accuracy margin. With 201 trips (after cleaning), a strong basis for a study of mobility behavior is delivered, providing useful information for use in urban planning and decision-making processes.

3.3 Materials and Equipment

The methodology comprises three principal phases aimed at examining user mobility patterns and their consequences for urban development. The initial phase emphasizes GPS tracking, during which participants' travel data is gathered and examined via Geo Tracking Software. To collect real-time movement data of informal motorcycle taxi trips, this study employed mobile GPS applications tailored to both iOS and Android platforms. For iOS users, the GPS Track application (Version 1.4.8, Developer: DMorneault, available on the App Store) was used. For Android users, the study utilized the GPS Logger application (Version 118, Developer: BasicAirData, available on Google Play). Both applications recorded geographic coordinates, time stamps, altitude, and velocity, with data exported in .GPX format for analysis.

Participants used their personal smartphones, with minimum requirements including GPS-enabled devices (Android 8.0 or iOS 13 and above) and a location accuracy within ±5 meters. No external GPS hardware was used. Then, for spatial network analysis, DepthmapX (Version 0.80b, University College London) was used to compute key space syntax metrics: Global Choice, Choice_R2, Choice_R3, Integration_HH, and Connectivity, based on a 1:10,000-scale street network extracted from OpenStreetMap (April 2025). Geospatial processing and trip visualization were conducted using QGIS (Version 3.34 “Prizren”), while using python programming language (Version 3.8) for data cleaning, trip classification, and speed calculations. Statistical correlation analysis was also performed using python. Finally, behavioral surveys were collected through Google Forms

3.4 Procedures and Protocols

This thesis is inspired by a method described in an article concerning a GPS-based application for tracking the movements of domestic cats. The study revealed activity patterns and environmental interactions by mapping their motions (Pearce,2016). This research utilizes GPS tracking to observe the routes and paths of urban mobility, particularly motorbike taxi users, examining behavioral patterns and interactions within the urban landscape. The methodology integrates GPS data, in-depth interviews (focus groups), and spatial analysis with Axial Maps to improve comprehension and decision-making in urban planning.

The methodology comprises three principal phases aimed at examining user mobility patterns and their consequences for urban development. The initial phase emphasizes GPS tracking, during which participants' travel data is gathered and examined via Geo Tracking Software. The data collection period lasts one week to record fluctuations in user behavior over weekdays, as well as during day and night. The chosen case study locations are regions within and surrounding university campuses—UEH University in Vietnam—to guarantee a varied spectrum of user interactions and mobility patterns.

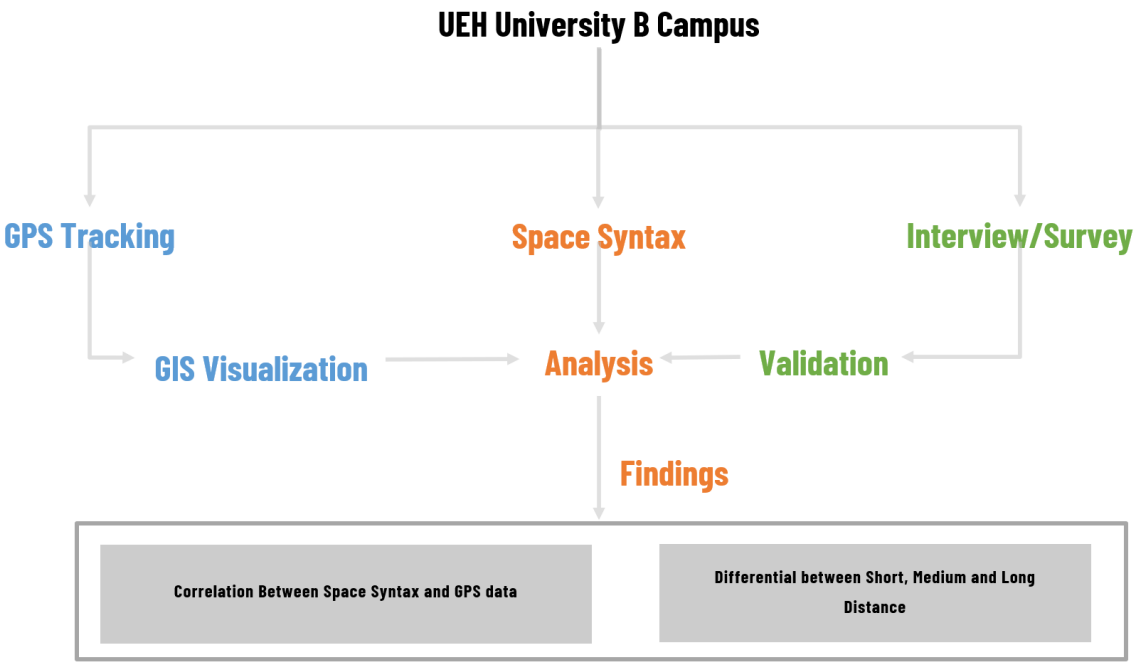

Figure 1. Data Collection.

The research incorporates user behavior analysis with the assessment of spatial hierarchy via Axial Maps. This research of connectivity, choice and spatial integration in metropolitan settings aims to reveal the typical and atypical or anomalous routes within the case study regions. The research integrates GPS mobility data with Axial Maps to elucidate the influence of urban structure on user behavior and decision-making regarding mobility. The study will use a dual-layered approach to discern individual routing decisions and correlate them with urban design elements, while also pinpointing sites where city hierarchy influences access and movement efficiency. Furthermore, the research also highlights how integrated top-down and bottom-up smart city approach can solve urban design challenges by making a broad view of motorcycle taxi users' behavior to make better decision making by using GPS Tracking and Space Syntax.

3.5 Data Analysis

Data collected from GPS tracking, space syntax analysis, and user surveys underwent a structured analytical approach. The GPS trajectory data recorded in GPX format were initially processed using Python scripting. This cleaning phase involved removing GPS signal errors, smoothing irregular trajectory points, and eliminating outliers to produce coherent and reliable paths suitable for spatial analysis. Subsequently, the cleaned datasets were imported into QGIS, where standardized geographic coordinate systems (EPSG:4326) were applied to ensure spatial consistency. Within QGIS, the length attributes for each recorded trip were calculated using geometric measurement tools and categorized into three defined distance classes: short (≤2 km), medium (2–5 km), and long (≥5 km).

For spatial network analysis, an axial line map representing the simplified street network around UEH Campus B was manually drawn in QGIS and exported as a DXF file. This map was imported into DepthmapX (version 0.80b) to compute space syntax metrics. The resulting spatial metrics were then re-imported into QGIS and linked to trip-level data to facilitate integrated spatial analyses. In this study, five key space syntax metrics were employed to assess the spatial structure of the urban street network and its influence on informal motorcycle taxi behavior. Connectivity measures the number of immediate connections a street segment has with others, reflecting local accessibility and navigational options within the immediate environment. Choice (Global Choice) quantifies how often a segment falls along the shortest paths between all other segments in the system. It identifies major through-

routes and corridors that are likely to carry high volumes of movement across the city. Choice_R2 and Choice_R3 represent local versions of Choice calculated at two and three steps (or angular radius), respectively. Choice_R2 captures micro-level movement within walkable areas such as campuses or retail grids, while Choice_R3 reflects mid-scale neighborhood movement and inter-district flow. Integration (HH) measures how easily a segment can be reached from all other segments in the system, indicating its overall spatial accessibility or centrality within the network.

To statistically assess relationships between spatial syntax variables, Python scripts utilizing SciPy libraries computed Spearman's rank correlation coefficients (ρ). Finally, all spatial layers—including GPS data and space syntax metrics—were overlaid and analyzed together in QGIS. This comprehensive analysis allowed the identification and categorization of primary thematic findings: spatial clusters associated with short-distance trips, integrated corridors preferred for medium-distance trips, arterial road alignments utilized in long-distance journeys.

4. Results

This study is focusing on understanding motorcycle taxi behaviors around UEH University in Ho Chi Minh City. The methodology integrates GPS tracking, space syntax analysis, and surveys/interviews to collect both quantitative and qualitative data. A total of 210 trips were recorded using GPS-enabled mobile applications, and after data cleaning, 201 trips were analyzed. Trips were classified by distance into short (<2 km), medium (2–5 km), and long (>5 km) trips. The data was further analyzed through spatial visualization tools to identify trip purposes, destinations, and routing behavior. Simultaneously, space syntax was applied to examine the integration and connectivity surrounding the university, revealing discrepancies between theoretical access and practical use. A survey of 38 participants complemented the GPS data, uncovering behavioral preferences, usage frequency, and motivations. Together, these methods offered a comprehensive view of informal mobility and its implications on urban transportation systems.

4.1 Distance Findings

4.1.1 Short Distance

Of the 201 trips analyzed, 39 trips (19.4%) were classified as short trips (<2 km). These trips were typically intra-district journeys, focused around high-density activity zones near the university. Popular locations included Vo Van Kiet Street, home to local markets and accommodations, and To Hien Thanh Street, known for its coffee shops, food outlets, and entertainment venues.

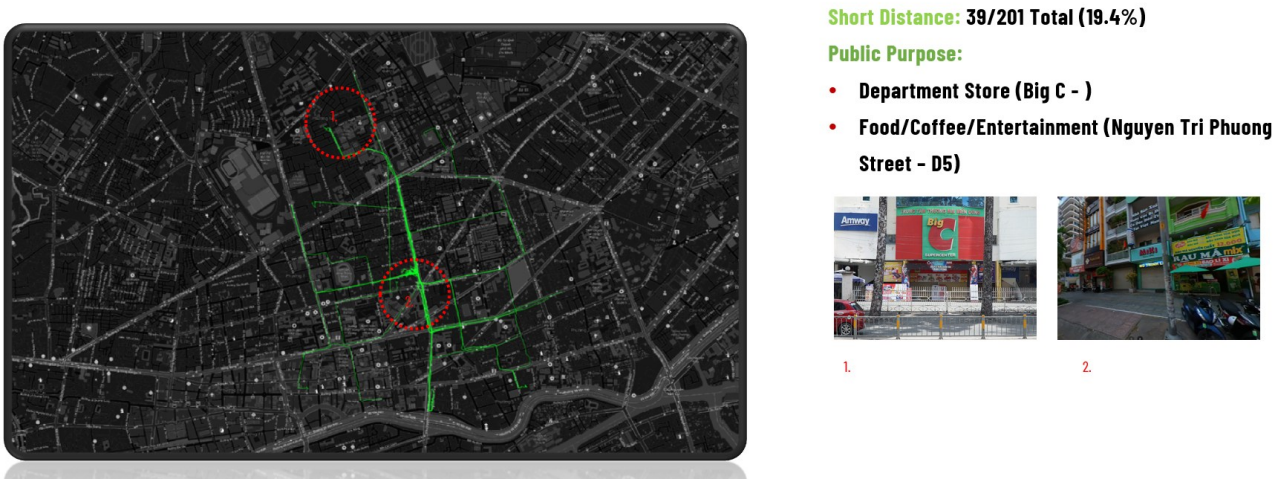

Figure 2: GPS Tracking for Short Distance Trips

These destinations suggest short trips are often chosen by daily routines and conveniences, such as grabbing food, meeting friends, or running errands. However, outliers were also noted. A few furthest trips reached the Chieu anh Cat Street (District 1) for Accommodations, Traditional Market and Tran

Hung Dao Street (District 1) for Foods and Coffee Shophouse. The distance, though short, required navigating across complex traffic conditions, highlighting the inefficiency of public transport even over short distances. Other outlier trips headed toward lesser-used alleys, possibly for short-term accommodation or service access, showing the nuanced needs of students and residents. The preference for motorcycle taxis for short trips may reflect a desire to avoid walking in hot weather, heavy traffic, or unsafe pedestrian conditions. However, the low proportion of short trips (only 19.4%) suggests that users may reserve motorcycle taxis for more substantial travel unless time-pressed or burdened with goods. This underlines the need for pedestrian-friendly infrastructure and short-distance micro-mobility options.

4.1.2 Medium Distance

Figure 3: GPS Tracking for Medium Distance Trips

67 trips (33.3%) were classified as medium-distance trips (2–5 km). These trips primarily served connections between residential areas, entertainment zones, and university campuses. One cluster was identified around Dan Chu Roundabout and To Hien Thanh Street , a location surrounded by F&B outlets, shops, and mid-range service centers. Another significant cluster connected V Campus to N Campus, showing that inter-campus connectivity was a recurring mobility concern.

Frequent destinations also included To Hien Thanh Street, known for its vibrant food scene, suggesting that mid-range trips are driven by lifestyle activities like dining and socializing. Interestingly, other estate apartment near District 8 appeared as outlier destinations. Despite being farther away, they were categorized as medium-distance due to route efficiency and highway usage. The medium-range trips represent a sweet spot for motorcycle taxis: distances that are too far to walk and not well-served by public transport. Survey responses showed users favored motorcycle taxis here due to speed, cost-effectiveness, and door-to-door convenience. This suggests a pressing need for flexible transit options and smarter routing systems in this range, especially for students and workers navigating urban sub-centers.

4.1.3 Long Distance

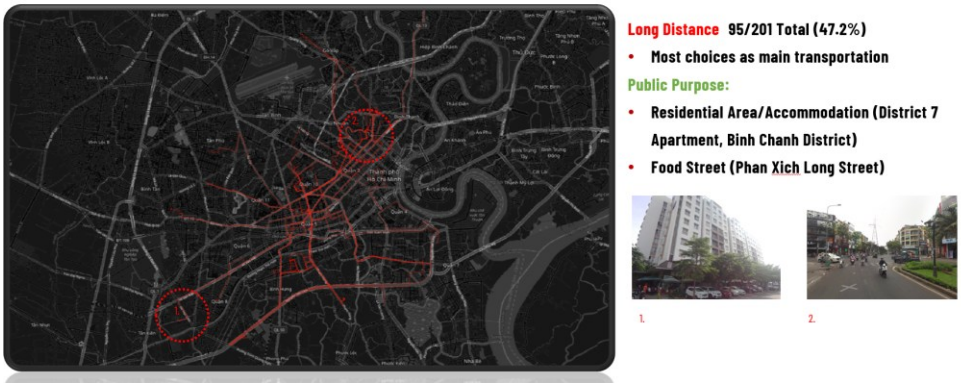

Figure 4: GPS Tracking for Long Distance Trips

The most frequent trip category was long trips (>5 km), totaling 95 trips (47.2%). These journeys highlight a critical dependency on motorcycle taxis for daily commuting, residential relocation, and cross-district movement. Key destinations included Phan Xich Long Street (a major food and entertainment district), No Trang Long Street (residential clusters), and District 7's apartment areas, especially near Eco Green and the Binh Chanh border. These reflect a common pattern: residents living farther from the university or commercial centers but relying on fast and flexible transport to remain connected.

Outlier trips extended to Thu Duc District, often for educational purposes. This included compulsory training programs held at campuses far from the user's residence. Another set of long trips connected B Campus to N Campus, reinforcing that even university-sponsored travel spans long distances, with little public transport support. Long trips being the largest proportion indicates that public transport does not sufficiently cover outer districts, and users turn to motorcycle taxis as a default. This reveals a mobility gap in HCMC's urban planning, where formal systems lack reach. These trips also cost more and expose users to greater risk and pollution. Efforts should be made to develop multi-modal transport systems, enhance last-mile connections, and offer subsidized options for students and low-income groups to reduce reliance on informal long-distance travel.

4.2 Survey Findings

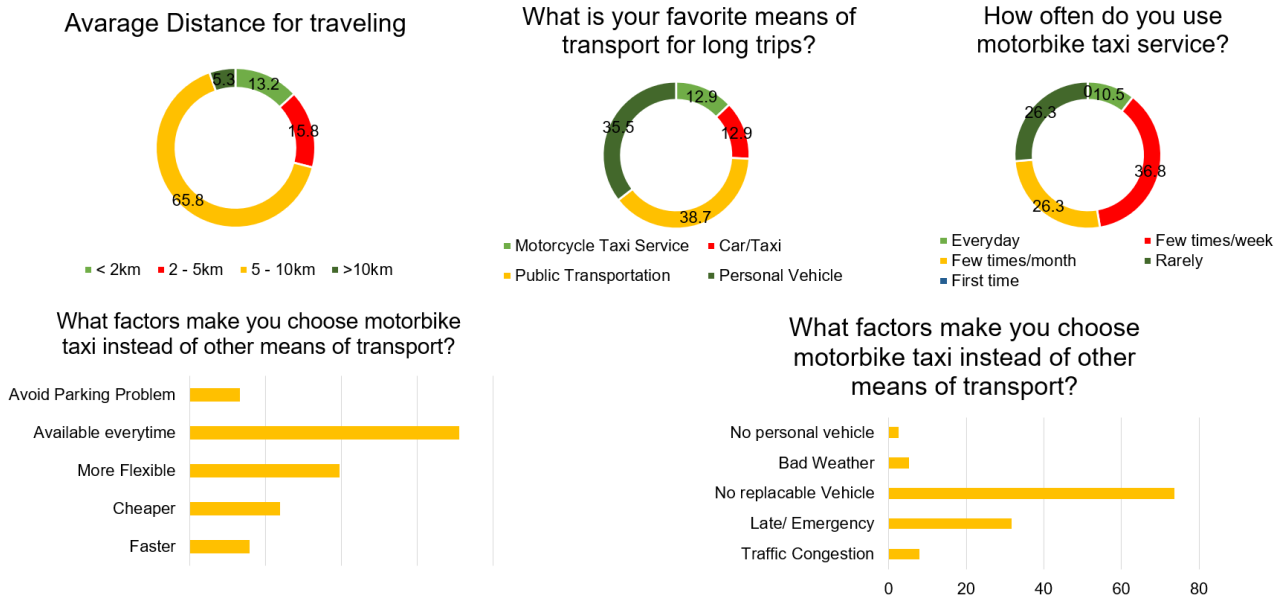

Figure 5: Survey Result

The survey of 38 respondents — primarily students and users around UEH Campus B — provides important behavioral insights into informal mobility patterns via motorcycle taxi services. The findings indicate that motorcycle taxis are widely used on a weekly basis, with 65.8% of participants using the service a few times per week and another 13.2% using it daily. Only 5.3% were first-time users, suggesting that motorcycle taxi services have become embedded in users' regular mobility routines. In terms of distance preferences, most respondents reported using motorcycle taxis for longer distances, with 38.7% selecting trips in the 5–10 km range and 35.5% for trips greater than 10 km. Only 12.9% reported preferring the service for short distances under 2 km. This trend directly aligns with the GPS data analysis, where long trips comprised the highest share of usage. The combination of low-cost, speed, and adaptability makes motorcycle taxis a go-to option for connecting distant locations, especially where public transit remains insufficient.

The primary reasons cited for choosing motorcycle taxis include speed (80%), availability and flexibility (70%), and the desire to avoid parking challenges (50%). Additionally, 36.8% of respondents said they use motorcycle taxis when facing traffic congestion, while others cited emergencies, lack of private vehicles, and weather conditions as motivating factors. These highlight the reactive and opportunistic nature of informal mobility use in urban settings. A key insight is the lack of affordable, reliable public transport, which seems to push users toward informal options for both routine and urgent mobility needs. This confirms the importance of motorcycle taxis not just as a convenience, but as a critical gap-filling mode in the city's transport ecosystem, especially among younger urban populations.

4.3 Space Syntax Findings

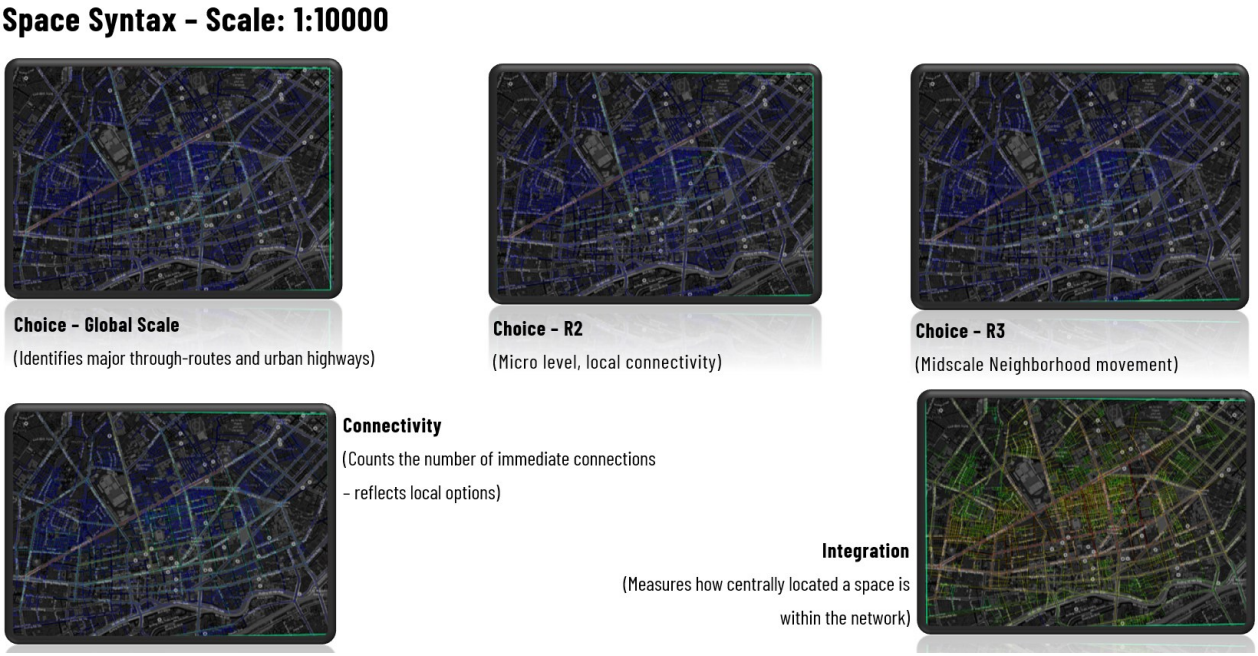

Figure 6: Space Syntax Maps – Choice, Connectivity and Integration Map

The spatial correlation analysis between space syntax metrics and motorcycle taxi trip characteristics revealed several significant relationships, in this research, Spearman's method is used to find co-relation between space syntax maps.

Variable 1	Variable 2	Spearman's ρ
Integration_HH	**Connectivity**	**0.52**
Integration_HH	Choice_Global	0.39
Choice_R2	**Choice_R3**	**0.70**
Choice_R3	**Choice_Global**	**0.85**
Choice_R2	Connectivity	**-0.07**

Figure 7: Co-relation Between Space Syntax Maps

A moderate-to-strong positive correlation was found between Integration_HH and Connectivity (ρ = 0.52), indicating that well-connected street segments are generally more globally integrated. Additionally, Integration_HH showed a moderate correlation with Global Choice (ρ = 0.39), suggesting that integrated spaces are also more likely to be chosen as through-routes in the urban network.

Notably, Choice_R2 and Choice_R3 exhibited a strong positive correlation (ρ = 0.70), reflecting consistent spatial patterns between two-step and three-step neighborhood-level centrality. The relationship between Choice_R3 and Global Choice was especially strong (ρ = 0.85), confirming that Choice_R3 serves as a robust local approximation of global betweenness, bridging neighborhood-scale movement and arterial path selection. Conversely, Choice_R2 and Connectivity displayed a slight negative correlation (ρ = –0.07), implying that streets with high two-step choice values are not necessarily the most locally connected. This distinction highlights the complexity of micro-scale routing, where movement preferences may prioritize route efficiency or continuity over simple nodal density.

Analysis of the relationship between space syntax metrics and GPS-recorded motorcycle taxi trips revealed distinct spatial patterns supported by statistically meaningful correlations. Long-distance trips frequently aligned with street segments exhibiting high Global Choice values, indicating a preference for arterial routes that offer continuity and fewer interruptions. This is supported by a very strong correlation between Choice_R3 and Global Choice (ρ = 0.85), affirming the role of Choice_R3 as a strong local approximation of global betweenness. Medium-distance trips corresponded to segments with moderate-to-high Choice_R3 values, reflecting a strong positive correlation between Choice_R2 and Choice_R3 (ρ = 0.70) and suggesting consistent spatial behavior across neighborhood-level connectors.

Short-distance trips were concentrated in areas with high local connectivity and micro-scale accessibility, evidenced by the spatial clustering around high Choice_R2 and Connectivity values. While the relationship between Choice_R2 and Connectivity showed a slight negative correlation ($\rho = -0.07$), this may reflect the difference between micro-level richness of options and actual segment-level connections. Additionally, Integration_HH correlated moderately with Connectivity ($\rho = 0.52$) and Global Choice ($\rho = 0.39$), indicating that well-connected and globally accessible segments are often part of highly integrated zones.

5. Discussion

Motorcycle taxis in Ho Chi Minh City operate not merely as an informal transport mode but as a spatially responsive mobility solution. Their routes reflect an adaptive alignment with both personal mobility demands and the inherent logic of the urban spatial structure. The integration of space syntax and GPS tracking demonstrates that riders selectively utilize street segments with varying levels of connectivity and choice, favoring efficient paths that minimize interruptions while maximizing accessibility.

This behavior underscores a critical insight: the underutilization of secondary roads, which often possess latent spatial potential, reveals a disconnect between formal urban design and actual lived mobility. Despite their structural capability to absorb traffic and support short-distance travel, these roads are overlooked in formal planning strategies. This gap has direct implications for congestion management, indicating that future transport policies must integrate informal mobility patterns to unlock underused urban infrastructure and enhance network resilience.

6. Conclusion

Summary of Key Findings

This study demonstrates the spatial logic underlying informal motorcycle taxi operations in Ho Chi Minh City by integrating GPS trajectory data, space syntax analysis, and user survey insights. The findings reveal that different trip types align with specific street network characteristics: short trips occur in locally connected grids with high Choice_R2 and Connectivity, medium trips utilize neighborhood-scale connectors (Choice_R3), and long-distance trips follow high Global Choice segments, reflecting arterial travel. Survey results reinforced these spatial patterns, highlighting user preferences for flexibility, time-efficiency, and access to areas underserved by formal transit. The moderate correlation between Integration_HH and trip activity suggests that global accessibility supports local movement more than long-distance travel. By combining spatial and behavioral data, this research offers a replicable method for analyzing informal mobility and underscores its functional role in urban transportation. The findings advocate for greater policy recognition of informal transport, particularly in enhancing first-last mile connectivity and adapting planning approaches to reflect real mobility behaviors in rapidly urbanizing contexts.

Recommendations for Future Research

Comparison studies should be considered as a secondary extension of this work. While the current research is only focusing on one area, future research could incorporate comparative analyses with cities like Bangkok, where motorcycle taxis are heavily used, or examine other Vietnamese cities such as Hanoi and Da Nang. Within Ho Chi Minh City, further comparisons between inner urban districts and peri-urban areas would help capture regional contrasts and mobility inequalities. Furthermore, future work should focus on multi-site studies to validate behavioral consistency across urban zones. Researchers could incorporate real-time congestion metrics, app-based usage data, and public transport overlays to model comprehensive multimodal systems. Finally, pilot programs connecting universities with licensed motorcycle taxi services may serve as scalable mobility solutions for educational hubs, closing current gaps in last-mile access, safety, and service reliability

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