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Analyzing Student Mobility Patterns and Route Preferences: A GIS- and Mental Map-based Study at Politeknik Negeri Ujung Pandang, Indonesia

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Abstract

Current understanding of students' mobility patterns often overlooks the integration of perceptual experiences with spatial behavior, particularly in rapidly urbanizing Global South contexts where informal infrastructures and cognitive factors critically shape mobility. This study addresses this gap by analyzing route preference determinants at Politeknik Negeri Ujung Pandang using mental map sketches (n=165), questionnaires, and GIS-based spatial analysis. Key findings reveal: 1) dense morning commutes within 500m of campus versus afternoon dispersal into alternative routes up to 2km; 2) distance ($r = 0.876$, $p < 0.01$) and travel time ($r = 0.699$, $p < 0.01$) dominate choices, outweighing convenience ($r = 0.196$, $p < 0.05$); and 3) gendered behaviors, with 65% of alternative route users were males. The findings validate Hägerstrand's Time-Geography model and recommend arterial corridor optimization and safety retrofits, advancing an equitable framework for campus mobility planning.

INTRODUCTION

Understanding student mobility patterns is critical for optimizing urban transportation systems, particularly around educational hubs where students constitute major commuter cohorts. While prior research has identified key factors shaping mobility behavior, including socio-demographics [1,2], built environment characteristics [3,4], and travel time/congestion [5,6], existing studies predominantly rely on quantitative methods (e.g., GPS tracking [7], travel surveys) that often overlook the cognitive and perceptual dimensions of route choice [5]. This gap is especially pronounced in rapidly urbanizing Global South contexts like Indonesia, where informal infrastructure and spatial inequalities uniquely constrain mobility.

The present study bridges perceptual and spatial analysis by integrating mental maps, guided by Lynch's cognitive mapping framework [8], with GIS analytics and Spearman correlation to examine commuting patterns at Politeknik Negeri Ujung Pandang (Tamalanrea Campus). Mental maps, elicited through free-sketching on blank paper [9,10], capture students' subjective route experiences and help uncover how safety perceptions, landmarks, and social preferences shape mobility decisions. When digitized and analyzed using GIS, these sketches allow for spatial hotspot detection through kernel density analysis and desire-line mapping, effectively complementing traditional quantitative approaches.

Despite increasing attention to urban mobility, three critical gaps remain that this research seeks to address. First, from a methodological perspective, much of the existing literature neglects cognitive dimensions of mobility,

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focusing heavily on observable travel behavior while overlooking how individuals perceive and interpret their commuting environment [11–17]. Second, while several regionally relevant studies have emerged from Southeast Asia -including in Japan, Malaysia, and Indonesia [9,13,18], they tend to concentrate on mode choice or macro-scale accessibility, often missing the granular, route-level decisions and perceptual factors that influence daily student travel. As such, cities like Makassar remain underexamined, despite their acute urban growth and infrastructural limitations. Third, on a practical level, policy responses and transport interventions are often generalized and lack contextual sensitivity, particularly for campus-based populations whose mobility behaviors are shaped by distinct spatial, temporal, and social conditions.

By centering student perceptions and embedding them within spatial analysis, this work not only contributes to advancing theoretical discourse in transportation geography but also offers grounded, actionable strategies to improve mobility equity and campus accessibility in developing urban contexts.

METHODS

Study Area

Campus 1 of Politeknik Negeri Ujung Pandang, located in Tamalanrea, Makassar, South Sulawesi, Indonesia, is also known as Tamalanrea Campus. Figure 1-A illustrates the area under study within the Mamminasata region, forming the spatial context for analyzing student commuting patterns. The Mamminasata region is commonly associated with the Makassar metropolitan area and includes neighboring districts: Makassar City, Maros Regency, Sungguminasa Regency, and Takalar Regency. The Tamalanrea Campus is adjacent to Hasanuddin University, sharing access roads. The primary arterial road, Jalan Perintis Kemerdekaan, which serves as the primary corridor for campus access, handles traffic from the west and northeast, supplemented by two main roads and four alternative roads (Figure 1-B). This corridor functions as the primary mobility backbone for both campuses.

To analyze route preferences, respondents were clustered by mobility flows from the west or northeast. Road networks were classified inti main roads - high-capacity, multi-lane roads with pedestrian facilities [19,20], and alternative roads (secondary routes for congestion avoidance).

Data Processing Workflow

Figure 2 outlines the data processing workflow. Primary data included mental maps and questionnaires. Mental maps, hand-drawn by respondents, were digitized and analyzed using GIS-based kernel density to identify mobility hotspots and patterns. Questionnaires captured variables for route preferences, analyzed via Spearman's correlation (non-parametric). Interviews supplemented the classification of route types.

Participants and Data Collection

A total of 165 returned mental maps and questionnaires were collected in this study. In this process, respondents filled out the questionnaire and then drew the mental map. The respondents consisted of 50.3% males, the rest females, while most respondents were aged 20 years or older (89.7%). Most respondents (54.5%) resided outside the Mamminasata region.

Questionnaire

The questionnaire was filled out using Google Forms for two months, from May to June 2024. The questionnaires were delivered to random Politeknik Negeri Ujung Pandang students who studied in the Tamalanrea Campus. Each respondent used the same ID across the mental map, questionnaire, and follow-up interview. The questionnaire consists of 6 variables, starting from socio-demographic data of students as the actors of mobility patterns [21–23], origin-destination [9,18], travel time [22], travel distance [22], routing [22,24], and convenience [22,24]. The responses were used to understand the cognitive reasoning for choosing the route from/to campus over another.

Mental Map

The present study utilized mental maps as a primary data collection tool to analyze students' mobility patterns between their homes and the campus. As illustrated in Figure 4 (parts A and B), respondents were asked to draw their typical commuting routes on blank paper manually. These sketches were then digitized using Google Earth to create a project file titled mental map.kmz (Figure 4-C), each participant's routes were organized into folders labeled with their unique IDs.

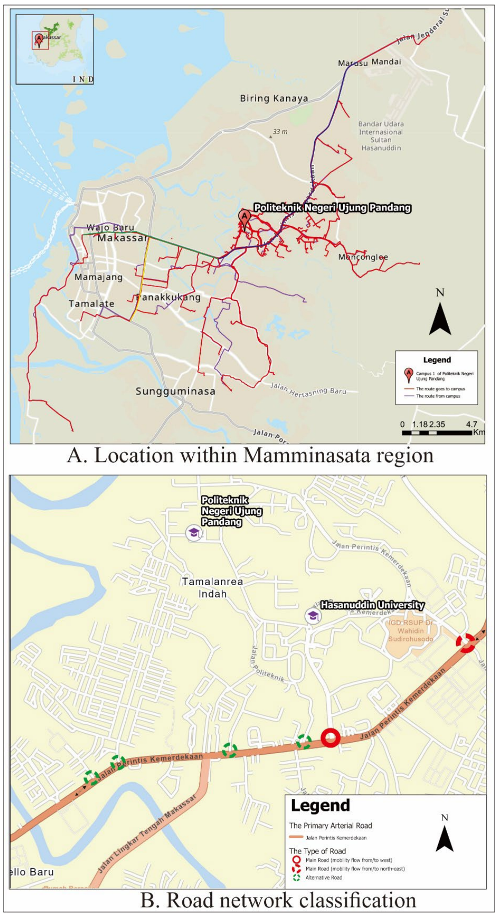

Figure 1. Study Area: (a) Location within the Mamminasata Region; (b) Road Network Classification

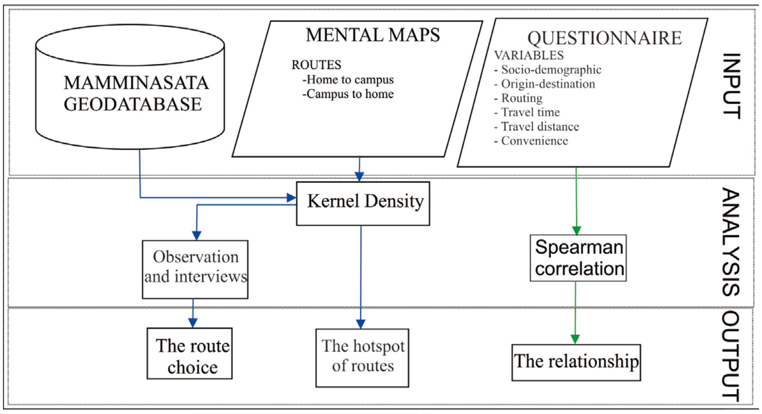

Figure 2. General Processing Scheme

Table 1. Socio-demographic Characteristics of Respondents

	Choice	Frequency	Ratio (%)
Gender	Male	83	50.3
	Female	82	49.7
Cluster age	<20	17	10.3
	≥20	148	89.7
Domicile	Makassar	65	39.4
	Maros	7	4.2
	Sungguminasa	3	1.8
	non-Mamminasata	90	54.5

During the mapping process, respondents were asked to depict two distinct trips: the journey from home to campus in the morning (referred to throughout this study as the morning commute) and the return journey from campus to home in the afternoon (the afternoon commute). These labels will be consistently used in the results and discussion sections to differentiate temporal commuting behavior. The participants verified all routes directly to ensure spatial and directional accuracy.

Once the mental maps were digitized, the study classified the commuting behavior into two categories based on route similarity: respondents who selected different routes depending on the direction of travel (Figure 4-1), and those who used the same route for both morning and afternoon commutes (Figure 4-2). In addition, the commuting routes were categorized according to the road classification (see Figure 1B). A summary of this categorization framework is provided in Figure 3.

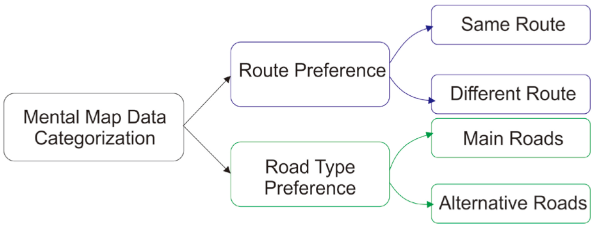

Figure 3. Mental Map Data Categorization

RESULTS AND DISCUSSION

Hand-drawn mental maps (Figure 4) provide an initial lens to explore student commuting behavior and reveal spatial patterns in daily mobility to and from campus. This visual analysis helps identify how students navigate the urban environment and which routes they prioritize, offering insight into broader movement dynamics. Two distinct behavioral clusters emerged from this analysis: the first, "Different Routes," consists of students who alternate between inbound and outbound paths (Figure 4-1). Morning trips generally favor direct arterial roads to accommodate fixed class schedules (reflecting Hägerstrand's coupling constraints). In contrast, afternoon trips tend to shift toward quieter or safer alternatives, guided by greater autonomy (authority constraints). The second cluster, labeled "Same Route," includes students who consistently use the same path for both morning and afternoon commutes (Figure 4-2). These individuals prioritize familiarity and efficiency, typically relying on major corridors such as Jalan Perintis Kemerdekaan. While this mental map analysis highlights the spatial dimension of commuting behavior, a deeper understanding of students' route decision-making, particularly the roles of distance, time, convenience, and gender, will be further explored through statistical and behavioral analyses presented in Tables 2–4.

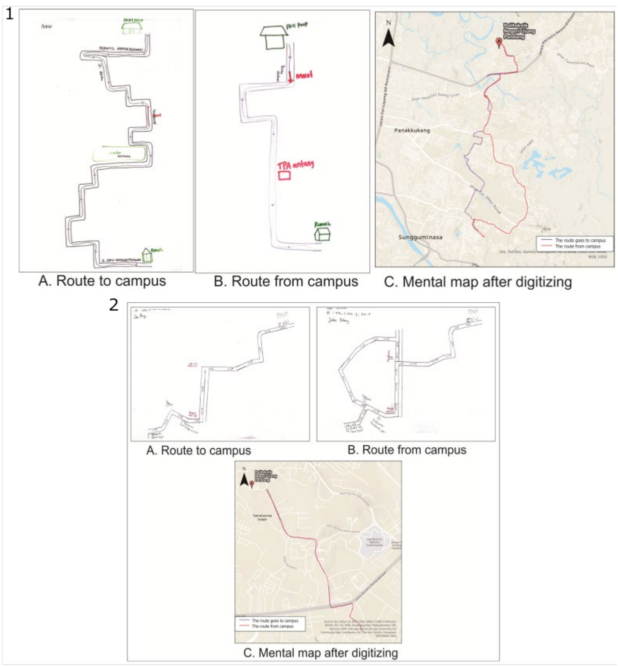

Figure 4. (1) Sample of Mental Maps from Respondent ID 06B_1 in the Cluster of Different Routes; (2) Sample of Mental Maps from Respondent ID 24C in the Cluster of Same Route

Figure 5 presents a Geographic Information System (GIS) based analysis of mobility patterns to and from Tamalanrea Campus. It combines Kernel Density Analysis and buffer analysis to quantify these patterns spatially by exploring the concentration and distribution of travel routes around the Tamalanrea campus. Two primary datasets are analyzed: the routes to the campus (purple lines) and the routes from the campus (red lines).

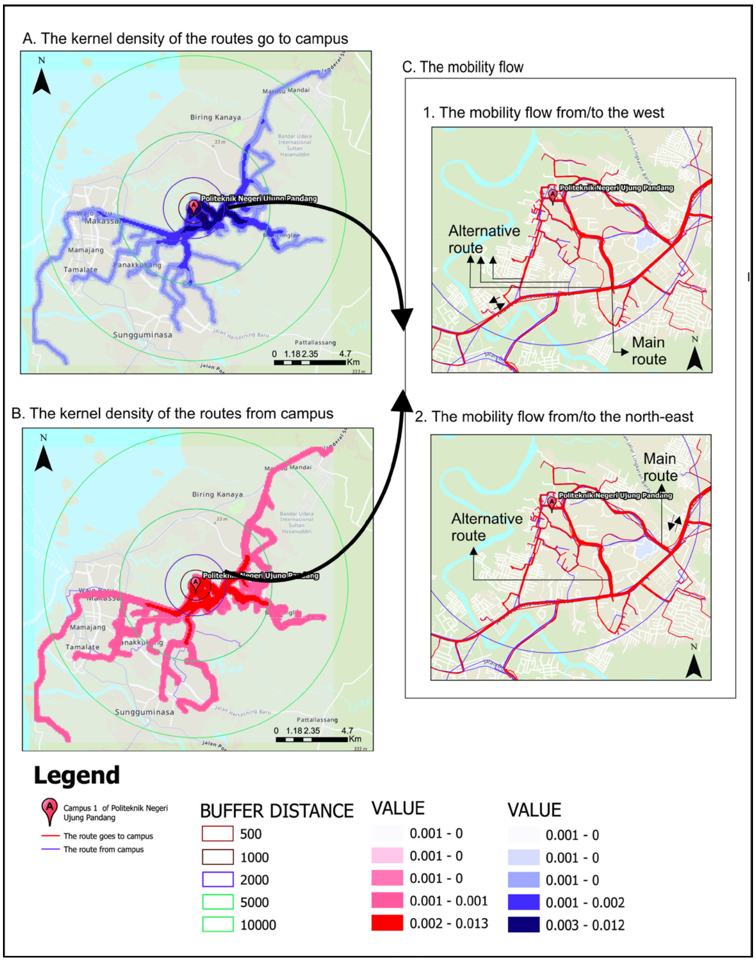

Figure 5. Kernel Density Analysis and Buffer Analysis

The maps show kernel density results, which highlight the concentration of routes. In Figure 5-A, the purple lines represent the density of routes leading to the campus, with darker areas indicating higher traffic flow. These routes converge near the campus, reflecting its role as a focal point for students. In contrast, Figure 5-B shows the density of routes departing from the campus, represented by red lines. These routes are more dispersed, indicating varied destinations for individuals leaving the campus.

The buffer zones provide spatial context, marking distances of 500 m, 1000 m, 2000 m, 5000 m, and 10,000 m from the campus. These buffers help analyze how route density changes with distance. The highest density of routes (both to and from the campus) was observed within the inner buffers (0–1000 m), where travel paths are concentrated on primary access roads. Beyond this range, route density decreases, with traffic dispersing into multiple smaller roads or alternative paths. In the mid-range buffer zones (500–2000 m), the kernel density analysis reveals a moderate density of travel routes. In Figure 5-A (to campus), the purple density lines spread out and thin in intensity, with only a few main routes maintaining moderate density, likely reflecting major arterial roads. In Figure 5-B (from campus), the red density lines also fan out, showing a diversification of routes as individuals disperse to various destinations. These zones act as transitional areas where traffic is distributed across multiple pathways. To enhance mobility in these areas, interventions such as improved traffic flow, signage, or public transport connectivity could help reduce congestion in high-density routes.

Two inset maps focus on mobility flows from/to specific directions (Figure 5-C). Figure 5-C-1 highlights traffic flow from/to the west, showing a dominant main route and an alternative route. The main route handles a significant portion of the traffic, as indicated by its high density. The other focus is on traffic flow from/to the northeast, where similar primary and secondary route patterns are observed.

The kernel density and buffer analyses reveal distinct spatial-temporal patterns in student commuting behavior to and from Politeknik Negeri Ujung Pandang. During morning commutes to campus, routes within the 0–2000 meter buffer zone exhibit consistent moderate density values (0.003–0.012), highlighting a strong convergence of students along established access corridors. This pattern aligns with the mental map analysis, which revealed a clearly defined core mobility corridor predominantly used during morning hours, reflecting structured routines driven by class schedules. In contrast, afternoon commutes demonstrate more varied and dispersed patterns, with density values ranging from 0.001 to 0.013, as students depart at flexible times and head to diverse destinations. These shifts suggest that post-campus travel is shaped by personal activities, social engagements, and the need to avoid congested or unsafe routes, as also seen in the more fragmented mental map pathways.

These dual mobility patterns (structured in the morning and flexible in the afternoon) correspond with Hägerstrand's time-geographic constraints model, which emphasizes how individual movement is bounded by time, space, and social obligations [25,26]. Morning commutes reflect capability and coupling constraints, requiring students to reach campus at fixed times and prioritize time-efficient routes. Afternoon commutes, by contrast, reflect weaker coupling and authority constraints, allowing for more autonomous decisions and the use of alternative paths. The consistently low density in middle-distance zones (5000–10,000 m) across both directions further indicates transitional areas where route consolidation has either not yet occurred (morning) or has already dispersed (afternoon), offering greater freedom of movement.

These findings suggest that transportation interventions should focus on infrastructure improvements along the high-density final approach corridors (0–2000 m) to enhance morning commuting efficiency. For afternoon mobility, more adaptive solutions—such as demand-responsive transit or improved safety in alternative routes—could better accommodate dispersed travel behaviors. Middle-distance zones may require differentiated strategies that balance route flexibility with reliable access. Overall, integrating mental map insights with GIS analysis and time-geographic theory provides a deeper understanding of how students navigate spatial and temporal constraints, offering a more human-centered foundation for urban mobility planning.

Spearman Correlation and Interview

Table 2. Summary of Variables in the Questionnaire

Variable	Question	Mean	SD*
Route	I always use this route(s) for my commute to/from campus	6.14	1.932
Convenience	The choice of transportation mode for commuting to and from campus is influenced by convenience	3.76	1.017
Safety	The choice of transportation mode for commuting to and from campus is influenced by safety	3.68	0.903
Time and distance	The choice of transportation mode for commuting to and from campus is influenced by the efficiency and effectiveness of time and effort	3.92	1.03
Distance	Average distance traveled to and from campus	2.48	0.881
Time	Average time traveled to and from campus	1.22	0.433

* SD: Standard Deviation

Table 3. Result of Spearman Correlation

	Distance	Time	Convenience
Routing	.854**	.677**	.178*

** p<0.01
*   p<0.05

Table 4. Results from the Interview of the Respondents Who Chose the Alternative Route

	Alternative route		The reasons
Route	**Male**	**Female**	
Goes to campus			Convenience, travel distance, travel time, and following friends
From the west	4	3	
From the north-east	9	9	
Total	13	12	
From campus	3	3	
To the west	16	8	
To the north-east	19	11	
Total	35	19	

Tables 2 and 3 display the findings from the questionnaire, while Table 4 delves into the results from the interview. Table 2 summarizes students' perceptions of key mobility factors, whereas Table 3 presents the results of Spearman's rank correlation, highlighting the strongest predictors of consistency in route usage. Subsequently, Table 4 enriches this analysis by examining qualitative differences in route behavior based on gender and travel direction, thereby enhancing our understanding of students' route decision-making processes.

The results show that students generally follow consistent routes (mean = 6.14, SD/Standard Deviation = 1.9), prioritizing time efficiency (mean = 3.92, SD = 1.03) and safety (mean = 3.68, SD = 0.903) over convenience (mean = 3.76, SD = 1.017). Although students live relatively close to campus (2.48 km on average, SD = 0.881), they still experience long travel times (1.2 hours, SD = 0.4) due to issues like traffic congestion and reliance on informal transport networks, indicating inefficient traffic in Makassar. While the analysis of Spearman's correlation confirmed that distance ($\rho = 0.854$, $p < 0.01$) and time ($\rho = 0.677$, $p < 0.01$) significantly impact route choices, while convenience ($\rho = 0.178$, $p < 0.05$) has a smaller effect.

Integrating quantitative and qualitative findings reveal how spatial proximity does not always translate to travel efficiency. While the statistical analysis (Tables 2 and 3) identifies distance and time as key determinants of route selection, the interview data (Table 4) illuminate the social and perceptual factors that moderate these preferences, particularly gender and directional behaviors. Qualitative interviews reveal that 65% of alternative-route users were male (35 males versus 19 females), often influenced by peer recommendations or perceived speed, while female students tend to stick to familiar paths for safety reasons. Northeast-bound commuters (28 males, 20 females) frequently employ informal shortcuts, demonstrating adaptive strategies in rapidly urbanizing areas. Moreover, 54 students opt for alternative routes when returning home in the afternoon, compared to 25 on their morning inbound journeys. These behavioral patterns align with Helmmie and Joewono's [27] finding that combining travel attributes with socio-demographic variables improves predictive power in mode-choice models. In our study, distance and time explain most of the variance in route selection, but gender and time-of-day add important nuance, underscoring the value of integrating demographic insights into route-choice analysis.

Bridging the quantitative and qualitative findings, it becomes evident that spatial proximity alone does not guarantee travel efficiency. Although most students commute short distances, prolonged travel times highlight non-physical barriers—such as congestion, limited transport options, and safety concerns—that shape commuting decisions. Afternoon flexibility allows especially male students to experiment with alternative routes, whereas female students often maintain consistent paths due to safety-related apprehensions. This divergence illustrates how mobility decisions are embedded in both physical accessibility and social–psychological factors.

These patterns align with Hägerstrand's time-geography model, where morning commutes reflect capability constraints (rigid schedules funneling students into efficient arterial roads), while afternoons embody authority constraints (autonomous detours for safety or convenience). Similar spatial disparities have been observed in Makassar's formal public transport system. Ridwan et al. [28] found that the Trans Mamminasata Bus corridors inadequately serve pedestrians and cyclists, with coverage areas falling short of the accessibility needs for non-motorized users. Their findings reinforce our conclusion that distance-based infrastructure improvements alone are insufficient without considering user-specific constraints and perceptual safety.

To address these dynamics, practical interventions should prioritize high-density zones (0–2000 m) through road widening and traffic signal optimization, enhance alternative routes with streetlights and pedestrian crossings, implement gender-responsive strategies such as guarded shuttles, and expand campus transit for long-distance commuters (> 5 km). This synthesis of statistical rigor, behavioral insight, spatial analysis, and theoretical framing underscores the need for infrastructure policies that reconcile efficiency with equity in rapidly developing cities like Makassar.

CONCLUSIONS

By integrating mental maps, GIS spatial analysis, and Spearman correlation, the present study closes a key methodological gap in mobility research, bringing together cognitive and quantitative perspectives to reveal how distance, time, and socio-psychological factors jointly shape student route choices. Contextually, our work addresses a neglected Southeast Asian setting, showing that morning commutes are tightly bound by class schedules (0–2 km coupling constraints). In contrast, afternoon travel reflects greater autonomy and safety concerns.

Rather than reiterating every intervention, the main takeaway for planners is that transport policies must be both spatially tiered and socially sensitive (core corridors need capacity upgrades, alternative paths demand safety enhancements, and longer distances benefit from demand-responsive links). This human-centered, scalable framework can guide campus-adjacent transport planning not only in Makassar but in other rapidly urbanizing Global South cities.

This study is limited by its focus on a single campus and by manual mental-map digitization, which may introduce respondent bias and mapping inconsistencies. Furthermore, the questionnaire and interview samples—while sufficient for exploratory analysis—may not capture the full diversity of student experiences.

Future work should validate these findings with dynamic travel data (e.g., GPS or mobile-phone traces), expand to multiple campuses across diverse Southeast Asian contexts, and examine additional factors such as road quality, public transport availability, and evolving land-use patterns. Such research will further refine equitable mobility policies that truly reconcile built infrastructure with how people perceive and navigate their urban environments. Future work should test this approach with dynamic movement data and multiple campus contexts, further refining equitable mobility policies that truly reconcile built infrastructure with how people feel, think, and move.

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