

Integrating Bangkok's Western Canals for Micro-Mobility and Last-Mile Connectivity: A Spatial Analysis of Man-Powered Paddle-Boat Movement

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ABSTRACT

This study presents an intentionally extreme analytical scenario to expose gaps in urban mobility planning by evaluating the potential of Bangkok's western canal system to function as vernacular micro-mobility infrastructure for last-mile connectivity. The research provides the first empirical survey of canal-based mobility conducted using self-owned, man-powered paddle boats operated by local residents, generating primary data on everyday waterborne movement. Using geotagged field surveys and GIS-based spatial analysis, the study maps boat activity, access landings, navigability constraints, and connectivity to public transport. The results reveal concentrated corridors of active vernacular mobility alongside extensive segments constrained by sedimentation, fragmented hydrology, and inadequate access infrastructure. These patterns expose persistent spatial inequalities and weak integration between canal routes and the urban transport network. The findings position paddle-boat use as a form of vernacular micro-mobility with latent potential for low-carbon last-mile connectivity in peri-urban Bangkok, while underscoring that effective integration depends less on distance feasibility than on access-landing standards, hydrological management, and coordinated multimodal governance.

Keywords: canal-based micro-mobility, man-powered paddle boats, last-mile connectivity, vernacular mobility, Bangkok

INTRODUCTION

The historical formation of Bangkok is inseparable from its hydro-topographical context in which the Chao Phraya River and its extensive canal network functioned as the primary system for transportation, agricultural distribution, and inter-community exchange (Rau & Nutalaya, 2020; Tohiguchi et al., 2002). For centuries, canals supported everyday mobility by moving goods, enabling commuting, and sustaining socio-cultural interactions across dispersed settlements (Mateo-Babiano, 2012). However, rapid urbanization in the twentieth century redirected development toward road-based infrastructure, resulting in large-scale canal infill and the prioritization of automobilized mobility (Hossain & Iamtrakul, 2007). This transformation enhanced road connectivity but also produced long-term mobility challenges, including chronic congestion, gaps in access to mass transit, and weak integration across transport modes.

Although canals remain a significant physical element within the urban landscape, most are not well integrated into Bangkok's contemporary mobility network (Unakul, 2012). Spatial data on canal usage are especially limited, and existing records rarely include the movement of privately owned or man-powered boats. This lack of evidence constrains efforts to position waterways within transport planning. Recent scholarship has therefore argued for the reactivation of canal transport as part of multimodal mobility strategies. Proposals include reintroducing small watercraft as feeder services capable of relieving road congestion and improving access for underserved communities (Doeppers, 2016). Pilot initiatives such as the Khlong Phadung Krung Kasem project demonstrate that investments in electric boats, standardized piers, and improved local access routes can reconnect fragmented neighborhoods with major transit nodes (Kingngoen & Srisatit, 2022). These initiatives support broader urban sustainability objectives that emphasize equitable mobility, environmental performance, and diversified modal choices (UN-HABITAT, 2024).

This study addresses a critical gap by presenting the first systematic spatial survey of man-powered paddle-boat movement along western Bangkok's canals. Western Bangkok (Thonburi) was selected as the study area due to its

retained canal morphology, semi-enclosed hydrological system, and continued presence of vernacular paddle-boat practices, which remain observable in everyday mobility. Unlike larger motorized vessels that require deeper and wider waterways, man-powered paddle boats are capable of navigating shallow, narrow, and hydrologically fragmented canal segments, making them uniquely suited for fine-grained spatial analysis of localized water-based movement. By documenting boat density, pier distribution, navigational conditions, and linkages to land-based transit, the research evaluates the potential of canal corridors as micro-mobility infrastructures that can strengthen last-mile connectivity and contribute to more sustainable and inclusive urban mobility systems. Accordingly, this study asks: To what extent can western Bangkok's canal network function as an efficient micro-mobility corridor for last-mile connectivity, and how does its spatial configuration compare with land-based transport accessibility?

LITERATURE REVIEW

Historical Transformation of Canal Infrastructure

The canal system in western Bangkok was originally constructed to support agricultural production, water management, and local mobility across low-lying floodplains. Designed as a combined hydrological and transportation network, the *khlongs* served multiple functions including irrigation, flood control, and small-scale transport between rural settlements and central markets (Rondinelli, 1983). In Thonburi and adjacent districts, canals shaped everyday life by enabling the circulation of goods, facilitating access to agricultural hinterlands, and connecting dispersed communities across a landscape defined by seasonally variable water levels (Tanabe, 1977).

Beginning in the mid-twentieth century, this water-based system was progressively overshadowed by the expansion of road infrastructure and the increasing dominance of land-based transport. The administrative merger of Bangkok and Thonburi accelerated canal infill,

altered flows, and severed many historic water routes, allowing the construction of major roads, bridges, and housing estates that reoriented the city toward automobilized mobility (Kiatthanawat et al., 2024; Wattanamano et al., 2024). As a result, many canals lost their transport functions and were repurposed primarily as drainage conduits. Declining maintenance further contributed to sedimentation, reduced navigability, and the deterioration of canal-side environments (Yodsurang, 2023).

Despite these changes, several canal corridors in the western region continue to function as localized water-mobility spaces, particularly Khlong Maha Sawat, Khlong Chak Phra, and Khlong Bang Chueak Nang. Their present role, however, is significantly diminished compared to earlier periods and remains largely informal and localized (Rabe & Leeruttanawisut, 2025). The contemporary *khlong* system retains a distinct spatial logic rooted in the amphibious relationship between land and water, where canals continue to structure urban morphology despite their diminished transport role (Casper, 2014; Yodsurang et al., 2026). These residual patterns indicate the persistence of water-based mobility

traditions, while also highlighting the broader marginalization of canals within Bangkok's evolving urban transport system.

Infrastructural Decline and Contemporary Constraints

The canal network in western Bangkok now faces significant infrastructural and hydrological constraints that limit its function as an effective mobility corridor. Persistent hydrological and infrastructural problems, including stagnant water, sediment accumulation, disrupted water flow, and increasingly fragmented canal segments, significantly undermine navigability (Numsuk, 2025). Government interventions have tended to prioritize drainage and flood mitigation rather than mobility, and the proliferation of floodgates designed to stabilize water levels often restricts the movement of boats, particularly for small and man-powered craft that depend on continuous flows (Figure 1). As a result, travel schedules must align with tidal cycles and floodgate operations, further discouraging everyday use.

Figure 1

Everyday Canal-Based Micro-Mobility and Informal Commerce Along a Western Bangkok Canal



Note. This scene shows how small boats function simultaneously as micro-mobility and mobile shops, relying on informal docking at canal-front houses and cafés. It exemplifies the continued social and economic role of canals in supporting short-distance travel and water-based livelihoods within urban neighborhoods.

The rapid expansion of the road network has intensified these pressures. Between 2000 and 2020, paved road area in Bangkok expanded by more than 40 percent, frequently intersecting or diminishing existing canal corridors and thereby weakening their continuity as transport routes (Iamtrakul et al., 2017). Consequently, boat-based mobility in the western districts has declined sharply, with many routes reporting fewer than one hundred daily passengers, which is insufficient to sustain regular service operations. These conditions reflect a broader trend identified in studies of Bangkok's urban morphology, which highlight how canals have shifted from versatile socio-ecological infrastructures to marginal drainage channels within an increasingly land-dominated city structure (Casper, 2014).

Despite these limitations, canals continue to hold strategic importance for communities located at the periphery of the BTS and MRT rail networks. In underprivileged or sparsely populated areas where road access is limited, waterways remain one of the few locally controlled and low-cost mobility options (Aritua et al., 2021; Cheranchery, 2024). This persistent relevance underscores the need to reconsider the potential of canal-based mobility in long-term transport planning and to understand how infrastructural degradation has constrained what was once an integral component of everyday urban life in Bangkok.

Resurrection and New Perspectives

Recent years have seen renewed attention to the revitalization of canal transport as part of Bangkok's broader transition toward sustainable and multimodal urban mobility. The reintroduction of public boat services along Khlong Phasi Charoen illustrates how targeted investment in pier infrastructure, vessel upgrades, service frequency, and local access routes can re-establish canals as both environmentally efficient and socially inclusive mobility corridors (Iamtrakul et al., 2017; Narin et al., 2021). Evidence from regional transport initiatives further indicates that when supported by modernized vessels and integrated fare systems, water-based transport can achieve measurable increases in ridership and user satisfaction, particularly in dense urban

settings where road congestion constrains mobility options (Calderon-Rivera et al., 2024; Janjevic & Ndiaye, 2014; Mihic et al., 2011).

Beyond formal services, the continued use of self-owned, man-powered paddle boats in many western districts indicates the presence of a vernacular mobility system that persists outside formal datasets. These small boats remain essential for residents who navigate narrow canals, shallow waters, and areas not accessible by motorized craft (Van Berkel, 2020). Their use demonstrates that canals continue to function as flexible, low-cost, and community-driven mobility spaces despite infrastructural decline. Recognizing these practices expands the understanding of micro-mobility to include human-powered watercraft that provide short-distance travel within neighborhoods and connect residents to larger transport networks. This perspective suggests that canals should not be viewed only as historical remnants but as potential micro-mobility infrastructures that can support equitable and sustainable mobility in parallel with Bangkok's formal transport system.

Micro-Mobility and Urban Connectivity

Micro-mobility refers to small, lightweight, low-powered vehicles that support short-distance travel, including bicycles, e-bikes, scooters, electric scooters, and other compact personal modes. Emerging scholarship recognizes that micro-mobility also encompasses human-powered watercraft when they serve comparable spatial and functional roles, particularly in settings where waterways remain active components of the urban landscape. These modes have gained global prominence as cities search for alternatives to automobile-oriented systems and pursue more human-centered mobility models. According to Madapur et al. (2020), micro-mobility is essential for improving accessibility within multimodal networks and for facilitating efficient transfers across transport modes. Micro-mobility modes address trips that are too long for walking but too short to justify car use, thereby filling the first-mile and last-mile gap (Abduljabbar et al., 2021). D'Acierno et al. (2022) further notes their affordability, operational flexibility, and low emissions, which position

micro-mobility as a key component of sustainable urban transport. In dense metropolitan environments, they offer adaptable and energy-efficient mobility, particularly when roadway congestion and urban form limit the performance of conventional transport systems (Fong et al., 2023).

Globally, micro-mobility has demonstrated its capacity to strengthen multimodal networks and support inclusive mobility. Research indicates that shared bikes and scooters can expand access to mass transit by efficiently linking riders to metro and bus stations, thereby increasing transit ridership (Nikitas, 2024). Cities such as Copenhagen, Seoul, and Paris have incorporated micro-mobility into broader sustainable mobility strategies, reducing dependence on private cars and supporting compact, transit-oriented urban forms (Lim & Lee, 2026; Nikitas, 2024). Effective implementation requires supportive infrastructure, including safe pathways, low-speed travel zones, docking or parking facilities near mobility hubs, and digital platforms that allow users to coordinate multimodal routes (Cui & Zhang, 2024; Lim & Lee, 2026). Scholars also emphasize the importance of integrated data sharing, safety policies, and equity considerations to ensure that micro-mobility services are accessible to diverse user groups (Comi & Polimeni, 2024). These principles together illustrate micro-mobility's role in improving connectivity, reducing environmental impacts, and distributing mobility opportunities more fairly across urban populations.

These global insights align with the spatial structure of Bangkok, particularly on the Thonburi side of the city, where an extensive canal network continues to influence local morphology. In the western districts, micro-mobility provides a flexible, low-emission alternative to areas where streets are narrow, discontinuous, or heavily congested. While land-based micro-mobility in Bangkok largely consists of bicycles and e-scooters navigating challenging traffic environments (Wibowo, 2023), water-based micro-mobility introduces an alternative layer of connectivity by utilizing existing canals for short-distance travel. Surveys conducted by the Kiatthanawat and Yodsurang (2025) indicate, however, that many canal segments have experienced declining navigability due to sediment accumulation, stagnant water, and

disrupted hydrological flows caused by floodgate operations. These limitations restrict the frequency and reliability of water-based trips and highlight the need for planning approaches that integrate canal, pedestrian, and transit infrastructures.

Within this context, water-based micro-mobility encompasses both motorized services, such as long-tail boats, and human-powered modes, including the self-owned paddle boats that remain common in several western neighborhoods. The continued use of paddle boats reflects a vernacular mobility practice shaped by shallow waters, narrow canal widths, and the absence of formal transport services. These human-powered boats illustrate how micro-mobility can emerge organically from community needs and can function effectively in areas that are underserved by land-based networks (Singh et al., 2025). The Khlong Phasi Charoen boat service demonstrates how structured waterborne services, including electric and low-emission vessels, can support first and last-mile access to BTS stations, major roads, and local communities (Office of Transport and Traffic Policy and Planning, 2019). Bangkok Metropolitan Administration (The Nation Thailand, 2025) has also explored strategies for integrating piers with sidewalks, feeder bus lines, and cycling routes, which aligns with micro-mobility principles of flexible and intermodal travel.

Compared with land-based micro-mobility, which is constrained by limited surface space, water-based modes can bypass road congestion and extend mobility into areas that remain disconnected from the rail network. Yet many canals are not meaningfully connected to public transport nodes, indicating a significant gap in the multimodal system (Iamtrakul & Raungratanaamporn, 2016; Iamtrakul et al., 2017). Targeted investments in canal accessibility, pier infrastructure, and hydrological management could enable water-based micro-mobility to support Bangkok's broader goals for sustainable and inclusive mobility. This is particularly relevant for advancing the vision of the 15-minute city, where reliable and locally accessible mobility options are essential for improving quality of life and reducing dependence on motorized travel.

Last-Mile Connectivity and the 15-Minute City

Last-mile connectivity refers to the final segment of a journey that links a major transit station to a traveler's ultimate destination. It is a critical determinant of the usability, efficiency, and attractiveness of urban transport systems (Kanuri et al., 2019). In the absence of reliable last-mile solutions, travelers often turn to private motorized vehicles, which contributes to traffic congestion, higher emissions, and reduced system efficiency. Cities seeking to address this challenge typically invest in pedestrian infrastructure, bicycle networks, shared micro-mobility services, and neighborhood-scale transport options that close the distance between transit hubs and everyday destinations. These considerations are especially relevant in Bangkok, where municipal initiatives such as the 15-minute park program and walkability policies aim to improve local accessibility and promote non-motorized travel in dense urban areas (Arifwidodo et al., 2025).

The concept of the 15-minute city, introduced by Moreno (2024), proposes that essential urban services, including workplaces, schools, healthcare, commerce, and recreation, should be accessible within a 15-minute walk or bicycle ride. This model reduces dependence on long-distance motorized commuting and encourages compact, mixed-use, and human-centered urban environments that support environmental sustainability (Allam et al., 2022). Last-mile connectivity is an integral component of this framework because it ensures that residents across different socio-economic groups can access transit nodes and urban amenities with minimal barriers (Allam et al., 2022). As such, policies that expand walkability, improve public space, and strengthen local mobility networks represent foundational steps toward achieving the 15-minute city vision.

Conversely, a city with an extensive canal system adds another dimension to the discussion. Many neighborhoods in western Bangkok are located far from BTS and MRT stations but remain closely connected to waterways. Canals therefore function as latent last-mile infrastructure, where self-owned, man-powered paddle boats provide a vernacular form of micro-mobility in areas with fragmented or congested

road networks. With improved access landings, pedestrian links, and multimodal coordination, water-based mobility can more effectively integrate these neighborhoods into the urban system and extend the 15-minute city concept beyond land-based networks.

METHODOLOGY

This study combines field-based observation with quantitative spatial analysis to examine canal-based mobility in western Bangkok. Using QGIS, it evaluates whether canals can function as a first-mile connector to land-based public transport, with particular attention to bus feeder access in areas where rail stations are difficult to reach. A key contribution is the on-site survey conducted using self-owned, man-powered paddle boats, which enabled direct access to narrow and hydrologically constrained canals and captured everyday mobility practices absent from official datasets. This mixed approach reveals practical constraints and hidden gaps in accessibility while strengthening the spatial accuracy of the mobility analysis.

Data Collection and Fieldwork

The research began with a comprehensive review of scholarly literature, government reports, historical maps, aerial imagery, and prior rapid assessments related to Bangkok's canal system and urban mobility (Kiatthanawat et al., 2024). This preliminary phase supported the establishment of a working database of water transport infrastructure in western Bangkok and guided the delineation of the study area and survey routes.

Fieldwork was conducted in November 2025 and focused on documenting main canals, sub-canals, existing boat routes, points of access/embarkation, and multimodal transfer points. Multiple site visits were undertaken across both weekdays and weekends during daytime hours (approximately 07:00–16:00). In several canal segments, repeated observation passes were conducted to verify boat activity patterns and reduce single-pass bias. Observations

recorded all boats present during the survey period, including vessels in motion and moored or stationary boats. A distinctive feature of this study was the use of self-owned, man-powered paddle boats operated by residents to conduct in-canal observations. This approach enabled direct access to shallow, narrow, or hydrologically fragmented canal segments that are not reachable by larger motorized vessels and allowed for the collection of highly localized movement patterns that are not recorded in formal datasets.

Systematic observations were conducted along canal corridors to assess navigability, hydrological conditions, and canal-side environments. Photo documentation and geotagged field notes were used to validate secondary spatial data and to reconcile discrepancies between mapped information and on-site conditions (Figure 2). This combination of documentary research and *in-situ* paddle-boat surveying ensured higher spatial accuracy and provided first-hand evidence of vernacular water-based mobility practices that have not been studied previously.

Data Analysis and Mapping

The study area encompasses a continuous canal corridor extending westward from the old course of the Chao Phraya River to Khlong Thawi Watthana. It is bounded in the north by Khlong Maha Sawat and in the south by Khlong Phasi Charoen, forming a large hydrological zone enclosed by multiple floodgates that create a semi-closed water management system (Figure 3). This configuration allows the canal network to retain a distinctive local mobility function while maintaining potential linkages to Bangkok's modern transport infrastructure. Many of the canals within this zone were excavated by early settlers for habitation, agriculture, and water-based travel, and include numerous short-cut canals that extend deep into residential and agricultural land (Kiatthanawat & Yodsurang, 2024). These settlement and canal patterns have created a fine-grained waterscape that supports vernacular mobility, including self-owned paddle boats. Its enclosed hydrological system and close interface with road and rail networks make this area a suitable case for systematic spatial analysis.

Figure 2

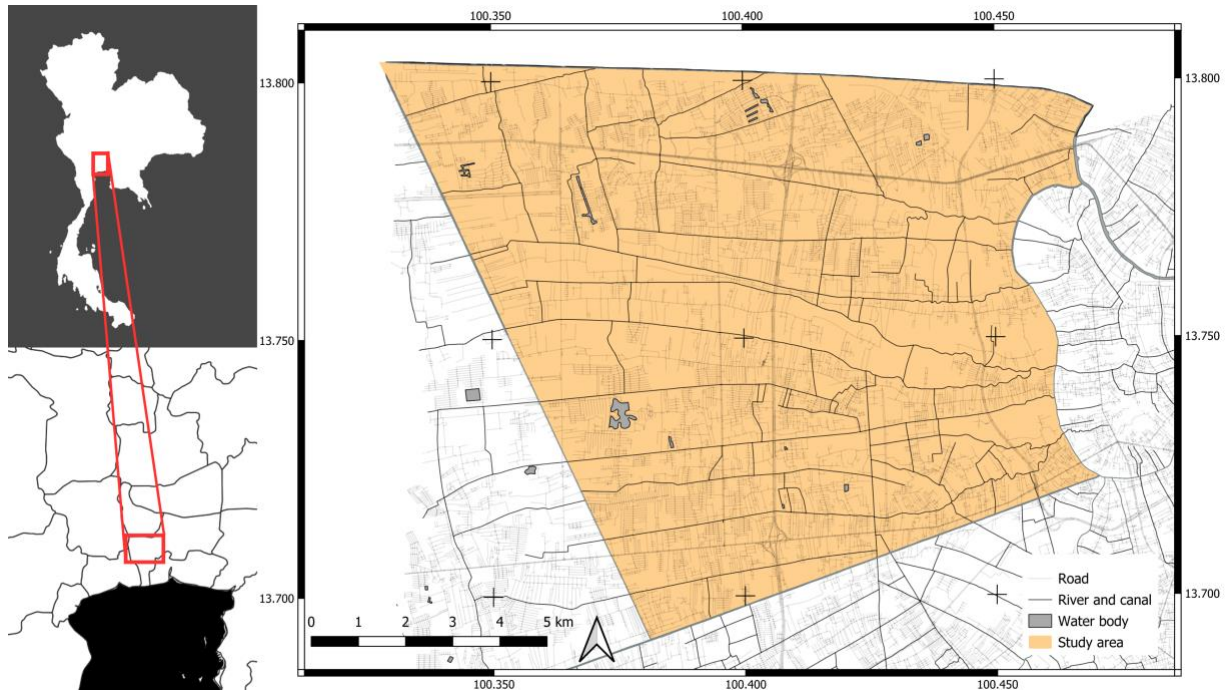
Canal-Side Environments and Small Paddle Boats Observed During the Rapid Field Survey, Showing Typical Residential Waterfronts, Informal Docking Structures, and Everyday Water-Mobility Conditions in Western Bangkok



Note. The photographs illustrate typical residential interfaces with the waterway, including small self-owned paddle boats, informal docking structures, and varying embankment conditions. These images document the everyday mobility landscape encountered along narrow and shallow canal segments and highlight the environmental and infrastructural constraints that shape water-based micro-mobility.

Figure 3

Map of the Study Area Showing the Canal Corridor Extending From the Old Chao Phraya River Course to Khlong Thawi Watthana, Bounded by Khlong Maha Sawat in the North and Khlong Phasi Charoen in the South



Note. The map depicts the hydrological boundaries and historically excavated canal branches that structure the study area and support vernacular water-based mobility, including the continued use of self-owned paddle boats.

A 1 km by 1 km vector grid was generated to provide a standardized unit of analysis across the study area (Figure 4). Spatial datasets were compiled for canal routes and navigable segments, points of access (embarkation and disembarkation landings), and public transport nodes (bus stops/MRT/BTS). All layers were projected into a meter-based coordinate reference system to ensure consistent distance calculations and spatial joins.

Connectivity and Activity Analysis

Connectivity was measured using a nearest-distance approach, calculating the distance from each canal route segment to the closest functional access landing point (disembarkation),

and aggregating results to a 1 km grid as an average canal-to-landing distance per cell. Transit stations were mapped as a separate public transport layer to contextualize potential multimodal integration. Activity intensity was captured by counting observed boat movements and the number of embarkation and disembarkation points within each cell, providing a proxy for vernacular mobility density and access opportunity. A working assumption was applied that 1 km requires roughly 15 minutes of paddling at an average speed of about 4 km/h. Tidal effects were not treated as a primary variable because the study area functions as a semi-closed system controlled by floodgates, where water-level changes are relatively moderate.

Figure 4
One-Kilometer Grid-Based Spatial Analysis of Boat and Pier Density in Western Bangkok. Darker Grid Cells Indicate Higher Concentrations of Observed Boat Activity and Pier Infrastructure, Highlighting Pronounced Mobility Clusters Along Key Canal Corridors



Note. The map illustrates spatial disparities between active and underutilized segments and provides the basis for hotspot identification in the study.

Connectivity–Activity Typological Classification

Grid cells were classified using a connectivity–activity matrix. Connectivity tiers were defined by distance to the nearest functional access landing point (disembarkation) (T1 $\leq 1,000$ m, T2 1,000–2,000 m, T3 ≥ 2000 m; and no boat/transit segment), while activity was classified as high (≥ 5 boat movements per cell) or low (< 5). This typology identifies core corridors, areas with demand but weak land-based linkage, and zones with latent potential. The analysis is intentionally framed as a stress-test scenario to expose development gaps. Although spatial proximity may suggest feasibility, real barriers remain, including the absence of safe landings, lack of formal piers, and no secure places to leave

boats, highlighting that canal-to-bus integration is primarily an infrastructure and governance issue rather than a distance-only problem.

RESULTS

Initial analysis showed that boat operations were strongly clustered in the districts of Taling Chan and Phasi Charoen (Table 1), forming a continuous corridor of activity extending from Khlong Lat Mayom to Khlong Bang Luang. In contrast, segments in Bang Khea and Thawi Watthana exhibited low or sporadic activity. These patterns indicate the presence of active vernacular mobility zones as well as underdeveloped areas that represent potential

sites for targeted infrastructure investment and improved multimodal integration.

Table 1 presents aggregated canal-based mobility indicators classified by district in western Bangkok. The results reveal strong spatial concentration in Taling Chan and Phasi Charoen, which record substantially higher boat counts, density values, and numbers of functional access landings compared to Bang Khae and Thawi Watthana. This district-level contrast indicates that vernacular paddle-boat mobility is not evenly distributed across the study area but is instead concentrated in specific administrative zones where canal morphology, settlement structure, and access landing provision reinforce operational viability.

The grid-cell analysis presented in Table 2 reveals clear spatial variation in canal-based mobility and access infrastructure. Core corridor cells located within 1,000 meters of access landings account for the majority of observed boat activity, with 50 active cells generating 435 recorded movements. These cells also exhibit the highest average number of embarkation points, indicating concentrated and functionally viable vernacular mobility clusters. In contrast, transitional cells between 1,000 and 2,000

meters and peripheral cells beyond 2,000 meters record no observed boat activity despite the presence of some access infrastructure, suggesting that increasing distance significantly reduces operational feasibility. A separate group of 89 cells lacked modeled canal linkage within the connectivity framework; notably, 28 of these cells still recorded boat activity, accounting for 353 movements. This distribution highlights both distance-related accessibility constraints and the presence of active but structurally disconnected vernacular mobility. The classification rule applied in this study follows accessibility thresholds commonly used in transport planning to evaluate service catchments and micro-mobility range:

- Tier 1 High connectivity: mean distance < 1 km
- Tier 2 Moderate connectivity: mean distance 1–2 km
- Tier 3 Low connectivity: mean distance > 2 km
- No modeled canal linkage: The average distance is null (no data).

Table 1

District-Level Distribution of Observed Boat Activity, Density, and Functional Access Landings in Western Bangkok

District Name	Number of Boats	Average Boat Density (per km)	Point of Access (embarkation)
Bang Khea	32	2.90	249
Phasi Charoen	151	6.63	793
Taling Chan	496	8.28	1,838
Thawi Watthana	6	0.83	52

Note. This table summarizes aggregated statistics by district based on field surveys conducted in November 2025 (07:00–16:00, weekdays and weekends). “Number of Boats” includes all vessels observed, whether moving or stationary. “Average Boat Density (per km)” represents the calculated mean number of boats per kilometer of canal within each district. “Point of Access (embarkation)” refers to the total number of mapped functional access landings (embarkation and disembarkation points). Districts are presented for comparative analysis rather than ranked as top corridors.

Table 2
Grid-Cell Distribution of Boat Activity, Access Infrastructure, and Canal Connectivity in Western Bangkok

Classification	No. of Grid Cells	Cells with Boat Activity	Total Boat Activity	Average Embarkation Point (per cell)	Average Access Landings (per cell)
Core corridors (High activity, ≤1000 m)	74	50	435	26.09	5.72
Transitional zones (Moderate activity, 1000–2000 m)	21	0	0	1.71	6.65
Peripheral inactive (>2000 m)	24	0	0	0.00	5.79
No modeled canal linkage	89	28	353	12.53	0.00

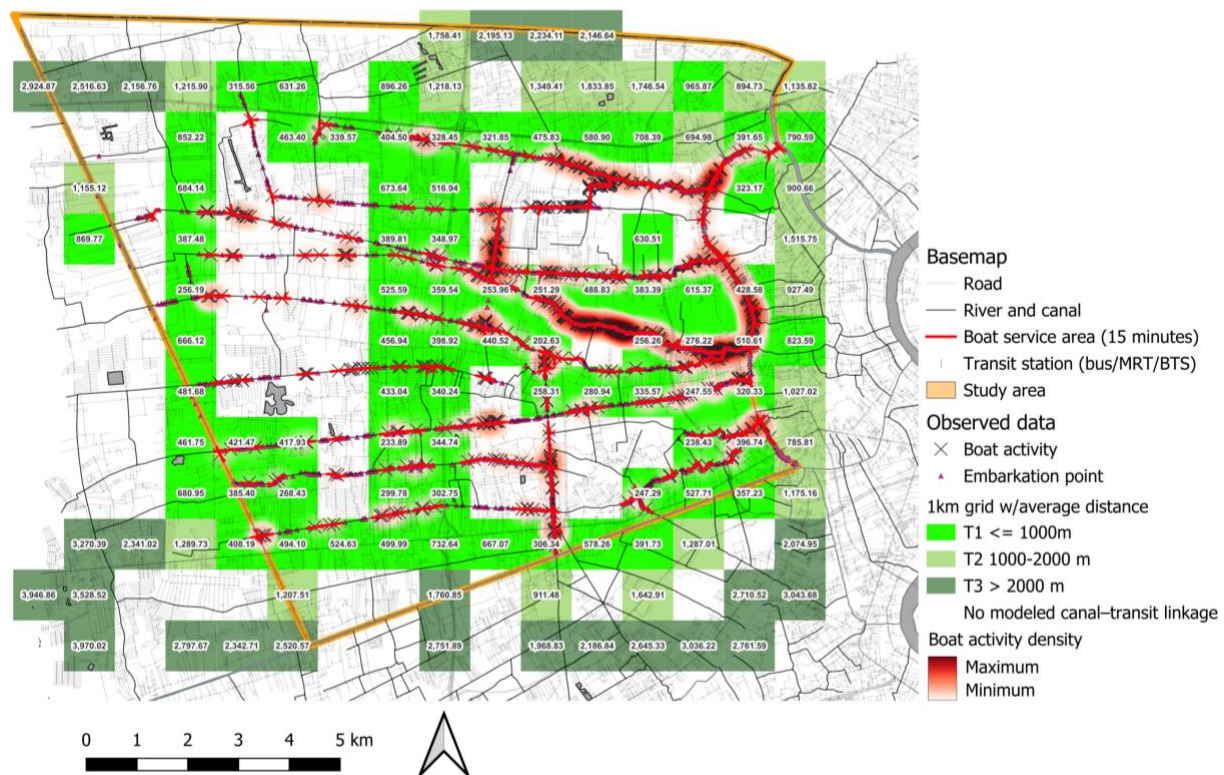
Note. Grid cells are grouped according to distance to the nearest access landing and modeled canal linkage. “Cells with Boat Activity” indicates the number of grid cells in which at least one active vessel was observed during field surveys conducted in November 2025. “Total Boat Activity” represents the aggregated count of observed boat movements within each category. Average values for embarkation points and access landings are calculated per grid cell. “No modeled canal linkage” refers to cells where canal connectivity distance could not be computed within the spatial model.

To interpret spatial accessibility within the canal network, each grid cell was classified into connectivity tiers based on the mean paddle distance required to reach a functional access landing point (point of disembarkation). These thresholds align with micro-mobility literature that defines short-range, man-powered movement as most efficient within one kilometer, with performance and usage probability dropping sharply beyond three kilometers (Abduljabbar et al., 2021; Madapur et al., 2020). Studies in active mobility and short-trip transport similarly use 1–2 km as a standard catchment for non-motorized feeder systems, where distance directly influences likelihood of use and multimodal transfer efficiency (Kanuri et al., 2019; Nikitas, 2024). Applying this rule to paddle-boat movement provides a meaningful proxy for operational accessibility within a vernacular canal-based system.

The classification reveals a strongly uneven pattern of canal-access connectivity across the study area. A large share of the grid consists of cells with no modeled canal linkage, indicating canals that exist physically but remain disconnected within the multimodal framework. Among active cells, high-connectivity areas form the largest group, representing locations where short paddle distances and frequent access landings create the strongest potential for multimodal integration. Moderate-connectivity cells function mainly as transitional zones with inconsistent access conditions, while low-connectivity cells remain substantial, requiring long paddle distances despite canal presence. Overall, the results show that canal-based mobility persists only where access conditions are favorable, confirming that the system operates as a fragmented and highly localized mobility network and underscoring the need for targeted improvements to access landings and canal–land interfaces.

Figure 5

Spatial Classification of Canal Connectivity and Boat Activity Density Across Western Bangkok



Note. Grid cells are classified according to the mean distance from canal segments to the nearest functional access landing point (disembarkation). Transit stations are shown as separate layers and are not used to define connectivity tiers

The summarized activity–connectivity matrix (Table 3, Figure 6) shows a highly uneven spatial structure across the canal network. Only twenty-six cells fall into the high-activity and high-connectivity category, forming the core vernacular mobility zone where boat frequency and access landings reinforce each other. Several additional clusters show high activity but remain constrained by low connectivity, indicating clear infrastructural gaps. A larger portion of the network consists of low-activity cells, where

moderate or low connectivity limits canal use despite the presence of access landings. More than sixty cells exhibit either such activity or access, reflecting hydrological discontinuity or complete disengagement from mobility functions. These combined patterns highlight the fragmented nature of canal-based movement and emphasize the importance of access landings as critical spatial determinants of mobility potential.

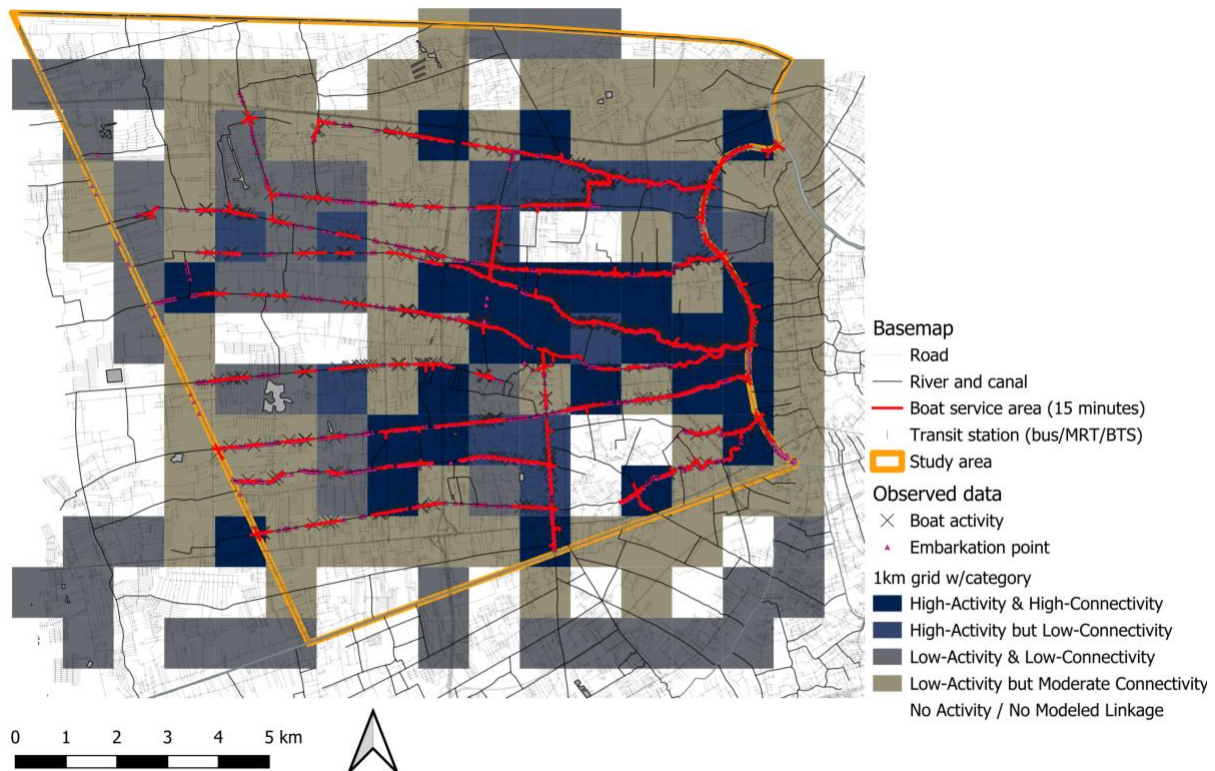
Table 3*Connectivity and Activity Analysis Summary Matrix*

Category	Number of Cells	Boat Activity (Criteria)	Connectivity Tier	Access Landing Density (per cell)	Summary Description
High-Activity & High-Connectivity	26	≥ 5	Tier 1, Tier 2	High (≥ 2 landings per cell)	Core vernacular mobility corridor. Strong convergence of movement and access. Includes Bang Chueak Nang, Bang Noi, and Lat Ta Niao clusters.
High-Activity but Low-Connectivity	14	≥ 5	Tier 3	Low (<1 landing per cell)	High demand but structurally weak access. Priority zones needing landing upgrades for integration (e.g., Row 57).
Low-Activity but Moderate Connectivity	69	< 5	Tier 1, Tier 2	Moderate (1–2 landings per cell)	Infrastructure exists but usage remains limited. Represents latent potential areas.
Low-Activity & Low-Connectivity	44	< 5	Tier 3	Sparse (0–1 landings)	Structurally disconnected segments with minimal mobility function. Requires major improvements.
No Activity / No Modeled Linkage	55	No boats (0)	N/A	None (0 landings)	Hydrologically inactive or isolated areas. Excluded from potential integration scenarios.

Note. Categories summarize patterns from the grid-level dataset of boat activity, access landings, and connectivity tiers derived from distance measures to the nearest landing. Access landing density distinguishes core mobility corridors from disconnected segments, while N/A denotes cells with no observed mobility or functional access.

Figure 6

Spatial Connectivity and Activity Classification



Note. The figure classifies grid cells based on canal activity intensity and multimodal connectivity. Activity is defined by boat density ("High-Activity" ≥ 5 boats). Connectivity is based on the average distance to the nearest functional access landing point (disembarkation) ("High/Moderate Connectivity" ≤ 1000 m). This matrix highlights gaps in the network: "Low-Activity/Moderate Connectivity" cells represent latent potential, while "High-Activity/Low-Connectivity" cells indicate areas needing urgent infrastructure upgrades.

DISCUSSION

These spatial results should be understood as an intentionally extreme analytical scenario. Connectivity analysis functions as a stress test to expose structural gaps in urban development rather than as a representation of existing operational conditions. By assuming movement feasibility based on distance alone, the analysis deliberately highlights how proximity does not translate into real accessibility. In practice, many theoretically connected areas remain functionally disconnected due to the absence of safe embarkation points, missing or informal piers, and the inability to securely dock or leave boats. This contrast between spatial potential and lived constraint underscores the depth of accessibility failure within Bangkok's canal system.

Spatial Analysis Interpretation and Comparison to Previous Research

The spatial mapping conducted in this study reveals distinct clusters of boat-based mobility within western Bangkok, particularly in the districts of Phasi Charoen, Bang Khae, and Chom Thong. Canal corridors such as Khlong Lat Mayom and Khlong Bang Luang exhibit the highest levels of activity, supported by quantitative observations in Khlong Bang Chueak Nang (146 boats) and Khlong Bang Noi (117 boats). In contrast, peripheral canals consistently recorded fewer than 20 boats. This pattern aligns with earlier studies which noted that although

many Bangkok canals have deteriorated, selected sections still support everyday water-based mobility (Iamtrakul & Raungratanaamporn, 2016; Iamtrakul et al., 2017). However, unlike previous work, this study integrates fine-grained empirical observations obtained through man-powered paddle-boat surveys, thereby documenting localized micro-mobility behaviors that were previously unrecorded.

The present study advances this understanding by introducing a systematic spatial hierarchy based on a 1x1 kilometer grid and spatial density and clustering analysis. These tools demonstrate that underutilized canals are not isolated anomalies, but part of a broader, spatially structured pattern shaped by accessibility, settlement density, and land-use fragmentation. The integration of firsthand mobility data collected through self-owned, man-powered paddle boats further enhances the granularity of the dataset, capturing movement patterns that are not documented in official records. This methodological addition reveals small-scale mobility behaviors that conventional surveys and high-level geospatial analysis tend to overlook, including trips occurring in narrow, hydrologically constrained, or unofficial canal segments. The results indicate that while many sections of the hydrological network remain degraded, several canal corridors retain the latent capacity to support short-distance mobility and multimodal linkages if complemented by targeted infrastructural and policy interventions.

Infrastructure Disparities, Governance Gaps, and Barriers to Modal Integration

Although certain canal corridors exhibit localized clusters of activity, the canal system faces critical infrastructural and governance limitations that significantly restrict its broader mobility potential. Field observations reveal that many canals lack the basic conditions required for safe and reliable travel. These deficiencies include the absence of standardized points of access (embarkation), poor or discontinuous pedestrian access, inadequate lighting, insufficient dredging, and irregular floodgate operation. Such constraints

reduce navigability and undermine everyday use, particularly in districts such as Nong Khaem and Bang Bon, where canals are physically present but remain severely underutilized. These findings are consistent with previous assessments that identify sediment accumulation, disrupted water flow, and fragmented management practices as major impediments to canal-based transport in Bangkok (Iamtrakul et al., 2017; Unakul, 2012).

These infrastructural disparities also produce patterns of inequality. Communities situated along well-maintained canals have access to more mobility options, while those located near poorly serviced waterways encounter barriers such as unsafe embankments, obstructed walkways, or unpredictable water levels. The analysis further shows that even where access points exist, their spatial distribution is highly uneven, leading to disparities in last-mile travel effort across neighborhoods. This uneven distribution of mobility opportunities reinforces spatial disadvantage and limits the capacity of canal corridors to function as inclusive transport infrastructure.

Comparative insights from global micro-mobility research further highlight the significance of integrated infrastructure. Successful systems rely on coordinated elements such as protected lanes, accessible docking points, and smooth multimodal transfers that connect local movement to larger transit networks (Chankrajang & Vechbanyongratana, 2020; Hossain & Iamtrakul, 2007). In contrast, Bangkok's canal network remains fragmented, lacks coherent multimodal interfaces, and does not yet meet the infrastructural standards necessary for consistent water-based mobility. As a result, the primary constraint on the expansion of canal-based micro-mobility is structural rather than demand-driven. The observed movement patterns, including the continued use of self-owned paddle boats, indicate that where infrastructure exists, residents are willing to use waterways. Yet the spatial analysis confirms that most households face long or inefficient paddling distances to reach functional access landings, which suppresses potential usage. However, without targeted improvements in canal maintenance, pier quality, and system-wide coordination, the integration of canal-based mobility into Bangkok's broader transport network will remain limited.

Recommendation of Policy, Governance, and Future Development

Addressing the gaps identified in this study requires repositioning canal mobility as a formal component of Bangkok's multimodal transport system rather than an informal, community-based mode. Such a shift demands coordinated governance among the Bangkok Metropolitan Administration, the Department of Water Transport, district offices, and private and community boat operators. An integrated policy framework should prioritize regular dredging and hydrological maintenance, standardized and safe pier infrastructure, and consistent floodgate operation to ensure reliable navigability. Enhancing signage, lighting, and wayfinding around access landings would further support safe multimodal transfer. In line with contemporary mobility systems, the development of unified ticketing platforms that link canal services with BTS and MRT networks, as well as micro-mobility docking areas for bicycles, e-scooters, and small electric boats, would strengthen multimodal access.

International cases offer valuable insight. Hong Kong's neighborhood transit networks, as seen in the 24.9% increase in MTR and bus patronage in 2023 (following the post-pandemic recovery and a new line opening) (MTR Corporation Limited, 2024), and Copenhagen's micro-mobility integration initiatives, demonstrated by the 148% increase in electric bicycle ownership between 2016 and 2020 (City of Copenhagen, 2021), show that targeted investment in small-scale, last-mile infrastructure can lead to substantial ridership gains. Drawing from these precedents, Bangkok could establish a Canal Mobility Integration Zone along high-potential corridors such as Khlong Bang Noi and Khlong Bang Chueak Nang. These zones should provide coordinated connections between access landings, feeder bus routes, cycling infrastructure, and 15-minute networks to support seamless multimodal travel. This re-framing of canals as micro-mobility infrastructure also aligns with emerging peri-urban planning frameworks that integrate ecosystem services and nature-based solutions within residential development (Irvine et al., 2023). In this sense, canal corridors

should not be treated solely as drainage or residual space, but as multifunctional blue-green infrastructure supporting mobility, hydrology, and ecological services simultaneously.

Improved canal-based accessibility may also generate measurable accessibility and land-value effects. Prior studies in the Bangkok Metropolitan Region demonstrate that transit accessibility significantly influences land value and development intensity (Tontisirin & Anantsuksomsri, 2021). While the present study does not model land value effects, the identification of high-potential corridors suggests possible secondary economic impacts if canal mobility were formally integrated.

From a broader planning perspective, the integration of vernacular paddle-boat mobility contributes to smart mobility and resilience transitions in Bangkok. Irvine et al. (2025) emphasize the integration of environmental systems within smart mobility frameworks. The canal network represents an underutilized environmental mobility layer within Bangkok's smart mobility vision, particularly in peri-urban districts where blue-green systems and transport planning remain institutionally disconnected.

Community participation is essential to long-term success, particularly given the continued use of self-owned, man-powered paddle boats observed in this study. Policies that incorporate community knowledge encourage local stewardship and support digital tools for real-time navigation, and canal status reporting can strengthen operational reliability and user confidence. Ultimately, a coordinated, evidence-driven governance structure has the potential to enhance mobility equity, reduce emissions, and transform Bangkok's canals into contemporary micro-mobility corridors aligned with the city's emerging 15-minute urban development vision. These reforms would reposition Bangkok's waterways from residual hydrological infrastructure into an operational, low-carbon mobility network capable of serving diverse urban populations.

CONCLUSION

This study demonstrates that Bangkok's canal network remains an important yet significantly underutilized component of the city's mobility system. Through the combined use of field observations, geospatial analysis, and the first systematic survey conducted using self-owned man-powered paddle boats, the research identifies clear spatial variations in water-based mobility, with the strongest activity concentrated along corridors such as Khlong Bang Chueak Nang, Khlong Bang Noi, and Khlong Lat Ta Niao. This methodological contribution provides empirical evidence of vernacular micro-mobility practices that formal datasets have historically overlooked.

While corridors such as Khlong Bang Chueak Nang and Khlong Bang Noi exhibit sustained activity, the majority are constrained by inadequate pier infrastructure, limited safety provisions, inconsistent hydrological conditions, and weak connections to land-based transport networks. These factors contribute to a fragmented mobility landscape that offers potential but lacks system-wide coherence. At the same time, the findings highlight both conceptual and practical implications for sustainable urban development. Water-based mobility can contribute to last-mile accessibility, reduce road congestion, and complement emerging micro-mobility strategies, particularly when supported by modern low-emission vessels, real-time information systems, and integrated multimodal transport nodes. By demonstrating how short-distance paddle-boat movement aligns with existing settlement patterns, this study expands the understanding of micro-mobility beyond land-based modes.

The alignment between canal-based mobility and the principles of the 15-minute city suggests that waterways can play a strategic role in promoting equitable, low-carbon, and neighborhood-centered urbanization. Recognizing canals as functional spaces for everyday travel reframes them as active mobility infrastructures rather than remnants of historic urban morphology. However, the stress-test framework applied in this study is distance-based and does not account for dynamic variables such as tidal currents, seasonal hydrological fluctuation, or qualitative

user preferences, which may influence actual operational feasibility.

Future policy directions should emphasize strategic investment in hydrological maintenance, standardized points of access (embarkation) infrastructure, and improved safety measures. Governance reforms that enable coordinated operations across agencies, along with meaningful community participation, are essential for long-term adoption. Enhancing multimodal integration between canals, pedestrian networks, micro-mobility services, and mass transit can further amplify the system's potential. Ultimately, the results reaffirm the enduring relevance of Bangkok's canal system as a resilient and historically grounded element of urban infrastructure with the capacity to serve as a contemporary micro-mobility corridor if supported by evidence-based planning and targeted infrastructural improvements.

Future research should extend this study through longitudinal monitoring to assess seasonal variation, hydrological fluctuation, and long-term behavioral patterns. Repeated surveys across different time periods would strengthen understanding of demand stability and infrastructural responsiveness. Comparative analysis with other canal cities in Southeast Asia or delta regions would further contextualize Bangkok's vernacular paddle-boat mobility within broader water-based transport systems and refine transferable policy frameworks.

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