EVIDENCE-BASED POLICY FRAMEWORK FOR TROPICAL UNIVERSITY WATERFRONTS: A FIVE-DIMENSIONAL SOCIAL EQUITY ASSESSMENT

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ABSTRACT

University waterfronts in Southeast Asia lack systematic policy frameworks linking community usage patterns to infrastructure investment, resulting in resource misallocation and social equity disparities. This study develops and validates a Five-Dimensional Environmental Quality (5D-EQ) framework addressing gaps in evidence-based institutional planning.

The framework integrates behavioral observation with environmental quality assessment across five dimensions: Accessibility, Landscape Character, Activity Diversity, Human-Nature Connection, and Safety & Comfort. Field testing at Chiang Mai University's waterfront employed validated inter-rater reliability protocols, normalized frequency analysis, and usage-accessibility correlation analysis across five zones.

Results revealed critical social equity concerns. Zone C showed highest community usage (NF=29.37) paired with severe accessibility deficits (ACC=1.90), indicating systematic mismatches between user needs and institutional provision. Universal deficiencies in human-nature connection across all zones highlighted unrealized community well-being potential.

The 5D-EQ methodology provides validated assessment protocols enabling systematic translation of behavioral evidence into measurable policy priorities. Framework application demonstrates scalability across Southeast Asian institutional contexts through cultural calibration protocols. This approach offers replicable methodology for evidence-based resource allocation, addressing common gaps where infrastructure investment misaligns with actual community usage patterns and social equity requirements.

Keywords: Evidence-Based Policy, Social Equity, Community Participation, Institutional Planning, Tropical Campus

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INTRODUCTION

University waterfronts function as critical public spaces requiring systematic policy approaches that balance community needs, social equity, and institutional resource constraints (Gehl, 2011). In tropical Southeast Asian contexts, these spaces face unique challenges in accommodating cultural preferences for evening communal activities, monsoon-climate adaptation, and intergenerational programming requirements. However, current institutional planning approaches often lack empirical evidence linking community usage patterns to infrastructure investment priorities, resulting in resource misallocation and social equity disparities (Mostafavi & Doherty, 2010).

The Huai Fai Hin waterfront at Chiang Mai University exemplifies these challenges, functioning primarily as transit corridor rather than community destination despite significant ecological and cultural importance. Limited infrastructure supporting diverse activities, inadequate accessibility provisions, and missed opportunities for human-nature connection indicate systemic policy gaps in evidence-based institutional planning (Browning et al., 2014; Marcus & Sachs, 2013).

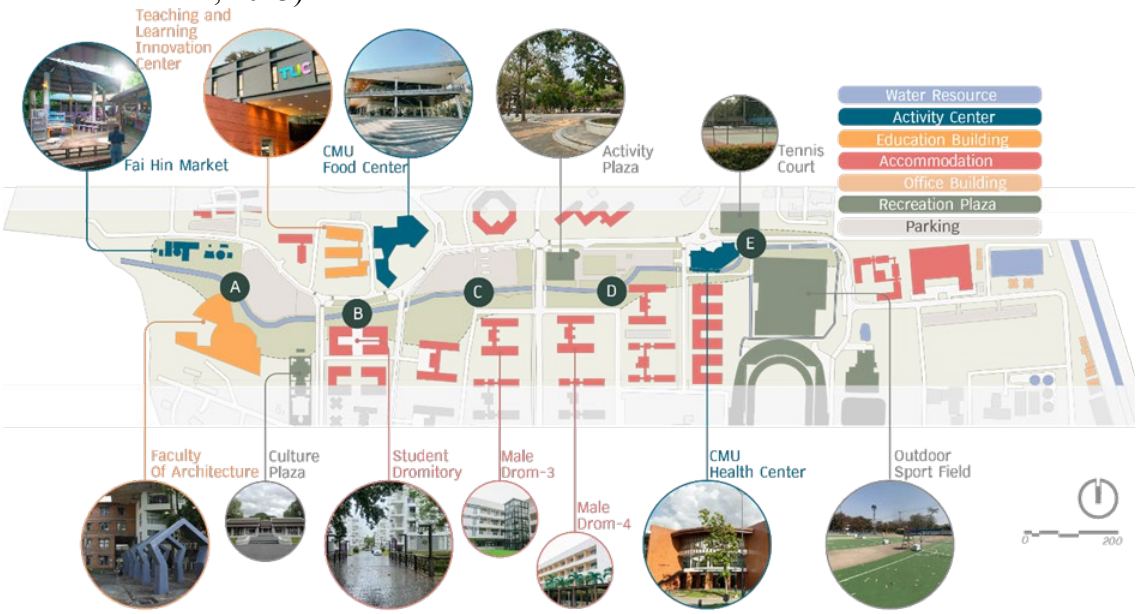

Figure 1 Study area map showing Huai Fai Hin waterfront with 5 zones (A-E) and major campus landmarks

This study addresses three critical research gaps: 1) lack of validated assessment tools linking community behavior to policy priorities in tropical institutional contexts, 2) insufficient understanding of social equity implications in campus waterfront utilization patterns, and 3) absence of systematic frameworks for translating empirical findings into measurable policy interventions. The research utilizes theoretical frameworks from sustainable waterfront development principles for university settings (Lee et al., 2017) to develop comprehensive assessment methodologies.

Research objectives are: (O1) develop and validate a reliable Five-Dimensional Environmental Quality (5D-EQ) assessment framework for evidence-based institutional policy making; (O2) document social equity patterns through systematic behavior-environment correlation analysis (Marcus & Sachs, 2013); and (O3) demonstrate framework application for community-centered resource allocation and performance measurement (Browning et al., 2014; Gehl, 2011).

LITERATURE REVIEWS

Theoretical Framework for Evidence-Based Institutional Policy

Evidence-based institutional planning requires integration of community participation, social equity assessment, and systematic performance measurement (Gehl, 2011). This study synthesizes five theoretical domains to develop comprehensive policy assessment methodology for tropical campus contexts.

Placemaking Theory emphasizes community-centered design creating meaningful public spaces through participatory engagement (Whyte, 1980; Gehl, 2011). In institutional contexts, this translates to spaces accommodating both functional circulation and destination programming while supporting diverse user interactions. Biophilic Design provides frameworks for community well-being through nature connection, addressing tropical campuses' needs for cooling microclimates and stress reduction (Browning et al., 2014).

Ecological Urbanism emphasizes sustainable institutional development through ecosystem-based approaches, including monsoon adaptation and biodiversity conservation (Mostafavi & Doherty, 2010). Sustainable Waterfront Policy integrates environmental protection with social equity and economic viability, emphasizing universal design principles and cultural integration (Breen & Rigby, 1996). Health-Oriented Public Policy supports community well-being through restorative environments and inclusive accessibility following established universal design guidelines (Carmona et al., 2010; Marcus & Sachs, 2013).

Community Participation and Behavioral Evidence in Institutional Planning

Traditional institutional planning approaches often lack empirical evidence linking community usage patterns to infrastructure investment priorities, resulting in resource misallocation and social equity disparities (Mostafavi & Doherty, 2010). Placemaking principles demonstrate that meaningful public spaces require systematic understanding of user behavior patterns and community engagement processes (Whyte, 1980; Gehl, 2011).

Research reveals that community behavioral evidence can systematically inform institutional resource allocation priorities through validated assessment protocols (Marcus & Sachs, 2013). The integration of systematic behavioral observation with environmental quality assessment enables identification of usage-accessibility mismatches that traditional planning methods cannot detect. This evidence-based approach addresses common gaps where infrastructure investment may not align with actual community usage patterns and social equity requirements.

Biophilic Design and Human-Nature Connection in Tropical Campuses

Biophilic design provides systematic frameworks for enhancing community well-being through nature connection, particularly relevant for tropical campuses requiring cooling microclimates and stress reduction opportunities (Browning et al., 2014). Research demonstrates that human-nature connection significantly impacts community space utilization patterns and psychological restoration outcomes.

In tropical institutional contexts, biophilic elements serve dual functions: environmental comfort through natural cooling and ventilation systems, and psychological well-being through direct and indirect nature experiences. The framework's emphasis on sensory engagement with natural elements—water sounds, vegetation textures, natural lighting patterns—provides measurable indicators for environmental quality assessment. These connections become particularly significant in monsoon-adapted tropical environments where covered social areas and elevated walkways must maintain human-nature connection while providing weather protection.

Ecological Urbanism and Sustainable Waterfront Development

Ecological urbanism emphasizes sustainable institutional development through ecosystem-based approaches, integrating monsoon adaptation strategies with biodiversity conservation goals (Mostafavi & Doherty, 2010). This approach recognizes institutional waterfronts as

complex socio-ecological systems requiring systematic integration of natural processes with community programming requirements.

Sustainable waterfront development principles provide operational frameworks for balancing environmental protection with social equity and institutional viability (Breen & Rigby, 1996). Traditional Southeast Asian architectural responses—elevated structures reducing flood risk, extensive roof overhangs creating covered social spaces, natural ventilation systems—demonstrate regionally-appropriate solutions for tropical campus waterfront challenges. These climate adaptations align with biophilic design principles while respecting regional building traditions and environmental constraints.

Regional Context and Knowledge Gaps in Southeast Asian University Waterfronts

Southeast Asian institutional waterfront research reveals significant policy gaps compared to temperate contexts (Mostafavi & Doherty, 2010). Regional universities demonstrate diverse usage patterns influenced by infrastructure policy and cultural practices, with some institutions achieving more distributed daily usage while others exhibit concentrated transit-focused patterns. Malaysian and Thai universities typically show morning-evening activity peaks consistent with monsoon adaptation and cultural preferences for cooler periods.

Thai campus research remains particularly limited, revealing critical policy gaps that systematic assessment frameworks must address: absence of validated assessment tools for tropical institutional contexts, insufficient understanding of community participation requirements, lack of evidence-based resource allocation frameworks, and minimal integration of traditional ecological knowledge with sustainability practices (Browning et al., 2014).

The Huai Fai Hin waterfront at Chiang Mai University exemplifies typical challenges facing Thai institutional waterfronts, functioning primarily as transit corridor rather than community destination despite significant ecological and cultural importance. Limited infrastructure supporting diverse activities, inadequate accessibility provisions, and missed opportunities for human-nature connection indicate systemic policy gaps in evidence-based institutional planning (Marcus & Sachs, 2013).

Five-Dimensional Environmental Quality Framework Development

The integration of multiple theoretical perspectives creates systematic foundation for comprehensive environmental quality assessment. Placemaking principles inform accessibility and activity diversity indicators; biophilic design shapes human-nature connection measures; ecological urbanism guides landscape character assessment; health-oriented principles underpin safety and comfort evaluation; while sustainable waterfront development provides cross-cutting integration ensuring policy coherence and implementation feasibility.

This theoretical synthesis addresses identified gaps through systematic methodology: Accessibility ensures equitable access across diverse user groups with tropical climate considerations; Landscape Character preserves institutional identity while supporting community well-being; Activity Diversity supports flexible programming accommodating temporal variations in tropical institutional life; Human-Nature Connection maximizes community well-being through environmental engagement opportunities; Safety & Comfort addresses both physical safety and thermal comfort essential for tropical community space utilization.

The framework enables systematic translation of community behavioral evidence into measurable policy priorities through validated assessment protocols, providing methodological foundation for evidence-based institutional planning that integrates community participation with systematic performance measurement.

RESEARCH METHODOLOGY

Research Design and Study Area

This study employed a mixed-methods case study approach, integrating quantitative behavioral observation and environmental quality assessment, based on a framework developed through qualitative synthesis of established theories. The research utilized a theory-driven approach synthesizing five core theories (Placemaking, Biophilic Design, Ecological Urbanism, Sustainable Waterfront Development, Health-Oriented Landscape) based on established waterfront development principles (Breen & Rigby, 1996) and sustainable waterfront campus development frameworks (Lee et al., 2017).

Research was conducted at Chiang Mai University's 1.03-kilometer Huai Fai Hin waterfront, segmented into five zones based on morphological and functional characteristics. Zone segmentation followed natural boundaries and usage patterns: Zone A (Eco-Market Edge), Zone B (Pedestrian Spine), Zone C (Central Green Hub), Zone D (Event Plaza), and Zone E (Health Loop Completion). This zoning approach enabled systematic comparison across diverse spatial conditions while maintaining ecological and social context integrity.

Five-Dimensional Environmental Quality Assessment Framework

The 5D-EQ framework comprises 20 sub-indicators (EQ01-EQ20) with four indicators per dimension, scored using 5-point scales with operational criteria. Accessibility (EQ01-EQ04) measures pathway compliance, universal design standards, and barrier-free access; Landscape Character (EQ05-EQ08) evaluates scenic quality, cultural integration, and ecological integrity; Activity Diversity (EQ09-EQ12) assesses programming flexibility and user accommodation; Human-Nature Connection (EQ13-EQ16) measures biophilic elements and environmental engagement opportunities; Safety & Comfort (EQ17-EQ20) evaluates lighting, cleanliness, surveillance, and emergency access.

Theoretical integration follows systematic mapping derived from Lee et al.'s (2017) 10 Principles into measurable field indicators across the five quality dimensions. Placemaking principles inform Accessibility and Activity Diversity indicators; Biophilic Design shapes Human-Nature Connection measures; Ecological Urbanism guides Landscape Character assessment; Health-Oriented principles underpin Safety & Comfort evaluation; while Sustainable Waterfront Development provides cross-cutting integration ensuring policy coherence and implementation feasibility.

Dimension scores are arithmetic means of constituent indicators. Overall EQ-20 score represents the mean of all 20 items, where higher scores indicate better environmental quality. This scoring approach enables both dimensional analysis and comprehensive quality assessment while maintaining statistical validity across diverse institutional contexts.

Table 1 Summary of EQ-20 dimensions, sub-indicator codes, and generic rating anchors

Dimension	Sub-indicator focus	Rating anchors (1-5 scale)
Accessibility (EQ01-EQ04)	Pathway width ≥2m; ramp compliance 1:12; signage clarity; chokepoint width ≥100cm	1=<25% compliance; 2=25-<50%; 3=50-<75%; 4=75-<90%; 5=≥90%
Landscape Character (EQ05-EQ08)	Plant diversity (10m radius); natural shade at seating; water view angles; water clarity	1=0-1 species/poor; 2=2 species/limited; 3=3 species/moderate; 4=4 species/good; 5=≥5 species/excellent
Activity Diversity (EQ09-EQ12)	Activity variety (20m radius); seating types;	1=0-1 types/limited; 2=2 types;

Dimension	Sub-indicator focus	Rating anchors (1-5 scale)
	flexible space (m²); convenience amenities ≤15m	3=3 types; 4=4 types; 5=≥5 types/diverse
Human-Nature Connection (EQ13-EQ16)	Clear water sounds; safe water-touch points; learning media/signage; biodiversity presence	1=none/absent; 2=limited/1 point; 3=moderate/2 points; 4=good/3-4 points; 5=excellent/≥5 points
Safety & Comfort (EQ17-EQ20)	Evening lighting ≥30 lux; cleanliness/no odor; passive surveillance; emergency exits ≤50m	1=poor/<25%; 2=fair/25-<50%; 3=moderate/50-<75%; 4=good/75-<90%; 5=excellent/≥90%

Description: Each dimension comprises four sub-indicators scored 1-5 using operational criteria. Dimension scores are arithmetic means of constituent indicators. Overall EQ-20 score is the mean of all 20 items; higher scores indicate better environmental quality.

Data Collection Protocol

Data collection included behavioral observation during three daily periods (06:00-09:00, 09:00-15:00, 15:00-19:00) and environmental quality assessment using the 20-indicator checklist. Two trained observers conducted assessments to enable inter-rater reliability verification using ICC(2,1) ≥ 0.70, Spearman's ρ ≥ 0.70, Mean Absolute Difference ≤ 0.75, and ≥95% agreement within ±1 point.

Behavioral mapping utilized Normalized Frequency (NF = total activities ÷ observation rounds) enabling cross-zone comparison. Environmental quality assessment employed standardized operational criteria derived from sustainable waterfront development principles (Lee et al., 2017).

Data Analysis

Normalized Frequency from behavioral mapping was correlated with 5D-EQ scores to identify usage-accessibility mismatches indicating social equity concerns (Gehl, 2011). Environmental quality scores were classified as Low (1.00-<2.50), Moderate (2.50-<3.50), or High (≥3.50) to enable systematic resource allocation prioritization and design intervention targeting.

RESEARCH RESULTS

Community Usage Patterns and Social Equity Concerns

Behavioral analysis revealed distinct usage patterns with Zone C exhibiting highest activity intensity (NF = 29.37) and Zone A lowest (NF = 10.28). Overall ranking: C > B > E > D > A. Evening periods showed highest activity across most zones, reflecting cultural adaptation to tropical climates.

Table 2 Normalized Frequency by Zone and Time Period

Zone	Morning (06:00-09:00)	Midday (09:00-15:00)	Evening (15:00-19:00)	All-day NF (mean)
A	7.17	7.65	16.04	10.28
B	19.75	29.40	5.83	18.32
C	28.85	25.55	33.73	29.37
D	3.67	8.75	23.22	11.87
E	8.75	9.56	27.65	15.31

Environmental Quality Assessment

Environmental quality assessment identified systematic deficiencies across zones. Critical gaps (≤2.50) included Accessibility in high-usage zones, universal Human-Nature Connection deficits (1.35-1.79 range), and Activity Diversity limitations in transit-oriented areas.

Table 3 Mean 5D-EQ scores by zone (A-E) and overall EQ-20 index

Zone	ACC	LC	AD	HNC	SC	Overall EQ-20	Critical Gaps (≤2.50)
A	1.86	3.55	2.68	1.79	3.38	2.65	ACC, HNC
B	3.75	3.25	2.38	1.38	4.25	3.00	AD, HNC
C	1.90	3.35	2.33	1.35	3.63	2.51	ACC, AD, HNC
D	2.28	3.08	3.00	1.45	3.98	2.76	ACC, HNC
E	3.38	2.94	2.19	1.69	3.81	2.80	AD, HNC

Social Equity Analysis

Correlation analysis revealed critical social equity concerns through usage-accessibility mismatches. As illustrated in Figure 2, Zone C demonstrates the highest social equity risk, positioned in the high-usage but low-accessibility quadrant (NF=29.37, ACC=1.90). This pattern indicates that the community's most utilized space simultaneously presents the greatest barriers to equitable access. In contrast, Zone B achieves optimal performance with balanced high usage and good accessibility (NF=18.32, ACC=3.75), while Zone A requires priority intervention due to both low usage and poor accessibility.

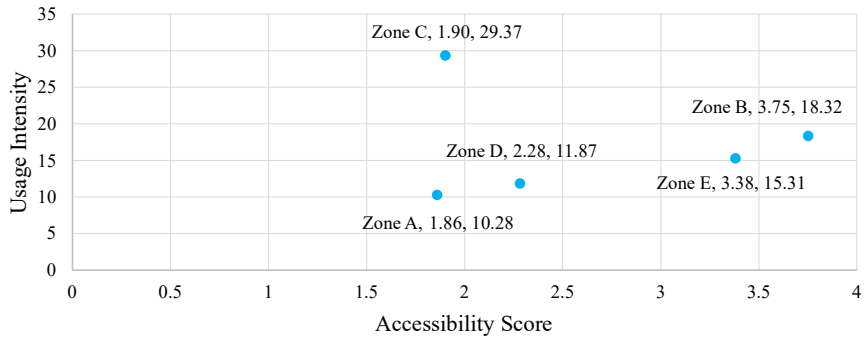

Figure 2 Social Equity Analysis Matrix - Usage vs. Accessibility by Zone

Results indicate systematic policy gaps where community's most utilized spaces present greatest barriers to equitable access, requiring immediate evidence-based intervention to address social equity disparities.

DISCUSSION

Evidence-Based Policy Framework and Social Equity Implications

The 5D-EQ framework enables systematic identification of usage-quality mismatches for evidence-based policy prioritization addressing social equity concerns. Zone C's high usage (NF=29.37) coupled with critical accessibility deficits (ACC=1.90) exemplifies how community behavioral evidence can reveal equity gaps hidden in traditional compliance-only assessments. This usage-accessibility mismatch indicates urgent policy intervention needs where institutional infrastructure provision fails to align with actual community usage patterns. Implementation analysis reveals systematic coordination challenges across organizational levels. Zone C's accessibility crisis requires coordination between Campus Development, Safety, Disability Services, and Student Affairs—creating potential delays between problem identification and solution implementation. University budget cycles create 3-4 year lags

between assessment findings and capital improvements, with short-term measures competing against long-term infrastructure investments.

The framework provides methodological contribution through validated assessment protocols enabling systematic translation of community behavioral evidence into measurable policy priorities. However, technical assessment excellence requires institutional coordination mechanisms for implementation success. Critical improvements include: establishment of Waterfront Steering Committee with multi-level representation, fast-track mechanisms for accessibility improvements, and quarterly coordination meetings between lead agencies to address cross-jurisdictional issues.

Regional Application and Cultural Adaptation Requirements

Framework application across Southeast Asian contexts requires cultural calibration addressing regional variations in community engagement patterns. Evening usage peaks across most zones reflect distinctly Thai cultural preferences for communal activities during cooler temperatures, with Zone D showing concentrated evening activity (23.22 NF compared to 3.67 morning NF). These diurnal activity rhythms align with monsoon-climate adaptation strategies, confirming framework relevance while identifying culture-specific policy considerations.

Thai cultural context influences spatial design requirements prioritizing thermal comfort over aesthetic considerations. Zone B's continuous shade corridor success validates regional institutional planning approaches recognizing traditional Thai architectural responses—elevated structures, extensive roof overhangs, and natural ventilation systems (Marcus & Sachs, 2013). Cultural preferences for cool, airy spaces and respectful teacher-student interactions require flexible programming supporting both daily informal use and periodic cultural events.

Traditional Thai social patterns emphasize communal gathering during cooler evening hours, requiring infrastructure planning prioritizing evening lighting, social seating arrangements, and semi-private gathering nodes over individual recreation spaces (Gehl, 2011). Monsoon season programming must accommodate seasonal shifts toward covered spaces, while Thai university calendars incorporating cultural and religious observances require flexible programming supporting water-related ceremonies and large-scale cultural events.

The framework demonstrates scalability across Southeast Asian tropical institutional contexts through systematic cultural calibration while maintaining core assessment structure. Cultural adaptation protocols enable incorporation of local values while preserving five-dimensional structure and behavioral-spatial correlation methodology essential for evidence-based institutional planning.

Table 4 Policy Implementation Matrix - Priority Actions by Zone and Investment Timeline

Zone	Primary Gaps (≤2.50)	Strategic Intervention	Policy Measures	Timeline	Lead Agency
A	HNC, ACC	Eco-Market Edge Development	Shaded seating + interpretation + UD ramps	Short-term	Physical Planning + Academic Affairs
B	HNC, AD	Pedestrian Spine Enhancement	Safe crossings + group seating + identity cues	Medium-term	Transportation + Community Relations
C	ACC, AD, HNC	Universal Green Hub	Water-touch terrace + lighting + accessibility	Priority	Campus Development + Safety
D	ACC, AD	Event Plaza Activation	Flexible infrastructure + shade systems	Medium-term	Student Affairs + Facilities

Zone	Primary Gaps (≤2.50)	Strategic Intervention	Policy Measures	Timeline	Lead Agency
E	ACC, HNC	Health Loop Completion	Path connectivity + guardrails + habitat pockets	Long-term	Health Services + Environmental

The Implementation Matrix demonstrates cultural adaptation through zone-specific strategies that acknowledge Thai social patterns and climate considerations. Zone C's designation as "Universal Green Hub" reflects Buddhist principles of inclusive access, while Zone D's "Event Plaza Activation" accommodates traditional festival programming requirements. Timeline flexibility allows adjustment for monsoon seasons and cultural calendar considerations, with medium-term and long-term phases coordinated with Thai university budget cycles and religious observances.

This cultural calibration ensures the 5D-EQ framework serves diverse regional contexts while respecting local values, environmental conditions, and institutional practices essential for sustainable waterfront development in Southeast Asian university settings.

Methodological Contributions and Implementation Framework

The 5D-EQ framework provides methodological contribution to evidence-based institutional planning through validated assessment protocols. Translation of assessment findings into institutional improvements requires systematic policy roadmap alignment with university planning cycles. Analysis of the Priority Actions Matrix (Table 4) reveals the need for multi-phase implementation strategy coordinated with Thai university budget cycles.

Phase 1 (0-12 months) prioritizes immediate safety and accessibility interventions, addressing Zone C's critical equity gap (NF=29.37, ACC=1.90). Phase 2 (12-24 months) focuses on activity enhancement, transforming transit-dominated zones into destination spaces with 40-60% increase in non-transit activities. Phase 3 (24-36 months) encompasses comprehensive landscape character and ecosystem integration, aligning with university's 5-year strategic plan and seeking external funding. Thai university budget cycles follow October-September fiscal years with 12-18-month advance planning. The implementation framework aligns 5D-EQ assessment findings with annual space utilization reports, enabling evidence-based budget request preparation within established institutional planning processes.

To ensure systematic performance measurement, primary KPIs derived from the 5D-EQ framework enable quarterly measurement across four weighted categories: Safety and Accessibility (30%), User Engagement and Social Equity (25%), Environmental Quality and Sustainability (25%), and Institutional Integration and Academic Value (20%). Each category includes specific measurable targets, such as 95% pathway width compliance, zero serious accidents, and minimum 15 native species diversity per assessment point.

Waterfront development objectives synchronize with broader university strategic priorities including Academic Excellence through outdoor learning space creation, Social Responsibility through universal accessibility demonstration, Operational Excellence through evidence-based infrastructure management, and Innovation leadership through living laboratory establishment for sustainability research. This alignment ensures institutional buy-in and resource allocation while maintaining accountability through measurable outcomes.

The study establishes post-implementation evaluation protocols enabling institutional learning through systematic performance measurement. Integration of community participation with evidence-based policy cycles requires five systematic phases: baseline assessment using validated protocols, collaborative planning with stakeholder engagement, phased implementation with performance monitoring, post-occupancy evaluation combining assessment with community feedback, and continuous improvement through adaptive management.

Implementation includes monthly user surveys, quarterly 5D-EQ spot checks, annual comprehensive assessment, and real-time incident reporting. Performance triggers establish clear intervention criteria: safety KPIs below target require 48-hour response, accessibility compliance below 90% triggers accelerated improvement plans, and user satisfaction below 3.5/5.0 initiates stakeholder consultation. Systematic documentation captures implementation experiences in searchable database enabling best practice identification and knowledge sharing. Professional development programs ensure institutional capability for universal design and participatory planning while student research integration creates opportunities within waterfront development projects.

This cyclical approach ensures policy decisions remain grounded in empirical evidence while enabling community participation integration and systematic knowledge building for tropical institutional development.

Comparative Analysis and Framework Advantages

The 5D-EQ framework addresses critical gaps in existing campus waterfront assessment through systematic integration of behavioral observation with spatial quality evaluation. Traditional approaches focus on single dimensions—user satisfaction surveys, infrastructure compliance audits, or environmental assessments—without correlation between usage patterns and spatial quality indicators. Established tools such as Project for Public Spaces (PPS) Place Diagram emphasize qualitative observation but lack standardized scoring protocols enabling cross-site comparison. The 5D-EQ framework advances this through validated 20-indicator checklist with operational criteria and inter-rater reliability verification, enabling systematic replication across institutional contexts.

The framework's systematic correlation between Normalized Frequency data and spatial quality scores enables identification of usage-accessibility mismatches impossible through single-dimension approaches. This integration revealed Zone C's critical social equity gap (NF=29.37, ACC=1.90) hidden in compliance-only assessments. Such comprehensive analysis provides institutional decision-makers with actionable insights that traditional assessment methods cannot deliver.

In terms of practical implementation, the framework demonstrates remarkable flexibility across institutional contexts through adjustable cultural calibration while maintaining core assessment structure. Smaller institutions can implement simplified versions focusing on critical indicators: Accessibility (EQ01-EQ04), Safety & Comfort (EQ17-EQ20), and Human-Nature Connection (EQ13-EQ16), addressing resource constraints while maintaining validity. Implementation requires 2-3 hours per zone assessment compared to weeks for traditional environmental studies, enabling quarterly monitoring functionality absent in annual comprehensive assessments. This responsiveness supports adaptive management addressing emerging issues without complete evaluation cycles.

While developed in Thai context, the framework's foundation in universal design principles and evidence-based planning enables adaptation across cultural contexts. The cultural calibration model provides systematic approach for incorporating local values: replacing Buddhist concepts with relevant spiritual traditions, adapting climate-specific requirements, and adjusting social space preferences while maintaining five-dimensional structure and behavioral-spatial correlation methodology. This cross-cultural transferability expands the framework's applicability beyond Southeast Asian institutional contexts.

The framework's direct linkage to Implementation Matrix (Table 4) and KPI framework enables immediate translation of assessment findings into budget requests, project prioritization, and performance monitoring. This addresses the common gap between assessment and action in institutional planning, providing systematic approach to cross-departmental implementation through Lead Agency assignments and shared performance metrics. Unlike static compliance assessments, the framework enables post-occupancy

evaluation using identical indicators, facilitating before-after comparison and intervention effectiveness measurement. Integration of user feedback through behavioral observation with technical compliance through spatial quality provides balanced accountability addressing both community satisfaction and institutional requirements while maintaining systematic evidence base for decision-making.

Limitations and Methodological Considerations

External Validity and Seasonal Pattern Limitations: Research conducted during single dry season represents a critical limitation affecting external validity. Monsoon season patterns, when outdoor utilization differs significantly due to flooding and temperature extremes, remain uncharacterized.

Zone-specific monsoon impacts would particularly affect high-usage areas: Zone C's accessibility crisis (ACC=1.90, NF=29.37) would worsen during flooding without alternative elevated routing, while Zone A's limited usage (NF=10.28) suggests complete abandonment during monsoon periods. Climate-adapted solutions require elevated walkways, covered social nodes at 100-meter intervals, and flexible programming spaces aligning with traditional Thai architectural responses of elevated structures and extensive roof overhangs (Browning et al., 2014).

Multi-seasonal data collection would enable development of season-specific assessment criteria within the 5D-EQ framework, strengthening validity for year-round policy planning.

Cultural Sensitivity and Qualitative Data Limitations: The 5D-EQ framework's quantitative 1-5 scoring system may inadequately capture qualitative environmental preferences valued in Buddhist/Thai cultural contexts, such as spiritual tranquility and intergenerational respect protocols.

Culturally-specific indicators require development: Spiritual Tranquility Index (quiet zones, natural sound buffering, appropriate placement of Buddhist symbols), Intergenerational Harmony Index (graduated seating enabling hierarchical respect while maintaining accessibility), and Cultural Event Integration Index (modular infrastructure for religious observances and water-related ceremonies).

Implementation requires collaboration with CMU's Buddhist Studies Department, local temple networks, and traditional knowledge practitioners through systematic consultation protocols and multi-generational user feedback (Marcus & Sachs, 2013).

Limited Statistical Power and Sampling Constraints: Five-zone analysis provides limited statistical power for robust correlation analysis. Behavioral observation sample sizes varied significantly across zones (12-28 observation rounds per zone due to weather constraints), creating uneven data quality and constraining analysis to descriptive rather than inferential statistics.

Dataset expansion strategies include: incorporating CMU's Mae Ping River sections and regional university partnerships (Maejo, Payap, RMUTL) to increase from 5 to 100+ zones across regional network; standardizing minimum 25 rounds per zone and 150 documented activities per zone; establishing Southeast Asian University Waterfront Research Network enabling shared resources and meta-analysis capabilities.

Resource-efficient approaches include tiered implementation: Level 1 (10 critical indicators), Level 2 (full 20-indicator assessment), Level 3 (regional network participation).

Additional Methodological Considerations: Assessment by only two observers with architectural backgrounds introduces systematic bias. Visible documentation may influence user behavior, potentially inflating Transit Use while underestimating Social Interaction activities. Single case study at CMU's research-status, suburban context limits applicability to institutions with different characteristics or resource levels. Data collection during regular academic semester may not represent usage patterns during examination periods or academic breaks when student populations change dramatically.

These limitations establish clear directions for framework development: multi-seasonal validation studies, culturally-sensitive indicator development, cross-institutional collaborative networks, and longitudinal implementation impact assessments. Framework refinement should prioritize practical applicability while maintaining empirical rigor for evidence-based institutional planning across diverse tropical campus contexts (Mostafavi & Doherty, 2010).

Regional Context and Tropical Campus Challenges

Southeast Asian University Waterfront Development Gaps: Southeast Asian institutional waterfront research reveals significant policy gaps compared to temperate contexts (Mostafavi & Doherty, 2010). Regional universities demonstrate diverse usage patterns influenced by infrastructure policy and cultural practices, with Singapore's comprehensive infrastructure enabling more distributed daily usage compared to concentrated transit-focused patterns observed in other metropolitan areas. Malaysian and Thai universities typically show morning-evening activity peaks consistent with monsoon adaptation and cultural preferences for cooler periods. Thai campus research remains particularly limited, revealing critical gaps in evidence-based resource allocation frameworks and systematic integration of traditional ecological knowledge with sustainability practices.

Tropical Climate Adaptations and Regional Solutions: Tropical campus waterfront development requires systematic monsoon adaptation addressing seasonal flooding, humidity management, and year-round accessibility (Breen & Rigby, 1996). The framework's Safety & Comfort dimension incorporates monsoon-specific infrastructure including elevated walkways, covered social areas, and natural drainage systems maintaining community access during weather extremes. Traditional Southeast Asian architectural responses provide regional design vocabulary: elevated structures reducing flood risk, extensive roof overhangs creating covered social spaces, and natural ventilation maintaining comfort during humid periods (Browning et al., 2014).

ASEAN University Waterfront Approaches: ASEAN universities demonstrate diverse waterfront development approaches reflecting national priorities and resource availability (Marcus & Sachs, 2013). Singapore’s National University integrates waterfront research and recreation through comprehensive planning, while Indonesian universities prioritize flood management over community programming due to infrastructure constraints. Thai universities occupy middle position with established infrastructure but limited evidence-based planning frameworks. The 5D-EQ methodology addresses this gap while enabling knowledge transfer across regional networks through standardized assessment and cultural adaptation protocols.

Framework Applicability and Regional Implementation: The 5D-EQ framework's systematic approach enables cross-cultural application while preserving necessary adaptations for diverse national contexts. Cultural calibration requirements identified in this study—particularly monsoon-responsive infrastructure, Buddhist/Thai spiritual considerations, and traditional ecological integration—provide templates for similar adaptations across Southeast Asian institutional contexts. Regional implementation through collaborative networks could address individual institutional resource limitations while building collective expertise for tropical campus waterfront development.

CONCLUSION

This study developed and validated the 5D-EQ framework for evidence-based institutional public space policy in tropical campus contexts. The key contribution demonstrates how community behavioral evidence can systematically inform resource allocation priorities, addressing common gaps where infrastructure investment misaligns with actual usage patterns and social equity needs.

Key Research Contributions

Methodological Innovation: The 5D-EQ framework enables systematic translation of behavioral evidence into measurable policy priorities. Social equity analysis revealed critical mismatches—particularly Zone C's high usage (NF=29.37) with accessibility deficits (ACC=1.90)—providing evidence-based foundations for resource allocation.

Cultural Adaptation Protocols: Framework application across Southeast Asian contexts demonstrates scalability through systematic cultural calibration. Developed indicators for spiritual tranquility, intergenerational harmony, and traditional ecological knowledge offer replicable approaches for contextualizing universal design principles.

Implementation Methodology: Evidence-based identification of usage-quality gaps enables targeted interventions through three-tiered approach: network-level connectivity, zone-specific infrastructure upgrades, and community engagement integration with measurable performance indicators.

Policy Impact and Future Applications

The framework addresses critical needs as institutions increasingly serve as community anchors requiring systematic decision-making tools. Multi-seasonal validation studies, cross-institutional collaborative networks, and culturally-specific indicator development represent priority directions for framework enhancement while maintaining empirical rigor.

The 5D-EQ methodology provides replicable foundation for transforming institutional public spaces through systematic, participatory, and evidence-based policy implementation across diverse tropical campus contexts.

Table 5 Implementation Checklist for Institutional Policy Makers

Implementation Area	Performance Target	Measurement Method	Monitoring Frequency	Compliance Standard
Universal Access	Pathway width ≥1.8m; ramp slope ≤1:12	Field audit with tape measure/clinometer	Semi-annual	≥95% compliance
Safety Infrastructure	Pedestrian yielding ≥90%; approach speed reduction ≥5 km/h	On-site observation during peak hours	Quarterly	Continuous improvement
Lighting Standards	Walkway illuminance ≥30 lux; uniformity ratio ≤3:1	Lux meter survey (5-point grid method)	Bi-annual	100% compliance
Community Spaces	Rest node spacing 120-180m; PM occupancy 40-60%	GIS measurement + behavioral observation	Quarterly	Target range achievement
Water Interaction	Safe water-touch points ≤150m intervals; all guarded	Site audit with safety checklist	Semi-annual	100% safety compliance
Environmental Quality	Native species ≥15 types; habitat indicators present	Ecological survey + biodiversity check	Annual	Biodiversity maintenance
User Experience	Wayfinding comprehension ≥80%; marker spacing ≤200m	User intercept testing	Quarterly	User satisfaction target
Incident Management	Zero serious accidents; maintenance response ≤48h	Safety reporting system + response logs	Continuous	Zero tolerance policy

Note: Accessibility standards based on Americans with Disabilities Act (ADA) 2010 Standards for Accessible Design and ISO 21542:2011 Building Construction - Accessibility and Usability of the Built Environment.

Implementation Framework

Policy implementation operates on five key principles: 1) evidence-based decision making using 5D-EQ results, 2) phased implementation prioritizing high-usage zones with critical gaps, 3) mandatory community participation through systematic consultation, 4) quarterly performance accountability, and 5) adaptive management with annual review cycles.

This systematic approach ensures resource optimization while maintaining social equity and community participation essential for sustainable institutional development.

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