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Transit-Oriented Development Indicators for Suburban Railway Stations in Thailand: A Context-Specific Fuzzy Delphi Approach

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Abstract

This study identifies suitable indicators for Transit-Oriented Development (TOD) in suburban areas of Thailand using the Fuzzy Delphi Method to gather expert consensus. While TOD has been extensively studied in urban cores, suburban regions with distinct characteristics, including lower densities, tropical climates, and prevalent informal transportation, have received limited attention. The research examined 48 indicators from international literature across three components: Transit System Indicators, Oriented System Indicators, and Development System Indicators. Through two rounds of expert consultation with ten professionals, 44 indicators were accepted, while four were rejected as being contextually inappropriate. Train service frequency (0.950), pedestrian walkway width (0.940), and mixed land use (0.940) emerged as the highest priorities. Rejected indicators included station retail outlets (0.710), pedestrian pathway gradient (0.670), high-rise building areas (0.670), and government service centers (0.677), revealing fundamental differences between suburban and urban TOD contexts. Three key themes emerged: climate-responsive infrastructure is essential in tropical environments, informal transportation modes require integration rather than elimination, and suburban development should pursue moderate-density horizontal mixed-use patterns rather than high-density urban forms. These findings provide practical guidance for evaluating and planning TOD around Thailand's expanding suburban railway network, supporting effective resource allocation and implementation strategies aligned with suburban realities while advancing sustainable mobility objectives.

Keywords: Transit-Oriented Development Indicators; Transit-Oriented Development; Fuzzy Delphi Method; Suburban; Railway Station

1. Introduction

Transit-Oriented Development (TOD) has emerged as a crucial concept in urban planning and the development of public transportation systems, emphasizing the creation of dense communities, mixed land-use patterns, and pedestrian-friendly environments (Ibraeva, A., et al., 2012; Vale, 2015). This approach has gained widespread recognition as a key strategy for reducing private vehicle dependency and promoting sustainable mobility (Loo, B. P. Y., & du Verle, F., 2016). However, while most TOD studies and applications focus on urban core areas, suburban regions with their distinct characteristics and challenges have received relatively little attention (Pengjun, Z., & Shengxiao, L., 2018).

Thailand is currently experiencing rapid urbanization and suburban expansion, particularly in peripheral metropolitan areas. This growth presents significant challenges in transportation planning and land-use management, characterized by low population density, high private vehicle dependency, and land-use patterns that differ substantially from those in urban cores (Kamruzzaman et al., 2014; Singh et al., 2014). The Thai government has invested substantially in expanding the regional railway network, with four major corridors spanning over 2,680 kilometers and serving 92 stations connecting suburban areas to urban centers. Research by Bolleter, J., & Ramalho, C.E. (2020) indicates that implementing Transit-Oriented Development (TOD) in suburban areas is more complex than in urban cores, requiring consideration of distinct accessibility factors and diverse transit connectivity needs.

The fundamental challenge in Thai suburban TOD implementation lies in the direct application of urban-centric principles without considering context-specific factors. Unlike dense urban cores, where TOD principles have proven effective, suburban areas in Thailand face different realities that significantly impact TOD feasibility and design. Additionally, the prevalence of informal transportation modes, particularly motorcycle taxis, which provide flexible first- and last-mile connectivity, necessitates station area designs that accommodate these services rather than exclude them.

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The cultural preferences for low-rise residential developments, fresh markets, and community-based activity spaces further distinguish Thai suburban contexts from Western models typically featured in TOD literature.

The absence of appropriate indicators hinders urban planners' and policymakers' ability to accurately evaluate Transit-Oriented Development (TOD) projects in suburban contexts, potentially leading to suboptimal development strategies (Schlossberg, M., et al., 2004). Developing suitable indicators for suburban TOD assessment is crucial, as indicators designed for urban cores may not fully capture the specific context and challenges of suburban areas. Previous studies have identified numerous indicators for evaluating TOD potential (Vale, 2015; Singh et al., 2014; Kamruzzaman et al., 2014), yet most originate from research conducted in urban core areas of developed countries with temperate climates and formal transportation systems. The direct application of these indicators to Thai suburban contexts may lead to misguided planning priorities, such as emphasizing high-density vertical development when moderate-density horizontal integration may be more culturally appropriate and economically viable.

To address these challenges, this study applies the Fuzzy Delphi Method, which has proven effective in urban planning and transportation research (Abdullah, R., et al., 2024). This approach combines expert knowledge with fuzzy logic to manage uncertainty and subjectivity in expert opinions. Rather than comprehensively examining all possible TOD factors, this research focuses on identifying which indicators, derived from international literature, are most relevant and applicable to the Thai suburban context. The study examines three critical components: transit systems, accessibility and connectivity, and spatial development, providing a comprehensive framework for evaluating TOD potential in suburban contexts while specifically addressing Thai challenges, including climatic impacts on walkability, integration of informal transport modes as intermodal transfer facilitators, and appropriate development densities that respect local cultural and market conditions.

The specific research objectives are: (1) to systematically compile TOD indicators from international literature relevant to suburban contexts; (2) to evaluate these indicators through structured expert consensus using the Fuzzy Delphi Method, determining which are most applicable given Thailand's specific challenges; (3) to develop a validated set of indicators specifically suited for assessing and planning TOD in Thai suburban railway station areas; and (4) to provide practical guidance for policymakers and planners in prioritizing interventions around suburban transit stations. By focusing on actionable, context-specific indicators rather than attempting comprehensive coverage of all TOD factors, this research aims to produce findings that can directly inform planning practice and support the development of more sustainable and livable suburban communities around Thailand's expanding railway network.

2. Literature Review

2.1 Transit-Oriented Development in Suburban Contexts

Transit-Oriented Development (TOD) represents a planning approach that integrates land use and transportation to create compact, walkable, mixed-use communities centered around high-quality transit systems. While extensively studied in urban core areas, suburban TOD presents distinct challenges requiring specialized consideration. Pengjun, Z., & Shengxiao, L. (2018) examined suburbanization and lifestyle mobility in Beijing's metro station areas, revealing that suburban passengers exhibit different travel patterns and activity choices compared to urban residents, with greater dependence on private vehicles for non-commute trips. This finding underscores the need for context-specific TOD strategies that acknowledge suburban realities.

Bolleter, J., & Ramalho, C.E. (2020) identified fundamental differences between urban and suburban TOD implementation, noting that suburban areas require greater attention to first-and last-mile connectivity, parking provision, and integration with existing low-density development patterns. Ahmad, M. S., & Suratman, R. (2020) conducted a critical review of suburban transit-oriented development, emphasizing that suburban TOD must balance transit accessibility with automobile accommodation during transitional periods, rather than immediately restricting car use, as in urban contexts.

2.2 Climate and Cultural Considerations in TOD

The influence of climate on TOD success remains underexplored in existing literature, which predominantly focuses on temperate regions. In tropical and subtropical contexts, high temperatures and humidity significantly impact pedestrian behavior and walking distances. Yang, W., Li, T., & Cao, X. (2024) studied TOD circles in the Tokyo metropolitan area, noting variations in sustainability performance from urban to suburban areas, partly attributable to environmental comfort factors affecting active transportation modes.

Cultural preferences and community characteristics also shape TOD viability. Ahmad, S., Rashid, M. F., & Suratman, R. (2022) assessed TOD readiness in Perak's suburban areas in Malaysia, finding that local community acceptance and cultural appropriateness of development densities were critical factors often overlooked in Western-derived TOD frameworks. This research highlighted the importance of considering traditional market spaces, religious facilities, and community gathering areas in suburban TOD planning.

2.3 Informal Transportation Integration

Developing countries often feature informal transportation modes that provide essential mobility services, particularly for first- and last-mile connectivity. Chatman, D. G. (2013) questioned whether TOD necessarily requires rail access, demonstrating that factors beyond rail transit, including bus services and informal transport, significantly contribute to TOD success. Gao, W., Yao, E., Zhang, Y., & Liu, S. (2024). Improved catchment area identification for suburban railway stations by incorporating whole-journey-based mode choices, recognizing that passengers often combine formal transit with motorcycle taxis, shared rides, and other informal modes.

The integration of informal transportation modes as legitimate components of the transit ecosystem, rather than obstacles to be eliminated, represents a crucial shift in suburban TOD thinking for developing countries. This approach acknowledges that motorcycle taxis, songthaews, and similar services offer flexible and affordable connectivity that formal systems struggle to replicate in lower-density suburban contexts.

2.4 TOD Indicators and Evaluation Frameworks

Comprehensive frameworks for evaluating TOD potential have been developed across various contexts. Vale, D.S. (2015) combined the node-place model with pedestrian shed ratio to evaluate station areas in Lisbon, creating a methodology that assesses both transit service quality and urban development characteristics. Singh, Y.J., Fard, P., & Zuidgeest, M. (2014) developed a spatial multi-criteria assessment approach for Arnhem and Nijmegen, incorporating accessibility, density, diversity, and design factors.

More recent research has refined TOD indicators for specific contexts. Li, Z., et al. (2019) analyzed variations, typology, and optimization of TOD among metro stations in Shanghai, identifying distinct suburban TOD patterns requiring different planning strategies than urban stations. Chen, X., et al. (2024) addressed integrated TOD with suburban rail network design for maximizing profits, demonstrating the economic viability considerations essential for suburban contexts. Xia, Z., et al. (2024) conducted a comprehensive literature review from 2000 to 2023, identifying built environment indicators that influence TOD performance, noting gaps in understanding suburban-specific factors.

2.5 Research Gaps and Study Rationale

Despite extensive TOD research, significant gaps remain regarding suburban contexts in developing tropical countries. Existing frameworks predominantly derive from urban core areas in developed temperate regions, potentially overlooking critical factors such as: (1) climatic impacts on walkability and necessary supporting infrastructure (covered walkways, rest areas) in hot, humid environments; (2) integration strategies for informal transportation modes as legitimate components of suburban transit ecosystems; (3) culturally appropriate development densities and land-use mixes that respect local preferences while supporting transit viability; and (4) context-specific station area amenities that reflect suburban travel patterns where stations serve primarily as transit points rather than destinations.

This study addresses these gaps by systematically evaluating which TOD indicators from international literature are most applicable to Thai suburban railway contexts, explicitly considering climatic, cultural, and transportation system characteristics unique to the region.

3. Research Methodology

3.1 Research Design and Expert Selection

This study applies the Fuzzy Delphi Method through a structured research process designed to identify context-appropriate TOD indicators for suburban railway stations in Thailand. The Fuzzy Delphi Method was selected for its effectiveness in managing uncertainty and subjectivity in expert opinions while building consensus on complex planning issues (Abdullah, R., et al., 2024).

The expert panel comprised 10 professionals with extensive experience in transit-oriented development, urban planning, and transportation engineering in Thailand. Expert selection followed purposive sampling criteria to ensure diverse perspectives and comprehensive expertise: (1) Academic experts: Four professors and associate professors from leading Thai universities specializing in transportation planning and urban development, with an average of 18 years of experience and publications in peer-reviewed international journals on TOD topics; (2) Government planners: Three senior planners from the Department of Public Works and Town & Country Planning and the Office of Transport and Traffic Policy and Planning, with direct involvement in railway station area planning projects and an average of 15 years of professional experience; (3) Practicing consultants: Three transportation and urban planning consultants who have conducted TOD feasibility studies and master planning projects for Thai railway stations, with an average of 12 years of consulting experience.

This expert composition ensures balanced perspectives incorporating theoretical knowledge, policy implementation experience, and practical market realities. The panel size of 10 experts aligns with recommendations by Habibi, A., et al. (2015) for Fuzzy Delphi applications, providing sufficient diversity while maintaining manageability for iterative consultation rounds.

3.2 Seven-Step Research Process

3.2.1 Study Area Delineation

This research focuses on evaluating Transit-Oriented Development (TOD) indicators for suburban railway stations along Thailand's regional railway network. The study area encompasses four main corridors: (1) Northern Line from Ban Phachi Junction to Chiang Mai Station (661 kilometers, 29 stations); (2) Northeastern Line from Ban Phachi Junction to Nong Khai Station (531 kilometers, 20 stations), with a branch to Ubon Ratchathani Station (309 kilometers, five stations); (3) Eastern Line from Chachoengsao Junction to Aranyaprathet Station (194 kilometers, five stations), with a branch to Ban Chang Station (125 kilometers, eight stations); and (4) Southern & Western Line from Ban Pong to Hat Yai Junction (860 kilometers, 25 stations).

The entire network comprises 92 stations and 2,680 kilometers of railway infrastructure. Station selection used a comprehensive assessment framework prioritizing: transportation significance (high-speed rail, light rail, provincial stations); economic positioning (special economic zones); appropriate land use within 500 meters (favoring urban zones over environmental conservation areas); population density thresholds; and excluding standalone bus terminals due to limited TOD potential. This selection ensures focus on stations with genuine suburban TOD development opportunities.

3.2.2 Indicator Data Collection

A comprehensive literature review identified 48 TOD indicators from 14 relevant studies published between 2012 and 2024, systematically documenting their frequency of appearance across the literature (Table 1). The researchers developed an evaluation framework categorizing these indicators into three primary components aligned with TOD theory and practice:

- Transit System Indicators (TS): 16 indicators covering service operations (train service frequency, multimodal transit connectivity, service hours), infrastructure facilities (park-and-ride capacity, kiss-and-ride areas, transit interchange facilities), and station amenities (basic amenities, retail outlets, wayfinding systems, accessibility features, security systems).
- Oriented System Indicators (OS): 15 indicators focusing on pedestrian infrastructure (walkway width, covered walkways, street crossings, continuous walkways, surface quality, universal design, gradient), access environment (route lighting, rest points, directional signage, route safety), and non-motorized transport (cycling networks, bicycle parking, shared pedestrian-cycling paths, walking distance to key points).
- Development System Indicators (DS): 17 indicators addressing land use and development (mixed land use, residential density, commercial distribution, high-rise building areas, vacant land development, land value, local employment), community facilities and services (educational facilities, healthcare facilities, religious facilities, recreational areas, community centers, government service centers, community market areas), and infrastructure and environment (public green space, basic infrastructure, environmental management).

Each indicator includes explicit measurement methodologies to ensure practical applicability and consistent evaluation across different station contexts.

3.2.3 Expert Data Collection

Data collection was conducted through a systematic two-round consultation process. In the first round, experts received a comprehensive questionnaire package including: (1) research objectives and methodology explanation; (2) definitions and measurement methods for all 48 indicators; (3) study area context describing Thai suburban characteristics; and (4) evaluation forms using a 7-point Likert scale ranging from "Extremely Important" (7) to "Extremely Unimportant" (1).

Experts assessed each indicator's importance for evaluating TOD potential in Thai suburban railway station areas, considering factors including: climatic appropriateness for hot, humid tropical conditions; compatibility with informal transportation modes prevalent in Thai suburbs; cultural appropriateness for Thai community preferences and lifestyles; practical measurability and data availability; and relevance to suburban rather than urban core contexts.

Experts also provided qualitative feedback explaining their ratings and suggesting modifications to indicator definitions or measurement approaches. The first-round questionnaire required approximately 90 minutes to complete. Following the initial analysis, indicators that did not meet the acceptance threshold (crisp value < 0.75) were revised based on expert feedback and re-evaluated in a second round with refined definitions and measurement criteria. The second-round questionnaire focused solely on previously rejected indicators, requiring approximately 30 minutes to complete.

3.2.4 Conversion of Variables into Fuzzy Numbers

The conversion of linguistic variables into triangular fuzzy numbers followed the methodology proposed by Habibi et al. (2015). Each expert's importance rating on the 7-point Likert scale was converted to a triangular fuzzy number (l, m, u), where l represents the lower bound (minimum acceptable value), m represents the most probable value (mode), and u represents the upper bound (maximum possible value).

The conversion scale used was: Extremely Important (7) = (0.9, 1.0, 1.0); Very Important (6) = (0.75, 0.9, 1.0); Important (5) = (0.5, 0.75, 0.9); Moderately Important (4) = (0.3, 0.5, 0.75); Unimportant (3) = (0.1, 0.3, 0.5); Very Unimportant (2) = (0, 0.1, 0.3); Extremely Unimportant (1) = (0, 0, 0.1).

This approach offers greater flexibility than crisp values in handling the inherent ambiguity and uncertainty in expert opinion expression, particularly for complex, multidimensional concepts such as TOD appropriateness.

3.2.5 Aggregation of Fuzzy Evaluation Values

The aggregation of fuzzy evaluations across experts was conducted using fuzzy arithmetic operations. For each indicator, the ten experts' triangular fuzzy numbers were combined using the fuzzy averaging method. The aggregated triangular fuzzy number for indicator i was calculated as:

$$\tilde{A}_i = (\tilde{l}_i, \tilde{m}_i, \tilde{u}_i) \quad (1)$$

where:

$$\tilde{l}_i = (l_{1i} + l_{2i} + \ldots + l_{10i}) / 10 \quad (2)$$

$$\tilde{m}_i = (m_{1i} + m_{2i} + \ldots + m_{10i}) / 10 \quad (3)$$

$$\tilde{u}_i = (u_{1i} + u_{2i} + \ldots + u_{10i}) / 10 \quad (4)$$

This method enables the synthesis of diverse expert opinions while preserving the uncertainty information embedded in the fuzzy representations (Abdullah & Othman, 2023).

3.2.6 Defuzzification

The conversion of aggregated fuzzy values back to crisp values employed the arithmetic mean method, as described by Wu and Fang (2011). For each indicator's aggregated triangular fuzzy number ($\tilde{l}$, $\tilde{m}$, $\tilde{u}$), the defuzzified crisp value was calculated as:

$$\text{Crisp Value} = (\tilde{l} + \tilde{m} + \tilde{u}) / 3 \quad (5)$$

This simple yet effective defuzzification method provides an intuitive interpretation of the fuzzy evaluation results, offering a clear understanding of the underlying data. Indicators with crisp values of≥ 0.75 were accepted as appropriate for evaluating Thai suburban TOD, representing a 75% consensus threshold commonly used in Delphi studies.

3.2.7 Expert Consensus Analysis and Indicator Finalization

The analysis of expert opinion consistency employed a consensus acceptance criterion of at least 75% agreement (crisp value ≥ 0.75), following the approaches of Murray and Hammons (1995) and Chu and Hwang (2008). After the first evaluation round, results were compiled and indicators were classified as either "Accepted" (crisp value ≥ 0.75) or "Requiring Review" (crisp value < 0.75).

For indicators requiring review, the research team analyzed qualitative expert feedback to identify specific concerns, then revised indicator definitions, measurement approaches, or contextual explanations to address these concerns. The revised indicators were presented to the same expert panel in a second round, along with clarifications addressing the concerns raised in the first round. This iterative process continued until consensus was achieved or it was determined that an indicator was genuinely inappropriate for the Thai suburban context despite attempts at refinement.

The final indicator set represents those achieving expert consensus as relevant, measurable, and appropriate for evaluating TOD potential around suburban railway stations in Thailand, considering the unique climatic, cultural, and transportation system characteristics of the context.

4. Analysis Results

4.1 Overview of Expert Evaluation Process

The evaluation of Transit-Oriented Development (TOD) indicators for Thai suburban railway stations was conducted through a systematic two-round expert consultation process involving ten experts with extensive experience in transportation planning, urban development, and TOD implementation in Thailand. The initial assessment of 48 indicators revealed varying levels of consensus, with 42 indicators achieving acceptance in the first round and six requiring refinement and re-evaluation. This section presents the comprehensive findings from both evaluation rounds, analyzing the indicators that achieved consensus as well as those that were ultimately rejected due to contextual inappropriateness for Thai suburban railway contexts.

4.2 First Round Evaluation Results

The first round of expert evaluation assessed all 48 indicators across three main components: Transit System Indicators (TS), Oriented System Indicators (OS), and Development System Indicators (DS). Each expert's linguistic assessment on the 7-point Likert scale was systematically converted into triangular fuzzy numbers, aggregated across all ten experts, and defuzzified to produce crisp values representing overall expert consensus.

The first-round results revealed that 42 out of 48 indicators (87.5%) achieved the acceptance threshold of a crisp value ≥ 0.75, indicating a strong overall consensus on the relevance of most international TOD indicators to the Thai suburban context. However, six indicators failed to meet this threshold, categorized into borderline indicators (0.70 < crisp value < 0.75) and low-consensus indicators (crisp value ≤ 0.70), requiring further examination and potential revision.

4.2.1 High-Consensus Indicators

Several indicators emerged with firm expert consensus, achieving crisp values exceeding 0.90 and demonstrating their critical importance for Thai suburban TOD evaluation:

- Train Service Frequency (TSO1: 0.950) received the highest rating among all indicators. Experts emphasized that frequent and reliable service is even more critical in suburban areas than in urban cores, as it helps compete with the convenience of private vehicles. One expert noted: "Without frequent service, suburban residents will not change their car-dependent behavior. Service frequency is the foundation of suburban TOD." The high consensus reflects recognition that lower suburban densities make service frequency the primary determinant of transit competitiveness against automobile travel.
- The pedestrian walkway width (OSP1: 0.940) achieved near-unanimous support, with experts emphasizing its particular importance in hot climates. Expert feedback revealed specific concerns about Thai suburban

conditions: "In Thailand's heat, people need wider walkways to avoid crowding in shaded areas. Narrow walkways force people into direct sunlight, significantly reducing walking willingness." Experts recommended minimum effective widths of 2.5-3.0 meters for main access routes to stations, substantially wider than typical suburban sidewalks, to accommodate comfortable pedestrian flow while allowing people to seek shaded portions of the walkway.

- Mixed Land Use (DSL1: 0.940) received strong consensus, with experts noting that suburban areas must develop mixed-use patterns to reduce travel distances and support transit viability. One urban planning expert commented, "Suburban areas often have single-use zoning that forces car dependency. Mixed land use within walking distance of stations is essential for TOD success, even more critical than in urban areas where destinations are already closer together." The high rating reflects understanding that land-use integration is foundational to reducing automobile dependency in suburban contexts.
- Additional high-performing indicators included Connecting Transit Services (TSO2: 0.910), emphasizing bus-rail connectivity and informal transport integration; Park & Ride Facilities (TSF1: 0.910), supporting mode shift during transitional periods; Cycling Network (OSN1: 0.910), recognizing potential for electric bicycles and properly shaded routes despite hot climate; Security Systems (TSA5: 0.910), addressing safety concerns in lower-density suburban environments; Community Market Areas (DSC7: 0.910), reflecting importance of traditional Thai fresh markets; and Local Employment (DSL7: 0.908), supporting two-way transit flows and service cost-effectiveness.

4.2.2 Indicators Requiring Review

Six indicators failed to achieve the acceptance threshold in the first round, revealing important contextual differences between Thai suburban areas and the international urban contexts from which these indicators originated:

Borderline Indicators ($0.70 < \text{crisp value} < 0.75$):

- Station Signage and Symbols (TSA3: 0.727) - Initial expert assessments were mixed, with some considering comprehensive wayfinding systems important for all contexts. In contrast, others argued that suburban stations' smaller scale and simpler layouts reduce this need compared to those in complex urban areas. The indicator proceeded to a second round with clarified definitions emphasizing basic rather than elaborate signage systems.
- Covered Walkways (OSP2: 0.717) - Despite Thailand's hot climate, this indicator received surprisingly moderate ratings. Qualitative feedback revealed that experts distinguished between "covered walkways" (fully enclosed or tunnel-like structures) and "shaded walkways" (those with a tree canopy or a simple roof structure). Several experts expressed concern that the indicator might be misinterpreted as requiring expensive enclosed corridors, which are inappropriate for suburban contexts. The indicator was revised to clarify that simple roof structures or tree canopies providing shade and rain protection would suffice.

Low-Consensus Indicators ($\text{crisp value} \leq 0.70$):

- Number of Retail Outlets in Stations (TSA2: 0.633) - This indicator received notably low ratings with substantial disagreement among experts. Government planners and consultants consistently rated it low, explaining that suburban passengers primarily use stations as transit points rather than destinations for shopping or dining. One consultant elaborated: "In Bangkok's urban metro stations, retail outlets attract customers and generate revenue. In suburban railway stations, passengers arrive shortly before trains and leave immediately after arrival. Retail outlets would not be viable commercially and do not serve suburban passenger needs."
- Pedestrian Pathway Gradient (OSP7: 0.633) - Low ratings reflected experts' observations that most Thai suburban areas are characterized by relatively flat terrain, making slope considerations less critical than in mountainous or hilly contexts. Several experts noted that this indicator may be relevant for specific locations, such as Chiang Mai's foothill areas, but has limited applicability to Thailand's Central Plains, Northeastern Plateau, and coastal areas, where most suburban development occurs.
- High-Rise Building Areas (DSL4: 0.633) - This indicator generated substantial discussion and disagreement among experts. Urban planners initially rated it moderately high, viewing high-rise development as a means to achieve transit-supportive densities. In contrast, government planners and consultants rated it very low,

citing market realities and cultural preferences. One consultant explained: "The Thai real estate market shows limited demand for high-rise residential buildings in suburban locations. Families prefer landed housing or low-rise condominiums. Emphasizing high-rises would not reflect market realities or cultural preferences and would likely result in unsuccessful developments."

- Government Service Centers (DSC6: 0.617) - Experts generally agreed that lower population densities in suburban areas do not justify or require concentrated government service provision near every station. Several noted that digital government services are increasingly reducing the need for physical service centers, particularly in suburban areas where residents have better internet access than those in remote rural areas. One expert commented: "Major government offices might locate near some important suburban stations, but this should not be a general TOD evaluation criterion for all stations."

4.3 Second Round Evaluation Results

Following a comprehensive analysis of the first-round results and expert feedback, the research team revised the definitions and measurement approaches for the six indicators that required review. The revised indicators were presented to the same expert panel in a second consultation round, with clarifications specifically addressing concerns identified in the qualitative feedback.

4.3.1 Successfully Revised Indicators

Two indicators achieved acceptance in the second round after definitional revision and clarification:

- Station Signage and Symbols (TSA3: 0.727 → 0.863) - The revised definition clarified that this indicator focuses on basic wayfinding elements (platform signs, exit indicators, route maps, universal symbols) rather than elaborate digital signage systems or complex wayfinding networks. Experts responded positively to this practical interpretation, with one noting: "Basic signage is important even in small stations, especially for elderly passengers and tourists unfamiliar with the area. We do not need sophisticated electronic systems, but clear, simple signs with universal symbols are essential for station functionality." The crisp value increased substantially from 0.727 to 0.863, well exceeding the acceptance threshold and confirming the importance of basic wayfinding infrastructure.
- Covered Walkways (OSP2: 0.717 → 0.787) - The revised definition explicitly distinguished between "covered walkways" (continuous weather protection along primary routes to stations, including simple roof structures, tree canopy, or arcade-style coverings) and "fully enclosed walkways" (expensive climate-controlled corridors). This clarification emphasized that in Thai suburban contexts, practical weather protection through affordable structures would suffice rather than costly enclosed facilities. Several experts commented that this interpretation made the indicator both more appropriate for suburban contexts and more financially achievable. The crisp value increased from 0.717 to 0.787, achieving acceptance and confirming the critical importance of climate-responsive pedestrian infrastructure.

4.3.2 Persistently Rejected Indicators

Four indicators remained below the acceptance threshold even after revision and re-evaluation, indicating genuine contextual inappropriateness for Thai suburban railway stations rather than merely unclear definitions:

- Number of Retail Outlets in Stations (TSA2: 0.710) - Despite attempts to revise the indicator to focus on minimal convenience retail (small convenience stores, coffee vendors) rather than extensive shopping facilities, expert consensus remained that retail provision within suburban stations is not a priority evaluation criterion. The second-round crisp value of 0.710 improved slightly from 0.633 but still fell short of the 0.75 acceptance threshold. Expert feedback emphasized: "In suburban areas, passengers primarily use stations as transit points rather than spending extended time within the station. Commercial activities should focus on the surrounding area, not inside the station building. Limited retail might include ticket vendors and perhaps one small convenience store, but this should not be an evaluation priority." This finding contrasts sharply with urban TOD literature, where station retail is often considered important for activation, revenue generation, and creating vibrant station environments.

- Pedestrian Pathway Gradient (OSP7: 0.670) - The second-round evaluation attempted to reframe this indicator as applicable to areas with any topographic variation, not just mountainous terrain, but expert ratings remained consistently low. The crisp value of 0.670 showed minimal improvement from the first round's 0.633, confirming limited relevance. Expert consensus indicated: "Most suburban areas being considered for TOD in Thailand are on level terrain. Resources should focus on other pedestrian infrastructure priorities like width, surface quality, shade provision, and lighting rather than gradient management." Several experts noted that for the few suburban stations in areas with topographic variation, the gradient would be addressed through standard engineering practices rather than requiring a specific TOD evaluation.
- High-Rise Building Areas (DSL4: 0.670) - This indicator generated the most extensive discussion in both evaluation rounds. The revised definition attempted to frame high-rise development as one option among several density strategies rather than a requirement, but expert consensus remained negative. The second-round crisp value of 0.670 showed minimal change from 0.633, confirming persistent rejection. Expert feedback revealed fundamental disagreement with emphasizing high-rise development in suburban contexts: "Suburban areas should maintain moderate density and building heights appropriate to their context. The Thai real estate market shows limited demand for high-rise residential buildings in suburban locations, and cultural preferences favor landed housing or medium-rise condominiums." Another expert elaborated: "TOD should increase density, yes, but through medium-rise buildings (4-8 floors), efficient land use, and horizontal mixed-use development, not through high-rises. That urban model does not fit suburban market conditions or community preferences." This rejection underscores the importance of context-appropriate density strategies that consider local market conditions and cultural preferences.
- Government Service Centers (DSC6: 0.677) - The second-round revision attempted to reframe this indicator as "access to government services" (including either physical centers or digital service points), but expert ratings remained consistently low. The crisp value of 0.677 showed minimal improvement from the first round's 0.617, remaining substantially below the acceptance threshold. Expert feedback emphasized: "Due to lower population density in suburban areas, a high concentration of government service centers near every station is neither necessary nor economically justifiable. Major government offices might be located near some important suburban stations serving as regional centers, but this should not be a general TOD evaluation criterion applied to all suburban stations." This finding reflects the distinct service provision patterns appropriate for lower-density suburban contexts, where regional centers serve multiple communities rather than every station requiring comprehensive government services.

4.4 Final Accepted Indicator Framework

The two-round evaluation process resulted in 44 accepted indicators out of 48 initially proposed (91.7% acceptance rate), demonstrating a strong overall consensus while identifying four indicators that were genuinely inappropriate for the Thai suburban railway context. Table 2 presents the complete results showing crisp values and acceptance decisions for all indicators across both evaluation rounds.

Table 1. Transit-Oriented Development Indicators

		Transit System Indicators (TS)			
	Service Operations		**Infrastructure Facilities**		**Station Amenities**
TSO1	Train service frequency	TSF1	Park & Ride facilities	TSA1	Basic amenities
TSO2	Connecting transit services	TSF2	Kiss & Ride Areas	TSA2	Station retail outlets
TSO3	Multimodal transport integration	TSF3	Vehicle/motorcycle parking	TSA3	Station signage and symbols
TSO4	Ticketing system	TSF4	Transit connection points	TSA4	Ramps and elevators
TSO5	Service information system	TSF5	Information service points	TSA5	Security systems
TSO6	Service hours				
		Oriented System Indicators (OS)			
	Pedestrian Infrastructure		Access Environment		Non-Motorized Transport
OSP1	Pedestrian walkway width	OSE1	Route lighting	OSN1	Cycling network
OSP2	Covered walkways	OSE2	Rest points along routes	OSN2	Bicycle parking

	Pedestrian Infrastructure		Access Environment		Non-Motorized Transport
OSP3	Street crossings	OSE3	Directional signage	OSN3	Shared pedestrian-cycling paths
OSP4	Continuous walkways	OSE4	Route safety	OSN4	Walking Distance to key points
OSP5	Walking surface quality				
OSP6	Universal design implementation				
OSP7	Walkway gradient				

Development System Indicators (DS)

	Land Use and Development		**Community Facilities/Services**		**Infrastructure and Environment**
DSL1	Mixed land use	DSC1	Educational facilities	DSE1	Public green space
DSL2	Residential density	DSC2	Healthcare facilities	DSE2	Basic infrastructure
DSL3	Commercial distribution	DSC3	Religious facilities	DSE3	Environmental management
DSL4	High-rise building areas	DSC4	Recreational areas		
DSL5	Vacant land development	DSC5	Community centers		
DSL6	Land value	DSC6	Government service centers		
DSL7	Local employment	DSC7	Community market areas		

Table 2. Results of Expert Consensus Evaluation

Transit System Indicators (TS)

	Service Operations				**Infrastructure Facilities**				**Station Amenities**			
Code	Opinion's mean	Crisp value	Result	Code	Opinion's mean	Crisp value	Result	Code	Opinion's mean	Crisp value	Result
TSO1	(0.87,0.98,1.00)	0.950	Accepted	TSF1	(0.80,0.93,1.00)	0.910	Accepted	TSA1	(0.65,0.84,0.96)	0.817	Accepted
TSO2	(0.80,0.93,1.00)	0.910	Accepted	TSF2	(0.70,0.87,0.98)	0.850	Accepted	TSA2**	(0.42,0.65,0.83)	0.633	Rejected
TSO3	(0.77,0.91,1.00)	0.893	Accepted	TSF3	(0.65,0.84,0.96)	0.817	Accepted		(0.51,0.73,0.89)	0.710	Rejected
TSO4	(0.68,0.86,0.97)	0.837	Accepted	TSF4	(0.68,0.86,0.97)	0.837	Accepted	TSA3*	(0.53,0.75,0.90)	0.727	Rejected
TSO5	(0.68,0.86,0.97)	0.837	Accepted	TSF5	(0.65,0.84,0.96)	0.817	Accepted		(0.72,0.89,0.98)	0.863	Accepted
TSO6	(0.65,0.84,0.96)	0.817	Accepted					TSA4	(0.78,0.91,1.00)	0.897	Accepted
								TSA5	(0.80,0.93,1.00)	0.910	Accepted

Oriented System Indicators (OS)

	Pedestrian Infrastructure				**Access Environment**				**Non-Motorized Transport**			
Code	Opinion's mean	Crisp value	Result	Code	Opinion's mean	Crisp value	Result	Code	Opinion's mean	Crisp value	Result
OSP1	(0.85,0.97,1.00)	0.940	Accepted	OSE1	(0.70,0.87,0.98)	0.850	Accepted	OSN1	(0.80,0.93,1.00)	0.910	Accepted
OSP2*	(0.50,0.75,0.90)	0.717	Rejected	OSE2	(0.65,0.84,0.96)	0.817	Accepted	OSN2	(0.78,0.91,1.00)	0.897	Accepted
	(0.60,0.82,0.94)	0.787	Accepted	OSE3	(0.68,0.86,0.97)	0.837	Accepted	OSN3	(0.65,0.84,0.96)	0.817	Accepted
OSP3	(0.70,0.87,0.98)	0.850	Accepted	OSE4	(0.65,0.84,0.96)	0.817	Accepted	OSN4	(0.68,0.86,0.97)	0.837	Accepted
OSP4	(0.65,0.84,0.96)	0.817	Accepted								
OSP5	(0.78,0.91,1.00)	0.897	Accepted								
OSP6	(0.65,0.84,0.96)	0.817	Accepted								
OSP7**	(0.42,0.65,0.83)	0.633	Rejected								
	(0.46,0.69,0.86)	0.670	Rejected								

Development System Indicators (DS)

	Land Use and Development				**Community Facilities/Services**				**Infrastructure and Environment**			
Code	Opinion's mean	Crisp value	Result	Code	Opinion's mean	Crisp value	Result	Code	Opinion's mean	Crisp value	Result
DSL1	(0.85,0.97,1.00)	0.940	Accepted	DSC1	(0.78,0.91,1.00)	0.897	Accepted	DSE1	(0.78,0.91,1.00)	0.897	Accepted
DSL2	(0.78,0.91,1.00)	0.897	Accepted	DSC2	(0.70,0.87,0.98)	0.850	Accepted	DSE2	(0.65,0.84,0.96)	0.817	Accepted
DSL3	(0.70,0.87,0.98)	0.850	Accepted	DSC3	(0.65,0.84,0.96)	0.817	Accepted	DSE3	(0.68,0.86,0.97)	0.837	Accepted
DSL4**	(0.42,0.65,0.83)	0.633	Rejected	DSC4	(0.68,0.86,0.97)	0.837	Accepted				
	(0.46,0.69,0.86)	0.670	Rejected	DSC5	(0.65,0.84,0.96)	0.817	Accepted				
DSL5	(0.68,0.86,0.97)	0.837	Accepted	DSC6**	(0.40,0.63,0.82)	0.617	Rejected				

	Land Use and Development				Community Facilities/Services			Infrastructure and Environment
DSL6	(0.65,0.84,0.96)	0.817	Accepted		(0.47,0.69,0.87)	0.677	Rejected	
DSL7	(0.80,0.93,1.00)	0.908	Accepted	DSC7	(0.80,0.93,1.00)	0.910	Accepted	

Note: Result: Accepted if Crisp value ≥ 0.75, Rejected if Crisp value < 0.75

* Indicators not meeting criteria in the first round but accepted in the second round

** Indicators not meeting criteria in both first and second rounds Table 3 summarizes the progression of accepted indicators through both evaluation rounds, showing improvements in Transit System Indicators (TSA) and Oriented System Indicators (OSP) categories following second-round revisions, while confirming persistent rejection of contextually inappropriate indicators.

Table 3. Summary of Consensus-Based Accepted Indicators

Round	Result	Transit System Indicators (TS)			Oriented System Indicators (OS)			Development System Indicators (DS)			Total
		TSO	TSF	TSA	OSP	OSE	OSN	DSL	DSC	DSE	
1	Accepted	6	5	3	5	4	4	6	6	3	42
	Rejected			(2)	(2)			(1)	(1)		(6)
2	Accepted	6	5	4	6	4	4	6	6	3	44
	Rejected			(1)	(1)			(1)	(1)		(4)

4.5 Thematic Analysis of Findings

The evaluation results reveal three significant themes regarding TOD indicator appropriateness in Thai suburban railway contexts, with important implications for planning practice and policy development:

4.5.1 Climate-Responsive Infrastructure is Critical, Not Optional

Indicators related to climate protection achieved strong acceptance, with pedestrian walkway width (0.940), covered walkways (0.787 after revision), route lighting (0.850), and rest points along routes (0.817) all exceeding the acceptance threshold. Expert feedback consistently emphasized that Thailand's hot, humid climate fundamentally shapes pedestrian behavior and infrastructure requirements in ways not adequately addressed in international TOD literature focused on temperate climates.

One expert articulated this point emphatically: "We cannot simply copy TOD principles from temperate countries. In Thailand, the 400-800 meter walking catchment commonly cited in TOD literature must include substantial shade and rest opportunities, or people will not walk regardless of land-use mix or density. Climate response is not optional—it determines whether pedestrian access is viable at all." Another expert provided specific guidance: "In Thailand's heat, acceptable walking distance to stations is substantially reduced compared to temperate climates unless we provide continuous shade through tree canopy, covered walkways, or building arcades. A 500-meter walk in full sun feels like 1,000 meters and will deter all but the most determined transit users."

This finding has significant practical implications for Thai suburban TOD projects. First, substantial resources must be allocated to climate-responsive pedestrian infrastructure, potentially increasing development costs compared to temperate-region TOD but making the crucial difference between success and failure in attracting pedestrian access. Second, the conventional TOD walking catchment of 400-800 meters may need to be reduced in Thai suburban contexts unless extensive climate protection infrastructure is provided. Third, the sequencing of TOD development should prioritize climate-responsive pedestrian infrastructure as foundational, before pursuing other TOD objectives, such as density increases or land-use mixing.

4.5.2 Informal Transport Integration is Essential, Not Problematic

Indicators supporting multimodal integration achieved strong consensus, with multimodal transport integration (0.893), transit connection points (0.837), and connecting transit services (0.910) all receiving high ratings. Expert feedback revealed a perspective on informal transportation that differs substantially from conventional TOD literature, which often views informal modes as problems to be eliminated or merely tolerated during transitional periods.

Thai experts, instead, view informal transportation—particularly motorcycle taxis, informal van services, and songthaews—as permanent and valuable components of the suburban transit ecosystem, requiring purposeful integration into station area design. One consultant explained: "We need designated waiting areas for motorcycle

taxis with shade and seating, clear zones for informal vans to load passengers, and integration with songthaew routes. These services extend station catchment areas far beyond walking distance and provide flexible connectivity that formal bus systems cannot match in low-density suburbs where destinations are dispersed and travel patterns are irregular."

A government planner elaborated on this integration approach: "Rather than viewing motorcycle taxis as competing with formal transit, we should recognize them as essential first-and-last-mile connectors. Stations should include dedicated motorcycle taxi waiting areas with comfortable facilities, clear numbering systems for passenger-driver matching, and potentially even formal licensing or registration systems to improve safety and service quality. Similarly, informal van services provide flexible connections to employment centers and residential areas not served by fixed-route buses."

This finding challenges conventional TOD frameworks and suggests that successful Thai suburban TOD requires reconceptualizing the transit ecosystem to include both formal and informal modes as complementary rather than competitive. Practical implications include: designating specific spaces for informal transport operations within station area plans; providing amenities (shade structures, seating, lighting) for informal transport operators and waiting passengers; potentially establishing formal coordination mechanisms between railway operations and informal transport services; and recognizing informal transport in ridership forecasting and catchment area analysis rather than assuming all station access occurs through walking, cycling, or formal connecting transit.

4.5.3 Suburban Development Patterns Should Differ from Urban TOD

The rejection of high-rise building areas (DSL4: 0.670) despite two rounds of evaluation, combined with limited enthusiasm for extensive station retail (TSA2: 0.710), reflects expert consensus that suburban TOD should not attempt to replicate urban TOD physical forms or intensities. This finding has profound implications for how TOD is conceptualized and implemented in suburban contexts.

Accepted indicators support an alternative suburban TOD model emphasizing moderate-density, horizontally mixed-use development: mixed land use (0.940), residential density (0.897), commercial distribution (0.850), and local employment (0.908) all received strong support, suggesting suburban TOD should focus on bringing diverse uses closer together at moderate densities rather than pursuing high-density vertical development.

One consultant summarized this perspective: "Successful suburban TOD in Thailand will look different from Bangkok's urban BTS stations surrounded by high-rise condominiums and shopping complexes. We need 4-8 story mixed-use buildings, not 40-story towers. We need fresh markets and local shops mixed with townhouses and low-rise apartments, not mega-retail complexes and luxury high-rises. The goal is the same—reduce car dependency and support transit ridership—but the physical form must fit suburban contexts, market conditions, and cultural preferences."

An urban planning expert elaborated on density strategies: "The emphasis should be on efficient use of land near stations through horizontal integration—mixing housing, shops, services, and offices in medium-rise buildings along station access corridors—rather than vertical integration in isolated towers. This approach matches Thai suburban real estate demand, provides gradual density transitions from stations to surrounding neighborhoods, and can be implemented incrementally as market conditions support development."

This finding suggests several practical implications for suburban TOD planning: First, zoning and planning guidelines should permit and encourage 4-8 story mixed-use development along station access corridors rather than requiring or emphasizing high-rise development. Second, density targets for suburban TOD should be calibrated to local market conditions and cultural preferences, potentially in the range of 50-100 dwelling units per hectare rather than the 100+ units standard in urban TOD guidelines. Third, station area master plans should emphasize horizontal land-use mixing and incremental infill development rather than comprehensive redevelopment centered on landmark high-rise projects. Fourth, public investment should prioritize enabling infrastructure (such as streets, sidewalks, and utilities) that facilitates small-scale, market-responsive development, rather than large-scale, government-coordinated projects.

4.6 Implications for Thai Suburban TOD Practice

The accepted indicator framework provides practical guidance for evaluating and planning TOD around Thailand's suburban railway stations. The 44 accepted indicators span transit service provision, pedestrian and cycling infrastructure, multimodal connectivity, land-use integration, community facilities, and environmental quality—offering a comprehensive yet context-appropriate evaluation tool.

The four rejected indicators highlight critical differences between Thai suburban contexts and the international urban settings from which much TOD literature originates. Thai suburban TOD should not prioritize extensive station retail, slope management in predominantly flat terrain, high-rise development, or concentrated government services—instead focusing resources on climate-responsive pedestrian infrastructure, informal transport integration, and moderate-density mixed-use development aligned with market demand and cultural preferences.

This context-specific framework enables more effective resource allocation, focusing limited public and private investment on interventions most likely to support transit ridership and sustainable development outcomes in Thai suburban contexts. The framework also provides a foundation for future research examining relationships between these indicators and TOD outcomes, potentially enabling predictive models for evaluating proposed suburban station locations or development scenarios.

5. Conclusions

The application of the Fuzzy Delphi Method to evaluate Transit-Oriented Development (TOD) indicators for Thai suburban railway stations has yielded significant findings that contribute to both theoretical understanding and practical implementation of suburban TOD in developing tropical countries. Through systematic consultation with ten experts across two evaluation rounds, this study successfully identified 44 context-appropriate indicators from an initial set of 48 derived from the international literature, achieving a 91.7% acceptance rate while revealing four indicators that were genuinely inappropriate for Thai suburban contexts. The highest-ranking indicators—train service frequency (TSO1: 0.950), pedestrian walkway width (OSP1: 0.940), and mixed land use (DSL1: 0.940)—demonstrate that fundamental factors in transit service provision, climate-responsive pedestrian infrastructure, and integrated land-use planning remain crucial for suburban TOD success. Conversely, the persistent rejection of indicators, including the number of retail outlets in stations (TSA2: 0.710), pedestrian pathway gradient (OSP7: 0.670), high-rise building areas (DSL4: 0.670), and government service centers (DSC6: 0.677), reveals important contextual differences between Thai suburban areas and the international urban settings from which most TOD frameworks originate.

The findings reveal three critical themes distinguishing Thai suburban TOD from conventional urban-centric frameworks. First, climate-responsive infrastructure emerges as essential rather than optional, with experts emphasizing that Thailand's hot, humid climate fundamentally shapes pedestrian behavior and infrastructure requirements in ways inadequately addressed in temperate-region TOD literature. The strong consensus on covered walkways, adequate walkway widths, rest points, and lighting reflects recognition that, without substantial climate protection, even well-designed mixed-use, transit-oriented developments will fail to attract pedestrian access regardless of proximity or land-use diversity. Second, informal transportation modes—particularly motorcycle taxis, van services, and songthaews—should be recognized as legitimate and essential components of the suburban transit ecosystem, requiring purposeful integration rather than elimination. This perspective challenges conventional TOD frameworks that often view informal modes negatively, suggesting instead that in lower-density suburban contexts, these services provide flexible connectivity that formal systems struggle to replicate cost-effectively. Third, suburban development patterns should differ from urban TOD, with expert rejection of high-rise emphasis reflecting consensus that moderate-density, horizontally mixed-use development (4-8 stories) better aligns with Thai suburban market conditions, cultural preferences, and incremental development capacities than attempts to replicate high-density urban forms.

These findings have important practical implications for multiple stakeholder groups. Government planners and policymakers can use the validated framework to more accurately assess TOD potential around existing and planned stations, prioritizing public investment in service frequency, climate-responsive pedestrian infrastructure, and zoning frameworks that encourage moderate-density mixed-use development rather than requiring high-rise projects. Transit operators should recognize service frequency as foundational to suburban ridership while actively coordinating with informal transport providers as partners rather than competitors. Property developers receive clear guidance that successful suburban station-area projects will emphasize moderate-density mixed-use buildings integrated into complete neighborhoods rather than isolated high-rise developments. Local communities can engage in TOD planning processes with confidence that appropriate suburban TOD will enhance rather than disrupt community character through moderate development intensities, preservation of community spaces such as fresh markets and religious facilities, and gradual density transitions.

While this study makes important contributions, several limitations should be acknowledged. The expert panel, though diverse, comprised only ten individuals, and the study focused on indicator identification rather than weighting or empirical validation of relationships between indicators and actual TOD outcomes. Future research should develop indicator weighting methodologies and composite indices, conduct empirical validation studies examining which indicators most strongly predict successful suburban TOD, explore detailed design guidelines

for climate-responsive infrastructure, investigate models for informal transport integration, and undertake longitudinal studies tracking station areas over time as TOD interventions are implemented. Comparative international research examining suburban TOD in other tropical developing countries could identify common challenges and successful strategies with potential applicability across contexts.

In conclusion, this research demonstrates that successful suburban TOD in Thailand requires context-specific approaches that acknowledge climatic realities, integrate informal transportation, and pursue culturally appropriate development forms rather than attempting to replicate urban TOD models. The validated framework of 44 indicators provides a practical evaluation tool for Thailand's expanding suburban railway network, supporting more effective resource allocation, policy development, and implementation strategies. By recognizing that suburban TOD is not simply scaled-down urban TOD but a distinct approach requiring different strategies, Thailand can develop more sustainable, livable suburban communities around railway investments, reducing automobile dependency while respecting suburban character and community preferences. As Thailand continues railway network expansion into suburban areas, applying these context-sensitive insights can support improved TOD outcomes, contributing to broader goals of sustainable urban development, reduced greenhouse gas emissions, and enhanced quality of life for suburban residents. The framework developed through this research offers both a validated assessment tool and a strategic roadmap for prioritizing interventions, ultimately enabling more successful Transit-Oriented Development implementation in Thai suburban contexts and potentially informing similar efforts in other developing tropical countries facing comparable challenges.

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