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Context sensitive transit oriented development assessment: AHP weighted TOD standards for regional railway hubs in Thailand

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A B S T R A C T

This study develops a context-specific Transit-Oriented Development (TOD) evaluation framework for Thailand's regional railway hubs by integrating the Analytic Hierarchy Process (AHP) with established TOD Standards. Through expert-based pairwise comparisons, we determined that transit accessibility (19.1%), connectivity (15.0%), and walkability (14.1%) represent priority criteria for the Thai context, contrasting with the uniform weighting system of international standards. We applied this AHP-weighted framework to assess six regional railway stations: Chiang Mai, Phitsanulok, Nakhon Ratchasima, Khon Kaen, Pattaya, and Hat Yai Junction. Comparative analysis revealed that Hat Yai Junction achieved the highest TOD potential ranking under both standard (74/100) and AHP-weighted (79.7/100) methods, followed by Chiang Mai (72/100 standard; 78.8/100 weighted). The most notable scoring differential appeared in Nakhon Ratchasima (69/100 vs. 78.4/100), demonstrating the significant impact of context-sensitive weighting. All stations showed common weaknesses in cycling infrastructure (average 3.2/5) and car use reduction metrics while achieving the highest scores in transit accessibility criteria. Station-specific evaluation identified targeted improvement priorities: enhancing cycling networks in Chiang Mai, improving pedestrian infrastructure in Phitsanulok, and increasing block connectivity in Pattaya. This contextualized framework gives planners a practical tool for prioritizing TOD investments in Thailand's regional centers.

1. Introduction

Technological advances and infrastructure development worldwide have led to a continuous increase in travel demand. However, unplanned development has resulted in traffic congestion, air pollution, and urban sprawl (UN Habitat, 2020). The United Nations has established Sustainable Development Goals (SDGs), particularly Goal 11, which focuses on making cities and human settlements inclusive, safe, resilient, and sustainable (United Nations, 2015). This has prompted many countries to seek efficient and sustainable urban development models. Transit-Oriented Development (TOD) is a globally recognized concept that effectively addresses these challenges (Cervero & Sullivan, 2011; Litman, 2018). Countries that have successfully implemented TOD principles, such as Singapore, Hong Kong, Sweden, and Japan, have demonstrated clear benefits in reducing car dependency, decreasing greenhouse gas emissions, and creating vibrant, high-quality urban spaces (Knowles & Ferbrache, 2019; Pojani & Stead, 2018).

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TOD is gaining increasing attention in Southeast Asia, particularly Malaysia, Indonesia, and Thailand (Hasibuan et al., 2014). In Thailand, urban development has been characterized by sprawl and heavy reliance on private vehicles over the past few decades, resulting in severe traffic congestion in major cities, especially in Bangkok and regional centers (World Bank, 2021). Recognizing this issue, the Thai government has begun to adopt more systematic and sustainable approaches by planning mass transit systems and transit-oriented development.

Thailand's 20-year National Strategy (2018-2037) and the Transport Infrastructure Development Master Plan (2015-2022) prioritize upgrading the rail network as the country's primary transportation and logistics backbone (Office of the National Economic and Social Development Council, 2018). Developing double-track railways nationwide and high-speed rail connections between regions provides opportunities for TOD implementation around key railway stations, particularly in regional centers that serve as economic, tourism, and service hubs for their regions.

The TOD Standard developed by the Institute for Transportation and Development Policy (ITDP) is an internationally recognized assessment tool (ITDP, 2017). It measures development across eight key principles: WALK (walkability), CYCLE (cycling infrastructure), CONNECT (connectivity), TRANSIT (public transportation), MIX (mixed land use), DENSIFY (density), COMPACT (compactness), and SHIFT (transition from private vehicle use), covering critical factors that influence the success of TOD projects.

This study aims to analyze and evaluate the potential of six regional railway hub stations in Thailand: Chiang Mai, Phitsanulok, Nakhon Ratchasima, Khon Kaen, Pattaya, and Hat Yai Junction stations, using the TOD Standard as the evaluation framework. The findings will provide crucial information for policymakers and planners to identify areas with the highest potential for TOD development and determine improvement strategies for areas with limitations. This will contribute to the sustainable development of Thailand's regional centers and enhance the quality of life for residents in the long term.

2. Literature Review

2.1 Transit-Oriented Development: Key Concepts and Evolution

Transit-oriented development (TOD) has been extensively studied since its pioneering conceptualization by Calthorpe (1993), who defined TOD as a mixed-use community that encourages people to live and work in areas accessible by walking from public transit. This concept emphasizes the creation of moderate to high-density areas with mixed land uses and pedestrian-friendly designs, which has become a fundamental principle of modern urban planning worldwide.

Cervero and Kockelman (1997) introduced the influential “3Ds” framework—density, Diversity, and Design—to evaluate the built environment's influence on travel behavior. Their study in the San Francisco Bay Area demonstrated that environments characterized by high density, diverse land uses, and pedestrian-friendly designs significantly reduced private vehicle use and promoted non-motorized travel, which are central objectives of TOD development.

The TOD concept has evolved to incorporate additional dimensions in recent years. Ewing and Cervero (2010) expanded the framework to include "Destination accessibility" and "Distance to transit" in their meta-analysis of over 50 studies examining the relationship between built environment and travel behavior. They found that destination accessibility and transit access had the most decisive influence on reducing car use, while walking was most affected by land-use diversity and street network quality.

2.2 International TOD Implementation and Best Practices

Curtis et al. (2009) compiled TOD case studies from around the world, including the United States, Australia, Europe, and Asia. Their work suggested that key success factors for TOD implementation include effective land use and transportation planning integration, supportive public policies, and multi-stakeholder involvement. Their work highlighted the importance of local context in determining appropriate TOD models for each area.

Knowles (2012) examined TOD development in Copenhagen, Denmark, from the Finger Plan to the Ørestad project. This research demonstrated that long-term planning and integration between urban development and mass transit systems are crucial for successful TOD implementation, particularly in creating sustainable urban growth patterns along transit corridors. The Danish experience illustrates that stable policies and long-term vision are essential for successful TOD development.

Successful TOD implementations have been documented in various cultural and geographical contexts. Jacobson and Forsyth (2008) analyzed TOD best practices across Europe, North America, and Asia, identifying key design elements contributing to thriving transit-oriented communities. They emphasized the importance of high-quality public spaces, mixed-use development, and context-sensitive planning that respects local character while maximizing transit accessibility.

2.3 TOD Assessment Methods and Metrics

The Institute for Transportation and Development Policy (ITDP) (2017) developed the TOD Standard, a comprehensive assessment tool for urban development projects based on TOD principles. This standard comprises eight key principles: walking, cycling, connectivity, public transportation, mixed-use, density, compactness, and car use reduction. It utilizes a scoring system applicable to projects in different contexts worldwide. This internationally endorsed standard has been implemented in cities across the globe.

Singh et al. (2014) developed a TOD index to assess the potential of areas around mass transit stations in Mumbai, India. This research integrated TOD principles with Geographic Information Systems (GIS) to analyze the level of "TOD-ness" in each area. Despite extensive railway networks, the study found that areas around Mumbai stations had high potential for further TOD development, particularly in improving pedestrian infrastructure, increasing green spaces, and diversifying land uses.

2.4 TOD in Developing Countries and Asian Contexts

Cervero et al. (2013) studied integrating mass transit systems with urban development in several developing countries, including Asia. They identified key challenges in TOD implementation in developing countries, including institutional limitations, inadequate financing mechanisms, and misalignment between transportation and land-use planning. Their research proposed strategies to address these challenges, such as establishing inter-agency coordination committees, using financial tools to attract private investment, and developing systems accommodating low-income populations.

In Southeast Asia, Hasibuan et al. (2014) examined TOD practices in Malaysia, Indonesia, and Thailand, finding that while policies increasingly support TOD principles, implementation faces significant barriers related to institutional fragmentation, land regulations, and infrastructure development timelines. Their analysis highlighted the need for context-specific approaches that consider the unique urban morphology and development patterns of Southeast Asian cities.

2.5 Recent Methodological Advances in TOD Evaluation

This comprehensive review demonstrates the rich body of research on TOD concepts, implementation strategies, and evaluation methodologies in international and Thai contexts. While studies on applying TOD standards to evaluate and select high-potential areas for development in Thailand's regional centers are emerging, this research aims to address this gap by using the TOD Standard to assess the potential of six regional railway hub stations across Thailand (Office of Transport and Traffic Policy and Planning (OTP), 2021).

3. Research Methodology

3.1 Selection of Study Sites

This research evaluates Thailand's six regional center (RC) railway stations: Chiang Mai, Phitsanulok, Nakhon Ratchasima, Khon Kaen, Pattaya, and Hat Yai Junction stations. These stations were selected according to regional center classification criteria established in the Master Plan for Urban Development and Transportation Infrastructure, considering geographic location, regional centrality roles, and socioeconomic significance (OTP, 2021). The spatial distribution of the selected stations encompasses all regions of Thailand, enabling comparison of physical, economic, and social characteristics across regional centers with different contexts.

3.2 TOD Assessment Indicators

The evaluation employed TOD Standard version 3.0 as the assessment framework, comprising eight key principles: WALK (pedestrian infrastructure quality, safety, and experience), CYCLE (cycling network safety and facilities), CONNECT (path directness and route alternatives), TRANSIT (access to public transportation), MIX (land use diversity and social inclusion), DENSIFY (residential and commercial density supporting transit), COMPACT (integration with existing urban fabric), and SHIFT (reduced private vehicle dependency). This framework enables systematic site analysis while adhering to internationally recognized TOD development principles.

3.3 Data Collection

Data collection was divided into two main categories: primary and secondary data, as shown in Table 1. For primary data, the research team conducted field surveys of areas surrounding the stations within a 500-meter radius for commercial areas and 500-1,000 meters for residential areas, following the concepts proposed by Calthorpe (2001) and Cervero (2013). The team interviewed and collected information from 30 stakeholders per site, including local officials, entrepreneurs, and residents, using semi-structured questionnaires covering travel patterns, area usage, and opinions on TOD development. The team also documented photographs and physical data of areas surrounding the stations. Secondary data was collected from Google Maps and satellite imagery to analyze road networks, pedestrian paths, and land use. Additional data from relevant government agencies included urban comprehensive plans, urban development plans, demographic data, economic information, and the Master Plan for Urban Development and Transportation Infrastructure and TOD-related studies in Thailand.

Table 1

Presents the data collection methods according to the TOD Standard indicators

Category	Indicator	Measurement Criteria	Measurement Method
WALK	Pedestrian paths	Number and percentage (%)	Google Maps, field surveys
CYCLE	Cycling routes and parking	Number and percentage (%)	Questionnaires, field surveys
CONNECT	Building access or connectivity	Number and Distance (m)	Google Maps, field surveys
TRANSIT	Access to secondary transportation	Distance	Google Maps, field surveys
MIX	Building usage	Area ratio (%)	Questionnaires, field surveys, data from government agencies
DENSIFY	Non-residential buildings, residential buildings	Number and Distance	Google Maps, questionnaires, field surveys, data from government agencies
COMPACT	Convenience of area access and other transportation	Number of channels	Google Maps
SHIFT	Parking and accessibility	Area ratio (%)	Google Maps, field surveys

Source: ITDP, TOD Standard (2017)

3.4 Data Analysis

3.4.1 Scoring Criteria

Scoring Based on TOD Standard Criteria: The collected data was analyzed and scored according to the TOD Standard criteria using a Scorecard adapted from the Institute for Transportation and Development Policy (ITDP, 2017). As established in the TOD Standard 3.0 framework, the total possible score was 100 points, divided across the eight principles: WALK (15 points), CYCLE (5 points), CONNECT (15 points), TRANSIT (prerequisite), MIX (25 points), DENSIFY (15 points), COMPACT (10 points), and SHIFT (15 points). This internationally recognized evaluation system comprehensively assesses the characteristics of the built environment that support transit-oriented development (ITDP, 2017). Scoring was conducted by research team members trained in TOD standards and experienced in urban area assessment, with score verification to ensure consistency and reduce bias in the evaluation. Scoring Based on Analytic Hierarchy Process (AHP) Criteria: The research methodology incorporated AHP to establish criterion weights tailored to Thailand's contextual requirements. This process involved interviewing ten Thai experts, including urban planners, transportation engineers, and relevant government agency executives. Following Saaty (2008), who established a 1-9 scale for pairwise comparisons, these specialists evaluated the relative importance of evaluation criteria. The consistency ratio was calculated to ensure reliable judgment patterns ($CR < 0.1$), as recommended by Ishizaka and Labib (2011). This methodological approach aligns with similar TOD evaluation studies conducted by Wey and Chiu (2013) in Taiwan, enabling the calculation of context-specific weights that reflect Thailand's distinct urban development priorities rather than relying solely on international standardized weights.

3.4.2 Data Processing and Comparative Ranking Analysis

After scoring each station using standard TOD criteria and AHP-derived weights, the research team conducted comprehensive ranking analyses to identify stations with the highest potential for regional TOD development. This dual evaluation approach revealed the relative positions of stations and significant scoring differentials across assessment categories. The team analyzed correlations between total scores and each area's physical, economic, and social characteristics to identify key determinants influencing TOD potential in the Thai context. These analyses enabled the formulation of context-specific development strategies that address international TOD principles and local priorities, enhancing the practical applicability of findings for sustainable urban planning in Thailand's regional centers.

3.4.3 Strengths and Weaknesses Analysis

The strengths and weaknesses analysis for each station examined scores in each category. Areas scoring high in specific categories were considered to have strengths in those aspects, while areas scoring low were identified as having weaknesses requiring improvement. This analysis also considered the context of each area, such as physical constraints, local policies, and social and cultural characteristics that might influence TOD development potential differently. Based on these strengths and weaknesses analysis, the research team formulated appropriate development and improvement strategies for each station, considering practical feasibility and stakeholder acceptance in the area.

3.4.4 Research Synthesis and Results Integration

The research findings were synthesized through comparative analysis to identify patterns across regional stations. Results were presented through data tables, visualizations showing relative strengths, GIS-generated maps, and station-specific recommendations addressing stakeholders' needs while maintaining academic rigor.

4. Analysis Results

4.1 Analysis Using AHP to Determine TOD Evaluation Criteria Weights

This study employed the Analytic Hierarchy Process (AHP) to establish context-specific weightings for TOD evaluation criteria in Thailand's regional railway hubs.

Table 2
Expert Ratings for WALK Criterion Compared to Other Main TOD Criteria

	Preference Rating Scale																		Number of Experts	Geometric mean
Left	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Right	(persons)	(G_i)
WALK	1		1		2		1		2		1		2					CYCLE	10	1.513
WALK					1		2		3		1		2				1	CONNECT	10	0.763
WALK							1		2		1		3		2		1	TRANSIT	10	0.336
WALK	1				2		2		2		1		2					MIX	10	1.390
WALK	2		1		2		1		2				1				1	DENSIFY	10	1.984
WALK	2		1		2		1		2				1				1	COMPACT	10	1.984
WALK	1		1		2		2		1		1		2					SHIFT	10	1.689

Table 3
Pairwise Comparison Matrix and Priority Weights of TOD Main Criteria

Main Criteria	WALK	CYCLE	CONNECT	TRANSIT	MIX	DENSIFY	COMPACT	SHIFT	G.M	Weight	λ
WALK	1.000	1.513	0.763	0.336	1.390	1.984	1.984	1.689	1.173	0.141	8.514
CYCLE	0.661	1.000	0.577	0.463	0.880	0.776	0.394	0.415	0.612	0.073	8.389
CONNECT	1.311	1.733	1.000	0.517	1.116	1.871	1.689	1.463	1.253	0.150	8.151
TRANSIT	2.979	2.159	1.935	1.000	1.215	1.322	1.427	1.427	1.589	0.191	8.687
MIX	0.719	1.136	0.896	0.823	1.000	1.427	1.463	1.390	1.072	0.129	8.193
DENSIFY	0.504	1.288	0.535	0.756	0.701	1.000	0.782	0.701	0.751	0.090	8.176
COMPACT	0.504	2.537	0.592	0.701	0.683	1.278	1.000	0.440	0.820	0.098	8.513
SHIFT	0.592	2.410	0.683	0.701	0.719	1.427	2.273	1.000	1.060	0.127	8.401
Total									8.330	1.000	
									CI = 0.098, CR = 0.070		

Table 4
AHP-Derived Weights and Consistency Ratios for TOD Sub-criteria

Sub	G.M	Weight	λ	Sub	G.M	Weight	λ	Sub	G.M	Weight	λ	Sub	G.M	Weight	λ
W1	2.248	0.384	5.098	C1	1.976	0.433	4.066	CN1	1.241	0.606	2.000	T1	1.000	1.000	1.000
W2	1.468	0.251	5.073	C2	1.294	0.284	4.031	CN2	0.806	0.394	2.000				
W3	1.038	0.177	5.092	C3	0.811	0.178	4.021								
W4	0.672	0.115	5.073	C4	0.482	0.106	4.069								
W5	0.434	0.074	5.063												
Total	5.861	1.000		Total	4.564	1.000		Total	2.047	1.000		Total	1.000	1.000	
CI = 0.024, CR = 0.022				*CI = 0.023, CR = 0.025*				*CI = 0.000, CR = 0.000*				*CR = N/A, CR = N/A*			
M1	2.855	0.380	6.336	D1	1.333	0.640	2.000	CP1	1.164	0.576	2.000	S1	1.962	0.577	3.003
M2	1.844	0.246	6.204	D2	0.750	0.360	2.000	CP2	0.859	0.424	2.000	S2	0.623	0.183	3.003
M3	0.813	0.108	6.023									S3	0.818	0.240	3.003
M4	1.042	0.139	6.121												
M5	0.532	0.071	6.098												
M6	0.422	0.056	6.144												
Total	7.507	1.000		Total	2.083	1.000		Total	2.023	1.000		Total	3.403	1.000	
CI = 0.067, CR = 0.054				*CI = 0.000, CR = 0.000*				*CI = 0.000, CR = 0.000*				*CI = 0.001, CR = 0.002*			

Ten Thai experts in urban planning, transportation engineering, and related fields participated in pairwise comparisons of TOD criteria using the established 1-9 scale, as shown in Table 2. The analysis of main criteria priorities, as shown in Table 3, revealed that Transit accessibility (19.1%), Connectivity (15.0%), and Walkability (14.1%) were identified as the highest priorities for

Thailand's TOD development context, with the consistency ratio (CR = 0.070) confirming the reliability of expert judgments. A detailed breakdown of sub-criteria weightings within each main criterion was further calculated, as shown in Table 4, with all sub-criteria maintaining acceptable consistency ratios (CR < 0.10). The comprehensive TOD evaluation framework integrating the ITDP's TOD Standard metrics with the Thai-specific AHP weightings is presented in Table 5, establishing a contextualized assessment tool that reflects both international TOD principles and local development priorities for Thailand's regional railway stations.

Table 5
AHP-Weighted TOD Standard Criteria for Thai Regional Railway Hubs

Main Criteria	Weight	Code	Sub-criteria	Weight(1)	Weight(2)
WALK (W)	14.1%	W1	1.A.1 Walkways: Percentage of walkway segments with safe, all-accessible walkways	38.4%	5.4%
		W2	1.A.2 Crosswalks: Percentage of intersections with safe, all-accessible crosswalks in all directions	25.1%	3.5%
		W3	1.B.1 Visually Active Frontage: Percentage of walkway segments with visual connection to interior building activity	17.7%	2.5%
		W4	1.B.2 Physically Permeable Frontage: Average number of shops, building entrances, and other pedestrian access per 100 meters of block frontage	11.5%	1.6%
		W5	1.C.1 Shade & Shelter: Percentage of walkway segments that incorporate adequate shade or shelter elements	7.4%	1.0%
CYCLE (C)	7.3%	C1	2.A.1 Cycle Network: Access to a safe cycling street and path network	43.3%	3.2%
		C2	2.B.1 Cycle Parking at Transit Stations: Ample, secure, multi-space cycle parking facilities are provided at all transit stations	28.4%	2.1%
		C3	2.B.2 Cycle Parking at Buildings: Percentage of buildings that provide ample, secure cycle parking	17.8%	1.3%
		C4	2.B.3 Cycle Access in Buildings: Buildings allow interior access and storage within tenant-controlled spaces for cycles	10.6%	0.8%
CONNECT (CN)	15.0%	CN1	3.A.1 Small Blocks: Length of most extended pedestrian block	60.6%	9.1%
		CN2	3.B.1 Prioritized Connectivity: Ratio of pedestrian intersections to motor vehicle intersections	39.4%	5.9%
TRANSIT (T)	19.1%	T	4.A.1 Walking Distance to Transit: Walking Distance to the nearest transit station	100.0%	19.1%
MIX (M)	12.9%	M1	5.A.1 Complementary Uses: Residential and nonresidential uses within the same or adjacent blocks	38.0%	4.9%
		M2	5.A.2 Access to Local Services: Percentage of buildings within walking Distance of an elementary/primary school, healthcare service/pharmacy, and source of fresh food	24.6%	3.2%
		M3	5.A.3 Access to Parks and Playgrounds: Percentage of buildings within 500m walking Distance of a park or playground	10.8%	1.4%
		M4	5.B.1 Affordable Housing: Percentage of total residential units provided as affordable housing	13.9%	1.8%
		M5	5.B.2 Housing Preservation: Percentage of households living on site before the project that is maintained or relocated within walking Distance	7.1%	0.9%
		M6	5.B.3 Business and Services Preservation: Percentage of pre-existing local resident-serving businesses and services maintained on-site or relocated within walking Distance	5.6%	0.7%
DENSIFY (D)	9.0%	D1	6.A.1 Nonresidential Density: Nonresidential density in comparison with best practice in similar projects and station catchment areas	64.0%	5.8%
		D2	6.A.2 Residential Density: Residential density in comparison with best practice in similar projects and station catchment areas	36.0%	3.2%
COMPACT (CP)	9.8%	CP1	7.A.1 Urban Site: Number of sides of the development that adjoin existing built-up sites	57.6%	5.7%
		CP2	7.B.1 Transit Options: Number of different transit options accessible within walking Distance	42.4%	4.2%
SHIFT (S)	12.7%	S1	8.A.1 Off-Street Parking: Total off-street area dedicated to parking as a percentage of the development area	57.7%	7.3%
		S2	8.A.2 Driveway Density: Average number of driveways per 100 meters of block frontage	18.3%	2.3%
		S3	8.A.3 Roadway Area: Total roadbed area used for motor vehicle travel and on-street parking as a percentage of the total development area	24.0%	3.1%
Total	100.0%			800.0%	100.0%

4.2 Comparative Analysis of Land Use Patterns in Transit Areas

Land use patterns around the stations within a 500-1,000 meter radius reflect the diversity of land utilization, proportions of different area types, and connectivity networks, which are crucial factors in evaluating the development potential according to TOD concepts in each area, as illustrated in Fig. 1 showing land use data and building types of the station.

Table 6
Comparative TOD Performance Evaluation of Six Regional Railway Hubs Using Standard and AHP-Weighted Criteria

Code	OBJECTIVE	POINTS	TOD Standard							AHP						
			Max	CM	PL	NR	KK	PY	HY	Max	CM	PL	NR	KK	PY	HY
W1	Walkways	3 (100%) 2 (90% or more) 1 (80% or more) 0 (Less than 80%)	3	2	1	2	2	2	3	5.4	3.6	1.8	3.6	3.6	3.6	5.4
W2	Crosswalks	3 (100%) 2 (90% or more) 1 (80% or more) 0 (Less than 80%)	3	2	1	2	2	1	2	3.5	2.4	1.2	2.4	2.4	1.2	2.4
W3	Visually Active Frontage	6 (90% or more) 5 (80% or more) 4 (70% or more) 3 (60% or more) 2 (50% or more) 0 (Less than 50%)	6	5	4	4	3	4	5	2.5	2.1	1.7	1.7	1.2	1.7	2.1
W4	Physically Permeable Frontage	2 (5 or more) 1 (3 or more) 0 (Fewer than 3)	2	2	2	2	2	2	2	1.6	1.6	1.6	1.6	1.6	1.6	1.6
W5	Shade & Shelter	1 (75% or more) 0 (Less than 75%)	1	1	1	1	1	1	1	1.0	1.0	1.0	1.0	1.0	1.0	1.0
		TOTAL	15	12	9	11	10	10	13	14.1	10.7	7.3	10.3	9.9	9.1	12.5
C1	Cycle Network	2 (Less than 100 m) 1 (Less than 200 m) 0 (200 m or more)	2	1	1	2	1	2	1	3.2	1.6	1.6	3.2	1.6	3.2	1.6
C2	Cycle Parking at Transit Stations	1 (Cycle racks <100m, All stations) 0 (Missing at some/ All stations)	1	1	0	1	1	1	1	2.1	2.1	0.0	2.1	2.1	2.1	2.1
C3	Cycle Parking at Buildings	1 (25% or more) 0 (Less than 25%)	1	0	0	1	0	1	0	1.3	0.0	0.0	1.3	0.0	1.3	0.0
C4	Cycle Access in Buildings	1 (Required by codes/ bylaws/lease) 0 (Not required)	1	1	1	0	1	0	1	0.8	0.8	0.8	0.0	0.8	0.0	0.8
		TOTAL	5	3	2	4	3	4	3	7.3	4.5	2.4	6.6	4.5	6.6	4.5
CN1	Small Blocks	10 (Shorter than 110 meters) 6 (Shorter than 130 m) 2 (Shorter than 150 m) 0 (Some blocks longer than 150 m)	10	6	6	6	6	6	10	9.1	5.5	5.5	5.5	5.5	5.5	9.1
CN2	Prioritized Connectivity	5 (2 or higher) 3 (1.5 or higher) 1 (Higher than 1) 0 (1 or lower)	5	5	2	4	3	2	2	5.9	5.9	2.4	4.7	3.6	2.4	2.4
		TOTAL	15	11	8	10	9	8	12	15.0	11.4	7.8	10.2	9.0	7.8	11.5
T1	Walking Distance to Transit	Meets TOD standard req. Does not meet TOD Standard req.	√, X	✓	✓	✓	✓	✓	✓	19.1	19.1	19.1	19.1	19.1	19.1	19.1
		TOTAL	N/A	N/A	N/A	N/A	N/A	N/A	N/A	19.1	19.1	19.1	19.1	19.1	19.1	19.1
M1	Complementary Uses	8 (Internal & contextual mix) 5 (Internal mix only) 3 (Contextual mix only) 0 (No mix)	8	8	5	8	5	5	8	4.9	4.9	3.1	4.9	3.1	3.1	4.9
M2	Access to Local Services	3 (80%+ buildings near three types) 2 (80%+ to 2 types) 1 (80%+ to 1 type) 0 (Fewer than 80% of buildings)	3	3	2	2	3	2	3	3.2	3.2	2.1	2.1	3.2	2.1	3.2
M3	Access to Parks and Playgrounds	1 (80% or more) 0 (Less than 80%)	1	1	1	1	1	1	1	1.4	1.4	1.4	1.4	1.4	1.4	1.4
M4	Affordable Housing	8 (50% or more) 6 (35% to 49%) 4 (20% to 34%) 2 (10% to 19%) 1 (1% to 9%) 0 (Less than 1%)	8	4	4	4	4	4	4	1.8	0.9	0.9	0.9	0.9	0.9	0.9
M5	Housing Preservation	3 (100% kept/moved <250m/paid/none before) 2 (100% moved <500m) 0 (<100%)	3	2	2	2	3	3	3	0.9	0.6	0.6	0.6	0.9	0.9	0.9
M6	Business and Services Preservation	2 (All kept/moved <500m/none before) 0 (Not all kept/moved)	2	1	1	1	1	1	1	0.7	0.4	0.4	0.4	0.4	0.4	0.4
		TOTAL	25	19	15	18	17	16	20	12.9	11.3	8.4	10.3	9.8	8.7	11.6

Code	OBJECTIVE	POINTS	TOD Standard Max	CM	PL	NR	KK	PY	HY	AHP Max	CM	PL	NR	KK	PY	HY
D1	Nonresidential Density	7 (> baseline, <500m) 5 (> baseline, 500-1000m) 3 (= or ≤5% < baseline, <500m) 2 (= or ≤5% < baseline, 500-1000m) 0 (>5% < baseline)	7	5	3	5	5	7	5	5.8	4.1	2.5	4.1	4.1	5.8	4.1
D2	Residential Density	8 (> baseline, <500m) 6 (> baseline, 500-1000m) 4 (= or ≤5% < baseline, <500m) 2 (= or ≤5% < baseline, 500-1000m) 0 (>5% < baseline)	8	5	6	6	5	5	6	3.2	2.0	2.4	2.4	2.0	2.0	2.4
		TOTAL	15	10	9	11	10	12	11	9.0	6.1	4.9	6.6	6.1	7.8	6.6
CP1	Urban Site	8 (4 sides) 6 (3 sides) 4 (2 sides) 2 (1 side) 0 (0 sides)	8	6	4	4	6	4	4	5.7	4.2	2.8	2.8	4.2	2.8	2.8
CP2	Transit Options	Maximum of 2 points For option: 2 (High-capacity transit line) 2 (Bike share system) 1 (Regular transit routes)	2	1	1	2	2	1	2	4.2	2.1	2.1	4.2	4.2	2.1	4.2
		TOTAL	10	7	5	6	8	5	6	9.8	6.3	4.9	7.0	8.4	4.9	7.0
S1	Off-Street Parking	8 (0% to 10% of site area) 7 (11% to 15%) 6 (16% to 20%) 5 (21% to 25%) 4 (26% to 30%) 2 (31% to 40%) 0 (more than 40%)	8	6	8	5	6	5	6	7.3	5.5	7.3	4.6	5.5	4.6	5.5
S2	Driveway Density	1 (≤2 driveways/100m) 0 (> two driveways/100m)	1	1	1	1	1	1	0	2.3	2.3	2.3	2.3	2.3	2.3	0.0
S3	Roadway Area	6 (15% or less of site area) 3 (20% or less of site area) 0 (More than 20% of site area)	6	3	5	3	3	4	3	3.1	1.5	2.5	1.5	1.5	2.0	1.5
		TOTAL	15	10	14	9	10	10	9	12.7	9.4	12.2	8.4	9.4	9.0	7.0
		TOTAL ALL	100	72	62	69	67	65	74	100	78.8	67.0	78.4	76.1	73.0	79.7
		RANK		2	6	3	4	5	1		2	6	3	4	5	1

Note: Chiang Mai Station (CM), Phitsanulok Station (PL), Nakhon Ratchasima Station (NR), Khon Kaen Station (KK), Pattaya Station (PY), Hat Yai Junction Station (HY)

The comprehensive assessment of Thailand's six regional railway hubs applied the standard TOD evaluation framework and the AHP-weighted criteria to identify relative strengths and development potential across diverse geographic contexts. Each station was systematically evaluated across all eight TOD principles: WALK, CYCLE, CONNECT, TRANSIT, MIX, DENSIFY, COMPACT, and SHIFT, with scores assigned according to established measurement metrics for all 28 constituent sub-criteria. As shown in Table 6, the dual-scoring approach revealed significant variations in performance across stations, with Hat Yai Junction achieving the highest ranking under both evaluation methods (scoring 74/100 using standard criteria and 79.7/100 with AHP weightings). Notable performance differentials were observed between evaluation approaches, particularly for stations with distinctive strengths in criteria receiving higher context-specific weightings in the Thai context, such as transit accessibility and connectivity. The comprehensive scoring matrix provides crucial insights for identifying targeted improvement strategies for each regional hub based on their specific performance profile.

4.3 Strengths and Weaknesses Analysis of Regional Railway Stations

Following the comprehensive TOD assessment using standard and AHP-weighted criteria, this study conducted an in-depth analysis of each station's strengths and weaknesses. The evaluation identified distinctive performance patterns across the six regional railway hubs, with each station demonstrating unique characteristics that could either facilitate or hinder effective transit-oriented development. Areas scoring high were determined to be strengths, while lower scores indicated weaknesses requiring targeted interventions. These strengths and weaknesses analysis, as shown in Table 7, provide crucial insights for developing customized improvement strategies that consider each location's specific urban context, existing infrastructure, and development potential.

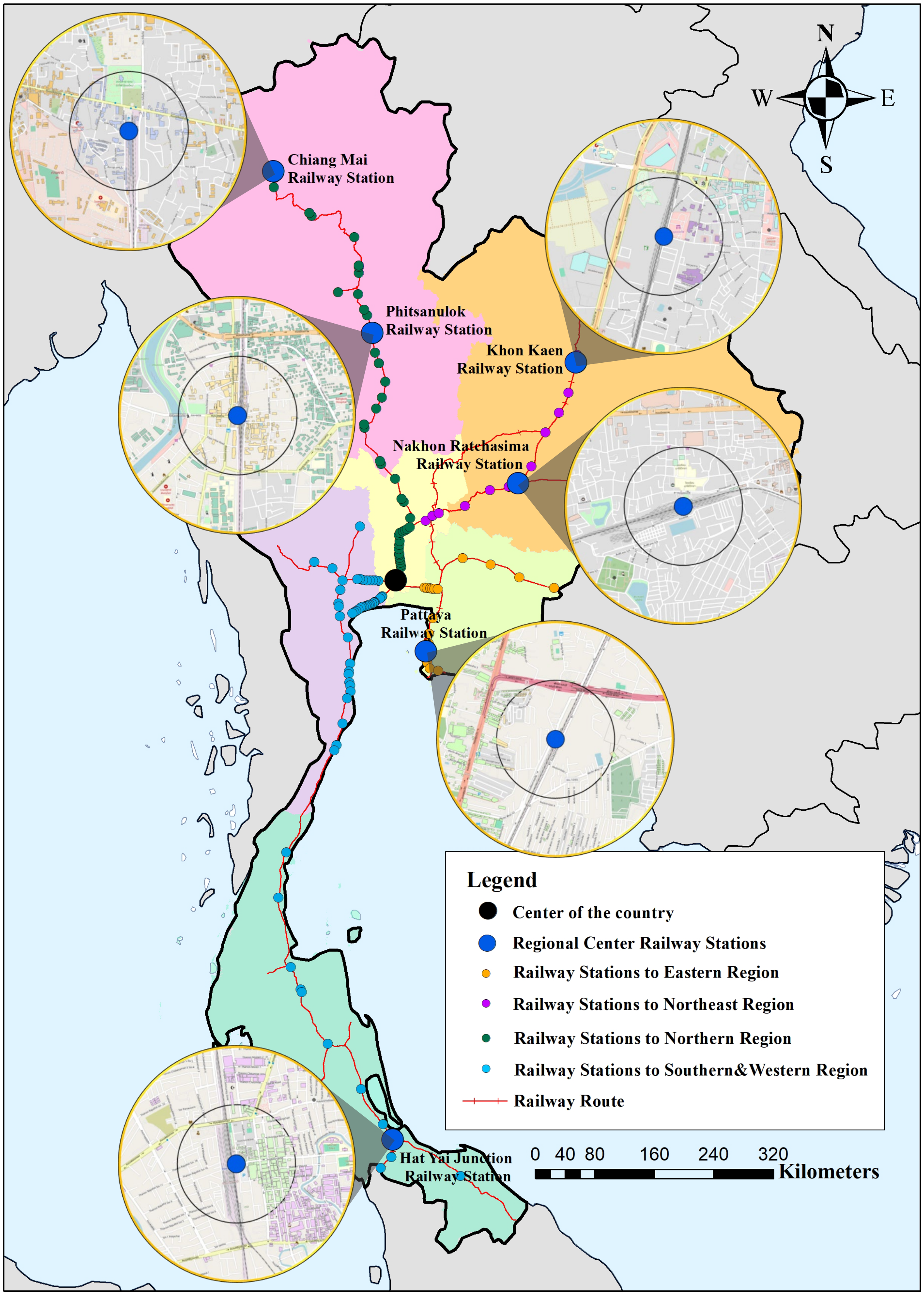

Fig. 1. Land Use and Building Typology within the Railway Station's TOD Zone

Table 7
Strengths and Weaknesses of Each Station

Station	Strengths	Weaknesses
Chiang Mai Railway Station	• Good quality and vibrant pedestrian paths • Good connectivity between blocks • Diversity of land uses	• Incomplete cycling network • Insufficient car use reduction
Phitsanulok Railway Station	• Good car use reduction • Appropriate density for city context	• Inadequate pedestrian path quality • Lack of safe cycling network • Limited diversity of land uses
Nakhon Ratchasima Railway Station	• Relatively good cycling network • Diversity of land uses • Appropriate development density	• Insufficient car use reduction • Inadequate development compactness
Khon Kaen Railway Station	• Good development compactness • Relatively good pedestrian path quality • Appropriate density	• Inadequate block connectivity • Incomplete cycling network
Pattaya Railway Station	• High development density • Relatively good cycling network • Acceptable pedestrian path quality	• Lack of development compactness • Inadequate block connectivity
Hat Yai Junction Railway Station	• Good pedestrian path quality • Excellent block connectivity • High diversity of land uses	• Insufficient car use reduction • Inadequate development compactness

5. Conclusion

This research presents a significant methodological contribution to TOD evaluation in emerging economies by developing and applying an AHP-weighted TOD Standard framework tailored to Thailand's regional railway hubs. The analysis revealed varying TOD potential across the six regional stations, with Hat Yai Junction demonstrating the highest composite score in both standard (74/100) and AHP-weighted (79.7/100) evaluations, followed by Chiang Mai (72/100 standard; 78.8/100 AHP-weighted). The most notable divergence between evaluation methods appeared in Nakhon Ratchasima, which ranked third under both systems but showed a substantial scoring differential (69/100 standard vs. 78.4/100 AHP-weighted). The AHP weighting approach highlighted the particular importance of transit accessibility (19.1%), connectivity (15.0%), and walkability (14.1%) in the Thai context, significantly reweighting these factors compared to the standard distribution. Comparative analysis of the eight TOD principles across stations revealed consistent performance patterns, with all stations scoring highest in transit accessibility while demonstrating notable weaknesses in cycling infrastructure and car use reduction. This contextualized evaluation framework offers policymakers, urban planners, and transportation authorities a practical tool for identifying high-potential TOD areas and designing targeted interventions that reflect international best practices and local development priorities, supporting Thailand's commitment to sustainable urban development.

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