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RESEARCH ARTICLE

Classification of Regional Railway Stations for Transit-Oriented Development (TOD) in Thailand

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ABSTRACT

This study aims to classify regional railway stations in Thailand according to their potential for Transit-Oriented Development (TOD) by applying the Node-Place Model in conjunction with factor analysis based on the 3Ds principle (Density, Diversity, Design). The research utilizes secondary data from the State Railway of Thailand, the Department of Provincial Administration, and the Department of Public Works and Town & Country Planning, along with surveys of Points of Interest (POI) within a 500-meter radius around the stations. The findings reveal that out of 589 regional railway stations, they can be classified into four categories based on TOD potential: Regional Hub Stations (very high potential) at 1.02%, Tourism and Cultural City Stations (high potential) at 3.74%, Secondary City Stations (moderate potential) at 6.79%, and Suburban/Rural Community Stations (low or no potential) at 88.46%. Key factors affecting TOD development potential include population density, land use diversity, number and types of POI, urban roles, and station classification levels. This study proposes appropriate development approaches for each station type: 1) Comprehensive TOD for Regional Hub Stations, 2) Tourism-oriented TOD for Tourism and Cultural City Stations, 3) Mixed-use TOD for Secondary City Stations, and 4) Community Connection Point development for Rural Stations. The research results can be applied to planning and policy-making for the development of areas surrounding regional railway stations in Thailand, aligning with the potential and context of each location.

INTRODUCTION

Transit-oriented development (TOD) is an urban development concept that has received widespread international attention as it supports sustainable growth and reduces dependence on private vehicles (Cervero & Kockelman, 1997; Curtis et al., 2009). The key principle of TOD is to promote high-density mixed-use development in areas surrounding mass transit stations, particularly within a 500-800 meter walking radius, or approximately 5-10 minutes from the station, which is a Distance that allows users to access the mass transit system without relying on motorized vehicles (Calthorpe, 1993).

In Thailand, rail system development is one of the key strategies for the country's transportation infrastructure development, with significant investment projects to develop and improve railway networks nationwide, including double-track railway construction and high-speed rail, which will enhance travel and transportation efficiency between regions (Office of Transport and Traffic Policy and Planning, 2020). However, investment in infrastructure alone may not be sufficient to achieve sustainable urban development without proper planning and development of the areas surrounding stations (Renne, 2009).

Thailand currently has over 500 regional railway stations spread throughout the country. However, each station has a distinct context and development potential, influenced by factors such as location, population density, surrounding land use, and its role in the area's economic and social systems.

Therefore, classifying railway stations according to their potential and specific characteristics is crucial for planning and developing Transit-Oriented Development (TOD) that is tailored to the context of each area.

This study aims to classify regional railway stations in Thailand according to their potential for Transit-Oriented Development (TOD) by applying Bertolini's (1999) Node-Place Model in conjunction with analyzing the density and diversity of activities based on the 3Ds principle (Density, Diversity, Design) by Cervero and Kockelman (1997). The analysis will consider factors in both the dimension of being a transportation connection point (Node) and the dimension of being a place (Place), which reflect the potential to be a center of activities and urban development.

The results of this study will lead to the classification of regional railway stations into four main categories: Regional Hub Stations, Tourism and Cultural City Stations, Secondary City Stations, and Suburban/Rural Community Stations. Each category has different potential and approaches for TOD development. The findings from this research will benefit relevant agencies at both policy and operational levels in determining strategies and approaches for developing areas surrounding railway stations that align with the potential and context of the area, ultimately leading to the efficient and sustainable development of urban and mass transit systems in the long term.

2. LITERATURE REVIEW

2.1 Transit-Oriented Development Concept

The Transit-Oriented Development (TOD) concept is an urban planning approach that focuses on creating dense, mixed-use communities around public transport systems, which are conducive to walking and cycling (Calthorpe, 1993). Calthorpe defined the appropriate TOD development radius as approximately 400-800 meters (or about 5-10 minutes' walking Distance) from a mass transit station, a Distance that people can access without depending on automobiles.

TOD development has gained popularity in many countries worldwide, including Asia, North America, Europe, and Australia, as it is a key strategy for addressing urban sprawl, traffic congestion, pollution, and inefficient energy use (Dittmar & Ohland, 2004). A study by Ewing & Cervero (2010) found that TOD development can reduce automobile use by 20-40% compared to traditional development and promotes greater use of public transport systems and non-motorized travel.

2.2 Node-Place Model and Mass Transit Station Analysis

Bertolini (1999) developed the Node-Place Model to analyze the potential of mass transit stations in serving as both transportation connection points (nodes) and places. The "node" dimension refers to the potential for connectivity with the transportation network and accessibility. In contrast, the "place" dimension refers to the intensity and diversity of activities in the area, which affects the attraction of people and economic activities.

The application of the Node-Place Model has become popular in analyzing and classifying mass transit stations in many countries. For example, Vale (2015) studied railway stations in Lisbon, Portugal, by combining the Node-Place Model with pedestrian shed ratio analysis to assess the potential for TOD development. Meanwhile, Lyu et al. (2016) developed a classification system for subway stations in Beijing, China, by analyzing both transportation factors and the surrounding land use.

2.3 The 3Ds Concept and Factors Affecting TOD Success

Cervero and Kockelman (1997) proposed the 3Ds concept, which consists of Density, Diversity, and Design as key factors affecting travel patterns and the success of Transit-Oriented Development. Density refers to the concentration of population and buildings. Diversity refers to the variety of land uses. Design refers to urban design characteristics that facilitate pedestrian movement.

Later, Ewing and Cervero (2010) expanded this concept into the 5Ds by adding Distance to transit and Destination accessibility, which influence people's travel behavior and public transportation use.

Kamruzzaman et al. (2014) investigated TOD classification systems in Brisbane, Australia, by examining multiple factors, including residential density, pedestrian accessibility, land use diversity, and connectivity to public transportation. The study found that areas with complete TOD

characteristics tend to promote sustainable travel more than areas with only partial TOD characteristics or without TOD characteristics.

Meanwhile, Yang et al. (2019) investigated the relationship between subway accessibility and urban vitality in Shenzhen, China, by analyzing the density of Points of Interest (POI), which reflect the intensity of activities and the diversity of land use.

2.4 Classification of Railway Stations Based on TOD Development Potential

The classification of railway stations according to TOD development potential is a crucial step in planning and determining appropriate policies for developing the areas surrounding stations. Reusser et al. (2008) classified railway stations in Switzerland into seven categories based on land-use characteristics and transportation connectivity, while Zemp et al. (2011) developed a railway station classification system for Europe, considering both the role in the transportation system and the urban context.

In the Thai context, the Office of Transport and Traffic Policy and Planning (OTP, 2020) proposed criteria for considering stations with potential for TOD development around rail systems in regional provinces throughout Thailand. These criteria encompass nine primary transportation factors, as outlined in Table 1.

Table 1. Key Factors for Identifying Potential TOD Railway Stations in Thailand's Regional Provinces

No.	Main Transportation Factors	High Potential	No Potential
1	Stations in major regional cities	√	
2	Provincial stations	√	
3	District stations	√	
4	First-class railway stations	√	
5	Second-class railway stations	√	
6	Halt/Stop stations		√
7	Stations in tourism and cultural cities	√	
8	Terminal stations for tourism in Special Economic Border Zones	√	
9	Other stations		
	9.1) Areas within a 500-meter radius around the station are in land use categories that promote urban development and located within municipal areas	√	
	9.2) Population density ≥ 1,000 people/km^2	√	
	9.3) Areas within a 500-meter radius around the station are in land use categories for environmental and natural resource conservation, such as forest conservation areas, agricultural land reform areas, rural and agricultural conservation areas, etc.		√

Source: Adapted from OTP (2020)

These criteria consider factors including station classification level, city importance level, tourism and economic roles, as well as land use and population density in the areas surrounding the stations. However, the classification of stations according to TOD development potential should also consider additional factors, such as the number and density of Points of Interest (POI), which reflect the vibrancy and economic activities in the area.

Based on the literature review, this study applies the Node-Place Model concept in conjunction with the analysis of factors according to the 3Ds principle and the OTP (2020) potential assessment criteria to classify regional railway stations in Thailand and propose appropriate TOD development approaches for each station type.

3. RESEARCH METHODOLOGY

3.1 Data Collection

This study primarily uses secondary data for analysis, collected from multiple sources. Data on regional railway stations was obtained from the State Railway of Thailand (SRT, 2024), which includes details such as names, locations, geographic coordinates, and station types (Class 1, 2, 3, and

halt stations). Additionally, population and density data was collected from the Department of Provincial Administration (2024), and land use data from the Department of Public Works and Town & Country Planning (2024) to analyze the areas within a 500-meter radius around stations, which is considered an appropriate Distance for TOD development according to Calthorpe (1993). The study collected Points of Interest (POI) data around stations using Google Maps and Google Street View searches, following the method described by Lyu et al. (2016). POI were classified into 10 main categories: government offices, educational institutions, healthcare facilities, shopping centers and markets, hotels and accommodations, tourist attractions, transportation hubs, religious sites, recreational areas, and business centers. The criteria for considering TOD development potential were adapted from the Urban Development with Transportation Infrastructure System Project (OTP, 2020).

3.2 Data Analysis

The data analysis began with an overview study of the distribution of all 589 regional railway stations, utilizing Geographic Information Systems (GIS) to illustrate their spatial distribution across various regions. Then, the TOD potential assessment criteria from OTP (2020), consisting of 9 transportation factors as shown in Table 1, were applied to evaluate the potential of each station. In the next step, the relationship between station class, location, urban context, and other factors was analyzed using Bertolini's (1999) Node-Place Model, which examines stations in terms of their function as transportation connection points (Node) and as places (Place). The study analyzed the number and density of Points of Interest (POI Density) within a 500-meter radius around the stations, which is an essential indicator of activity intensity and land use diversity, following the method of Yang et al. (2019). This involved calculating the number of POI per area and analyzing the proportion of different POI types, which reflects the potential to attract travel and economic activities. The station classification was adapted from the concepts of Vale (2015) and Kamruzzaman et al. (2014), considering both physical characteristics and development potential, resulting in the classification of stations into four groups: Regional Hub, Tourism and Cultural City, Secondary City, and Suburban/Rural Community. The analysis included population density along with land use based on the 3Ds concept (Density, Diversity, Design) by Cervero and Kockelman (1997) to assess TOD development potential.

4. ANALYSIS RESULTS

4.1 Overview of Regional Railway Stations in Thailand

Analysis of railway station data across Thailand (excluding Bangkok Metropolitan Region) revealed a total of 589 stations distributed throughout the country. These can be categorized as 87 Class 1 stations, 116 Class 2 stations, 204 Class 3 stations, and 182 halt stations or stops.

The spatial distribution analysis showed that railway stations are spread across all six regions of Thailand, with the highest number in the Southern region (161 stations), followed by the Northeastern region (127 stations), the Western region (97 stations), the Northern region (85 stations), the Central region (60 stations), and the Eastern region (59 stations), respectively. This distribution reflects the varying density of railway networks across different regions, with the Southern and Northeastern regions having denser networks than other regions.

The density of railway stations correlates with topographical features and the country's main railway routes, with high density along the Northern, Northeastern, and Southern lines. Class 1 and Class 2 stations are primarily located in major cities or serve as main connection points within the network, while Class 3 stations and halt stations are distributed in smaller communities and rural areas. Additionally, 15 junction stations serve as important connection points throughout the railway network, including Kaeng Khoi Junction, Hat Yai Junction, and Thanon Chira Junction.

4.2 Classification of Railway Stations and TOD Development Potential

The analysis and classification of railway stations in Thailand's regions (Tables 2-6) demonstrate the categorization of stations according to their Transit-Oriented Development (TOD) potential into four main types. Table 2 summarizes the classification along with appropriate development approaches, consisting of: 1) Regional Center Stations with very high potential, suitable for comprehensive TOD; 2) Tourism and Cultural City Stations with high potential, suitable for tourism and culture-oriented

TOD; 3) Secondary City Stations with moderate potential, suitable for mixed-use TOD; and 4) Suburban/Rural Community Stations with low potential, suitable for development as community connection points. Tables 3-5 show details of stations in each category, along with important information such as surrounding area characteristics within a 500-meter radius, population density, and number of points of interest (POI). Table 6 summarizes the distribution of all 589 stations according to their potential level in each region, which reveals that the majority (88.46%) have low or no potential. In contrast, only 1.19% have very high potential, and 3.57% have high potential.

Table 2. Station Classification and TOD Development Potential

Station Type	TOD Potential	TOD Development
1. Regional Center	Very High	Regional TOD Hub
2. Tourism and Cultural City	High	Tourism-Oriented TOD
3. Secondary City	Moderate	Mixed-Use TOD
4. Suburban/Rural Community	Low/No Potential	Community Connection Point

Table 3. Regional Center Stations with TOD Potential

No	Station	Reg.	500m Area Context	Density (people/ km^2)	Key POI
1	Chiang Mai	N	Old town area, Commercial zone, Hotels	3,200	32
2	Phitsanulok	N	Commercial zone, Educational institutions	2,850	30
3	Nakhon Ratchasima	NE	Commercial zone, Community, Educational institutions	3,500	35
4	Khon Kaen	NE	Commercial zone, Community, Educational institutions	3,100	32
5	Pattaya	E	Hotels, Shops, Beach	3,200	34
6	Hat Yai Junction	S	Dense commercial zone, Market	3,800	40

Table 4. Tourism and Cultural City Stations with TOD Potential

No	Station	Reg.	500m Area Context	Density (people/km^2)	Key POI
1	Ayutthaya	C	Historical park, Commercial area	2,100	25
2	Bang Pa-in	C	Community, Palace, Commercial area	1,800	15
3	Nakhon Lampang	N	Old town area, Market, Temples	2,300	22
4	Lamphun	N	Old town area, Temples, Community	1,950	18

No	Station	Reg.	500m Area Context	Density (people/km^2)	Key POI
5	Den Chai	N	Community, Market, Agricultural area	1,500	12
6	Sawankhalok	N	Community, Market, Temples	1,650	12
7	Sila At	N	Community, Commercial area	1,700	14
8	Nakhon Sawan	N	Commercial area, Residential area	2,500	21
9	Chonburi	E	Commercial area, Residential area	2,500	23
10	Bang Lamung	E	Community, Commercial area	2,400	18
11	Si Racha Junction	E	Commercial area, Industrial estate	2,800	25
12	Udon Thani	NE	Commercial zone, Residential area	2,900	31
13	Ubon Ratchathani	NE	Commercial zone, Community	2,400	20
14	Kanchanaburi	W	Historical area, River	2,100	24
15	Hua Hin	W	Hotels, Beach, Market	3,000	35
16	Cha-am	W	Hotels, Beach	2,600	28
17	Phetchaburi	W	Historical area, Palace, Community	2,200	22
18	Prachuap Khiri Khan	W	Community, Beach	2,100	20
19	Pranburi	W	Community, Beach, Park	1,800	16
20	Chumphon	S	Commercial area, Community	2,200	20
21	Surat Thani	S	Urban community, Commercial zone	2,200	18
22	Thung Song Junction	S	Commercial area, Community, Market	2,400	22

Table 5. Secondary City Stations with TOD Potential

No	Station	Reg.	500m Area Context	Density (people/km^2)	Key POI
1	Ban Phachi Junction	C	Community, Agricultural area	1,200	8
2	Tha Ruea	C	Community, Market, Port	1,350	10
3	Lopburi	C	Historical area, Military	1,800	18
4	Ban Mi	C	Community, Market, Agricultural area	1,100	7
5	Saraburi	C	Commercial area, Community	1,900	16
6	Kaeng Khoi Junction	C	Community, Factory	1,400	12
7	Map Kabao	C	Community, Factory	1,250	9
8	Ban Takhli	N	Community, Market	1,300	10
9	Pak Nam Pho	N	Commercial area, River	1,850	17
10	Chum Saeng	N	Community, River	1,200	8
11	Bang Mun Nak	N	Community, Market	1,150	9
12	Taphan Hin	N	Community, Market	1,200	8

No	Station	Reg.	500m Area Context	Density (people/km^2)	Key POI
13	Phichit	N	Commercial area, Community	1,600	14
14	Pichai	N	Community, Agricultural area	1,000	6
15	Uttaradit	N	Commercial area, Community	1,700	15
16	Chachoengsao Junction	E	Commercial area, Community, River	1,850	16
17	Prachinburi	E	Commercial area, Community	1,600	14
18	Aranyaprathet	E	Border market, Community	1,700	15
19	Kabinburi	E	Commercial area, Industrial estate	1,650	13
20	Sa Kaeo	E	Commercial area, Community	1,550	12
21	Pak Chong	NE	Tourist area, Community	1,800	17
22	Sikhio	NE	Community, Market	1,400	11
23	Thanon Chira Junction	NE	Commercial area, Community	2,000	19
24	Lam Plai Mat	NE	Community, Market	1,300	9
25	Buriram	NE	Commercial area, Sports stadium	1,900	18
26	Surin	NE	Commercial area, Community	1,850	17
27	Sisaket	NE	Commercial area, Community	1,750	16
28	Bua Yai Junction	NE	Community, Market	1,500	12
29	Ban Phai	NE	Community, Market	1,650	14
30	Nong Khai	NE	Border trade area, Mekong River	1,800	17
31	Ban Pong	W	Commercial area, Factory	1,700	15
32	Photharam	W	Community, Market	1,400	10
33	Ratchaburi	W	Commercial area, Community	1,950	19
34	Lang Suan	S	Community, Market, Fruit orchards	1,400	11
35	Na San	S	Community, Market	1,350	10
36	Phatthalung	S	Commercial area, Community, Lake	1,700	16
37	Khuan Niang	S	Community, Agricultural area	1,200	8
38	Padang Besar	S	Border market, Community	1,550	14
39	Yala	S	Commercial area, Community	1,800	17
40	Sungai Kolok	S	Border market, Community	1,750	16

Table 6. Summary of Stations by TOD Potential Level in Each Region

TOD Potential	N	NE	C	E	W	S	Total	%
Very High	2	2	-	1	-	1	6	1.02
High	6	2	2	3	6	3	22	3.74
Moderate	8	10	7	5	3	7	40	6.79
Low/No Potential	n/a	n/a	n/a	n/a	n/a	n/a	521	88.46
Total							**589**	**100**

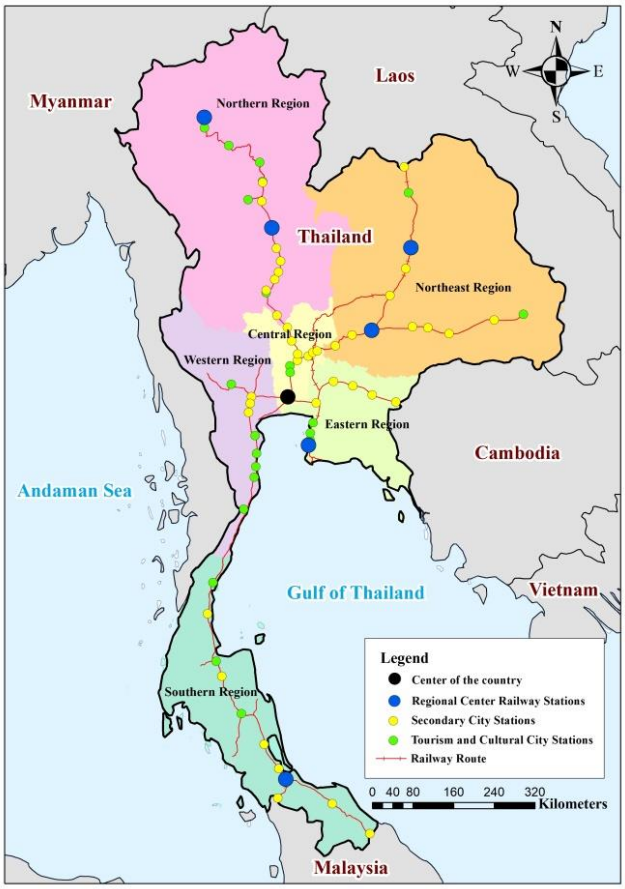

Figure 1. Stations with TOD Development Potential by Region

4.3 Appropriate TOD Development Approaches for Each Station Type

Regional Center Stations (Very High Potential): These stations should be developed as comprehensive Transit-Oriented Development (TOD) hubs, featuring high diversity and density. Development should promote mixed-use development comprising commercial areas, high-density residential areas, offices, and public service spaces. The focus should be on creating high-quality public spaces, promoting pedestrian and bicycle mobility, establishing feeder systems that connect to surrounding districts, and developing regional-level facilities such as convention centers, shopping malls, and educational institutions.

Tourism and Cultural City Stations (High Potential): These stations should be developed as Tourism-Oriented TOD, emphasizing conservation and promotion of cultural heritage. Development in these areas should consider local identity, promote tourism-related economic activities such as hotels, restaurants, and souvenir shops, and provide pedestrian and cycling routes that connect essential tourist attractions. Effective tourist management and efficient space utilization should be implemented to minimize the impact on local communities.

Secondary City Stations (Moderate Potential): These stations should be developed as Mixed-Use TOD with medium density, focusing on meeting local community needs. Development should promote mixed land use that is appropriate for small to medium-sized commercial areas, diverse residential formats, and community public spaces. Connections between stations and surrounding communities should be improved, and safe and comfortable pedestrian and cycling paths should be developed. Additionally, local economic development and employment opportunities should be promoted.

Suburban/Rural Community Stations (Low/No Potential): These stations should be developed as Community Connection Points aimed at improving access to public transport and essential services for local communities. Despite low TOD potential, basic amenities should be enhanced, including car and bicycle parking, bus stops that connect to nearby neighborhoods, small commercial areas that serve community-level needs, and small public spaces. Development should consider preserving rural identity and environmental conservation without encouraging excessive density.

5. CONCLUSION

This study has classified Thailand's regional railway stations according to their Transit-Oriented Development (TOD) potential by analyzing data from multiple sources, including the State Railway of Thailand, population data, land-use information, and Points of Interest (POI) surrounding the stations. The findings reveal that from a total of 589 regional railway stations (excluding Bangkok Metropolitan Region), they can be categorized into four main types based on TOD development potential: Regional Center Stations (very high potential) numbering six stations (1.02%), Tourism and Cultural City Stations (high potential) numbering 22 stations (3.74%), Secondary City Stations (moderate potential) numbering 40 stations (6.79%), and Suburban/Rural Community Stations (low/no potential) numbering 521 stations (88.46%).

Stations with very high and high potential are typically found in critical regional cities, coastal tourist towns, and cultural heritage cities. These stations are characterized by high population density (over 2,500 people per square kilometer), diverse activities and land uses in surrounding areas, and numerous Points of Interest (POI) (more than 20) within a 500-meter radius of the station. Stations with moderate potential are commonly found in medium-sized cities and border towns with considerable economic activity. The low- or no-potential stations, which constitute the majority, are typically located in rural areas, agricultural lands, or small communities with low population density and limited economic activity.

The spatial distribution of stations by TOD potential reveals that the Northern and Northeastern regions contain all four very high-potential stations. The Western and Eastern provinces have the highest proportion of high-potential stations, while the Southern region has the highest number of moderate-potential stations. Analysis using the Node-Place Model reveals that stations with a balance between their potential as transportation connection points (Nodes) and as places (Places) tend to have higher TOD development potential.

This study leads to proposed appropriate TOD development approaches for each station type: 1) Comprehensive TOD for Regional Center Stations, 2) Tourism and Culture-Oriented TOD for Tourism and Cultural City Stations, 3) Mixed-Use TOD for Secondary City Stations, and 4) Community Connection Point development for Suburban/Rural Community Stations. TOD development around transit stations should consider the specific context of each area, limitations, and development opportunities to maximize benefits in terms of transportation, economy, society, and environment.

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