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Applying the TOD Standard for Potential Location Selection for Sustainable Transit-Oriented Development in Chiang Mai Province, Thailand

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Abstract: Transit-oriented development (TOD) was organized as policies to promote the development of public transportation infrastructure in many countries, including the Thai government. Presently, Thailand is aiming for the growth of the city spreads in each region along with economic growth by stimulating sustainable development, especially in Chiang Mai Province. The purpose of this study was to implement the application of the TOD standard as an analytical tool in the context of Thailand. We adapted TOD standard as an instrument and indicator for physical data collection on areas that have the potential to be developed into TOD stations in Chiang Mai. The TOD standard as a selection tool will be used to score the selected three stations located on the Chiang Mai Red Line Mass Transit System Project that has the potential to develop into TOD. Data collection covers a radius from the stations of 500 meters and 500 – 1000 meters for commercial and residential land use, respectively. The scoring shows that the Airport station is the most potential area, followed by the Chiang Mai Rajabhat University and Nakornping hospital station. The results show that TOD standards had the potential to be used in the context of Thailand to enhance assessment, help in planning and drawing TOD policy for the upcoming station project, and identify specific TOD characteristics that need improvement.

Keywords: TOD Standard, transit-oriented development, transportation, urban planning, sustainable development.

将托德标准应用于泰国清迈省可持续公交导向发展的潜在选址

摘要：以公共交通为导向的发展(托德)被组织为促进包括泰国政府在内的许多国家公共交通基础设施发展的政策。目前，泰国的目标是通过刺激可持续发展，特别是在清迈省，随着经济增长，在每个地区扩大城市分布。本研究的目的是在泰国实施托德标准作为分析工具的应用。我们将托德标准改编为一种工具和指标，用于在有可能发展为清迈托德站的地区收集物理数据。托德标准作为一种选择工具，将用于对位于清迈红线公共交通系统项目中的三个有潜力发展为托德的车站进行评分。数据采集范围分别为 500 米和 500-1000 米的车站半径，分别用于商业和住宅用地。评分显示，机场站是最具潜力的区域，其次是清迈皇家大学和那空平医院站。结果表明，托德标准有可能在泰国背景下用于加强评估，帮助规划和制定即将到来的车站项目的托德政策，并确定需要改进的特定托德特征。

关键词：托德标准、以公交为导向的发展、交通、城市规划、可持续发展。

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1. Introduction

Modern technology has made communication or travel between different areas or countries more comfortable. Commuting has become a part of the everyday life of people worldwide, creating traffic problems. The traffic problem is a problem that the Thai government pays attention to and tries to solve from a systematic and sustainable perspective. Chiang Mai is an essential province in northern Thailand due to the dense population and many Thai and foreign tourists. Chiang Mai plans to develop a provincial mass transit system to connect the main route and the second transport network (feeder) in the province, expecting good results in transportation. This includes the development of transit-oriented development (TOD) of some potential stations on rail lines. This development affects promoting the sustainability of transportation [1]. However, the efficient TOD station needs a sufficient number of users to avoid the problem of loss, causing the government to waste the budget. Therefore, an analysis of site suitability factors is necessary.

TOD is one of the most effective ways to organize a new city using a public transportation hub. TOD creates sustainable urban growth, which can aid the problems and challenges of urban development, such as urban expansion, space usage, density, reducing air pollution, and traffic problems. It also promotes the economy and increases the source of careers in the community. TOD increases the potential to travel without relying on a car. A compact space allocation helps reduce travel distance. Buildings can be connected on foot or by bicycle for easier access to amenities and transportation, inducing more users to travel on public transportation. As a result, people in the community have a better life from the convenience of accessing business opportunities, education, and resources, as well as saving on vehicle costs and reducing pollution and traffic problems.

In summary, TOD is an effective strategy for improving sustainable urban development. This study aimed to analyze the location suitability factors for TOD by applying the TOD Standard as a criterion for analyzing and collecting physical data. Then summarize the results according to the scores and use them as data for choosing the TOD station in Chiang Mai Province.

2. Literature Review

Many studies have been conducted in Thailand to analyze spatial, physical potential, and suitability. Most researchers chose to combine various methods to establish appropriate location assessment criteria. However, no studies have focused on the site selection of TOD by adopting standardized criteria in Thailand, such as the TOD standard, a standard published by the Institute for Transportation and Development Policy (ITDP). This TOD standard is an assessment tool to rate plans and produce urban development based on TOD compliance and implementation objectives. This standard uses a scoring system that distributes 100 points to measure the use of 8 principles: walk, cycle, connect, transit, mix, densify, compact, and shift. This tool is approved by the TOD Standard International Expert Committee of Technical Experts [13].

Transit-oriented development, or TOD, is an urban development that combines mass transit modes with urban that is indistinguishable from land use. It is a way to propose the idea of blending and supporting high-density residential areas to create a compact city. Therefore, selecting a site for efficient and effective TOD development is a significant step because each area has different characteristics such as land use, density, urban design, and others. TOD developments may not be compatible with specific environmental conditions and land use characteristics. Therefore, it is necessary to have criteria and elements that serve as a guide for further development [2, 3].

2.1. Location Selection Guidelines for TOD

TOD is the most influential urban development. Selecting a location for TOD is a significant step toward urban sustainability. Each area has different characteristics, land use, density, design, surroundings, some of which may not agree with TOD development. Therefore, it requires criteria and guidelines for further development [2, 3].

From the research, TOD location selection can be divided into two forms.

1. Non-Standard

The researcher determines their variable and then analyzes it with selected techniques. The most selected techniques are Analytical Hierarchy Process (AHP) and Multi-Criteria Decision Analysis (MCDA), commonly used in Thailand and foreign research.

According to the research of Nattapong [3], the selection process for developing TOD is an unstable or ill structure related to factors and multiple criteria. Therefore, using Multiple Criteria Decision Making (MCDM) is appropriate. Other Thai and foreign researchers have combined multiple criteria with other tools. Such as, the research of NORO [4] applied TOD to Geographic Information System to (1) identify the potential of land use, (2) analyze the potential of the station for TOD, (3) prioritize TOD types using the GIS-MCDM technique, and (4) formulation of development guidelines and transport planning in the context of Malaysia.

2. Standard

This form has a tool developed with the relevant agencies. It covered several criteria and measurements to follow TOD. The instrument called TOD Standards was widely spread and published in a few languages, according to the Transportation Policy or the Institute

for Transportation and Development Policy (ITDP). In the case of Thailand, the TOD standard is not used in the area analysis. It is used as part of the design approach or in the Design Guidelines of government agencies. Nevertheless, some researchers use the TOD standard or the standard indicators.

In evaluating the land use area, Rawa Buntu Station in Ramdhani *et al.* [2] uses the matrix 5.A.1. ITDP Standard 3.0, which governs the use of complementary land and categories of diverse areas.

Additionally, Serra-Coch *et al.* [5] assess urban quality by graphical expression through mapping walkability based on the TOD-standard.

According to the research of Singh *et al.* [6] for TOD development planning around existing transit nodes, the TOD index was proposed for measuring the walking distance around transit based on TOD-ness research has presented similarity to ITDP Standard as it covers the seven principles of Walk, Cycle, Connect, Mix, Densify, Compact, and Shift. However, TOD standard measurement covers urban development characteristics but does not assess transport services. It also relies mainly on collecting preliminary urban design data. This applies the TOD standard complex with a station area more significant than a particular project.

Pongprasert [7] has summarized the TOD development in Thailand based on other research, including the TOD standard. It covers many issues, offers regulations to support more development of TOD projects, and emphasizes the city's overall responsibility over the investment.

It may be concluded that, in the analysis of selection of TOD development, these two forms are also recognized and applied to much research. Moreover, recently in Thailand, the TOD standard has been gaining more attention.

3. Methodologies

The TOD standard can be applied as an appropriate tool in the context of Thailand to support decision-making and promote TOD around stations in Chiang Mai. The research framework is presented in Fig. 1.

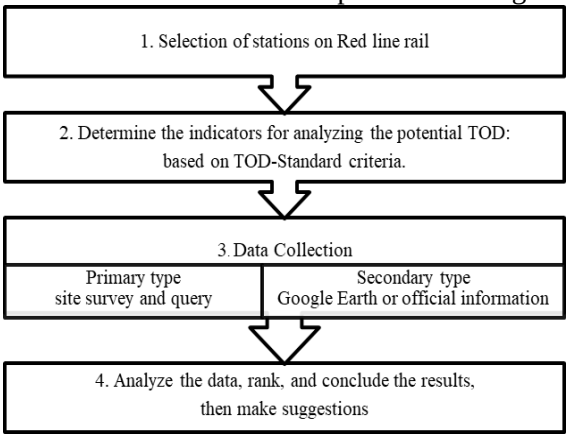

Fig. 1 Research framework

3.1. Selection of Stations on the Red Line Rail

This research collected data from three stations from the Chiang Mai Mass Transit System Project, Red Line [Nakornping Hospital - Mae Hia Saman Samakkhi Intersection]; an electric tram system (LRT/Tram) with a mixed running track at ground level and underground.

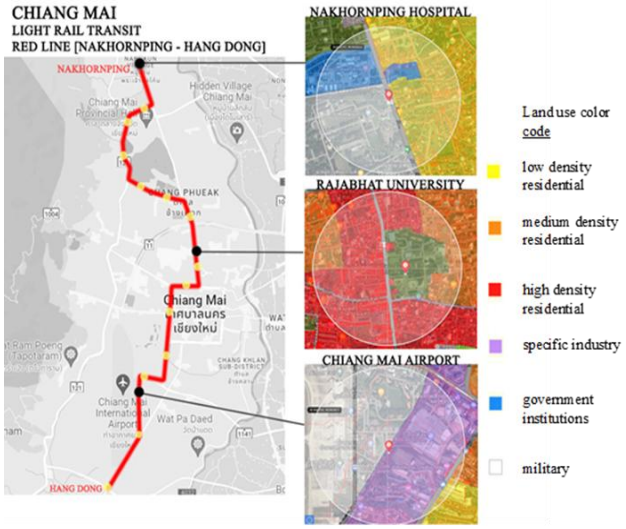

Fig. 2 The selected stations on the Red Line rail

These stations were selected as the representative of different accessibility groups after classifying and grouping all 16 stations into:

1. Stations of origin-destination with space that can be expanded to accommodate vehicles and people;
2. Stations convenient to access from government offices, educational institutions, and heavy traffic areas;
3. Stations that can accommodate various transits.

The selected stations on the Red Line rail are these three stations, as presented in Fig. 2.

3.2. Determination of the Indicators for Analyzing the Potential TOD Based on TOD-Standard Criteria

Data collection follows the TOD-Standard indicators, which are divided into eight principles (walk, cycle, connect, transit, mix, densify, compact, and shift). Each topic has different objectives and scoring.

3.3. Data Collection

There are two types of data collection:

1. *Primary type:* Site survey and query to local people for data and the extra details;
2. *Secondary type:* Using Google Earth or official information sites for the convenience of collecting quantitative data.

The selection of indicators is tailored according to TOD-standard, as in Table 1.

Table 1 Data collection

Metrics	Description	Measurement	Data Source
Walk	Walkway	Count, percentage (%)	Google map, site surveys
Cycle	Cycle route and parking	Count, percentage (%)	Google map, site surveys
Connect	Outdoor connection to or between each building	Count, distance (m)	Google map, site surveys
Transit	Changeable Secondary Mass Transit	Distance (m)	Google map, site surveys, official reports
Mix	Building usage	Area percentage (%)	Query, site surveys, official reports
Densify	Accommodation and non-accommodation buildings	Count, distance (m)	Google map, site surveys, official reports, query
Compact	Easy access	Route count	Google map
Shift	Parking and entry	Area percentage (%)	Google map, site surveys, queries

3.4. Data Analysis

Based on the principles from the TOD standard, the Scorecard and Metric (Excel) tool of the Institute for Transportation and Development Policy (ITDP) was used for scoring and numerical analysis to rank and conclude the results and suggestions.

4. Results

The results of the TOD standard scoring of all three stations showed metrics that have the potential for further development. The top three metrics (with 70% or more from max points) of each station are Nakornping hospital station (walk, mix, and shift), Chiang Mai Rajabhat university station (walk, mix, and compact), and Airport station (walk, mix, and shift).

When comparing the total metric scores of all 3 stations, it was found that the Airport station had the highest total score of 67 points, as shown in Table 2.

Table 2 TOD-Standard scorecard and metric scores

Metrics	Objective	Max points	Nakornping Hospital	Rajabhat University	Airport
Walk	A: The pedestrian realm is safe, complete, and accessible.	6	3	3	5
	B: The pedestrian realm is active and vibrant.	8	5	7	4
	C: The pedestrian realm is temperate and comfortable.	1	0	1	1
	Total Walk Score	15	8	11	10
Cycle	A: The cycling network is safe and complete.	2	1	1	1
	B: Cycle parking and storage are ample and secure.	3	1	2	2
	Total Cycle Score	5	2	3	3
Connect	A: Walking and cycling routes are short, direct, and varied	10	4	6	6
	B: Walking and cycling routes are shorter than motor vehicle routes	5	1	1	3
	Total Connect Score	15	5	7	9
Transit	A: High-quality transit is accessible by foot. [Possible only]	√	√	√	√
Mix	A: Opportunities and services are within a walking distance of where people live and work, and the public space is activated over extended hours.	12	10	9	8
	B: Diverse demographics and income ranges are included among local residents.	13	11	11	9
	Mix Score	25	21	20	17
Densify	A: High residential and job densities support high-quality transit, local services, and public space activity.	15	7	9	9
	Densify Score	15	7	7	9
Compact	A: The development is in, or next to, an existing urban area.	8	2	6	2
	B: Traveling through the city is convenient.	2	1	2	2
	Compact Score	10	3	8	4
Shift	A: The land occupied by motor vehicles is minimized.	15	11	10	15
	Shift Score	15	11	10	15
	Total Points	100	57	66	67

5. Discussion

From the research findings, all the three stations with results focusing on the TOD principle found that:

1. Walk

The neighborhood was developed to encourage walking. Populated sidewalks lined with people, activities, and services will improve the vitality of the local economy. So walkability can be considered a critical factor that shaped pre-industrial cities and promoted sustainable urban and resilient communities [8]. The Rajabhat University and Chiang Mai Airport station gained more scores for this development due to

their prepared environment for users' comfort (with built shade and shelter) and campaign to support various users.

2. Cycle

Non-motorized transport networks were prioritized. Safe areas and facilities for cyclists were planned for travelers. Cycling is an attractive travel option. It is an easy-access vehicle that helps save money, reduce carbon emissions and encourage exercise. Many Thai tourists prefer to cycle in the evening at comfortable temperatures. Suppose the city provides safe bike lanes, securely parking lots, and other facilities. In that case, it will increase the number of tourists who want to use their bikes for traveling [9]. All the selected stations had a satisfactory score, showing that their facilities were intended for non-motorized travelers.

3. Connect

A dense network of roads and routes was built so that walking and cycling routes were short, direct, and varied. Additionally, an urban design that is more permeable to pedestrians and cyclists than cars encourages non-motorized public transit modes and associated benefits. Therefore, Chiang Mai Airport station got more scores than Nakornping Hospital station because the station area was planned for easy walking access to the newly prepared building.

4. Transit

Development areas were to be located near the high-capacity community and public transportation to maximize the acceptable walking distance of 1,000 m for the nearest transit station and walking distance of 500 m for the local bus service that connects to the transit network. This distance is required at all TOD stations. It can also be an indicator of TOD identification [10].

5. Mix

An area was organized for mixed-use and planned for emerging income and demographics. Transit trips are short and within walkable distance while balancing inbound and outbound trips for control of neighborhoods' security. Moreover, this organized plan encourages walking and cycling, supports extended transit service hours, and creates a vibrant and accommodating environment. As a result, people of all ages, genders, income levels, and various characteristics can safely interact in public places. For this development, the Nakornping Hospital and Rajabhat University station gain more scores than Chiang Mai Airport because of their location's land use characteristics.

6. Density

Transit-oriented development leads to secure, convenient, well-populated, active residential areas and thriving commercial areas that support a wide choice of services and amenities. With increasing population density, there should be an adjustment in transit capacity and city growth to match the needs. Additionally, the densification of buildings should be adjusted to accommodate a healthy living environment, access to recreational spaces, and preservation of natural, historic, and cultural resources. The Chiang Mai Airport station gains more points because of the international airport's function, which supports travel and tourism. Additionally, this station is located in an area surrounded by industrial and commercial objects.

7. Compact

The compact urban design creates an area with a short public transportation journey, encouraging more people to use transit. The design promotes densification and the efficient use of the previously developed vacant lots. TOD can be used as a guide to better investment decision-making and its effects on surrounding property value [11]. The Rajabhat University station had the highest score because it was located in a high-density residential area far from the military, unlike other stations.

8. Shift

Even though parking and road control can increase mobility within the developed city, planned urban areas adhering to the above seven principles can reduce the importance of personal motor vehicle usage and the side effects of those vehicles. Furthermore, with fewer cars on the road, it is reasonable to reclaim the scarce and valuable urban space from unnecessary roadways and parking. Those spaces should then be reallocated for more socially and economically productive uses. Here, Chiang Mai airport station gains more points because of the function of an international airport as a gate connecting to other places.

From the research findings, all the 3 stations had the same top two metrics (walk and mix metric), which represent their location potential in relation to local facilities (school, hospital, shop, etc.) and opportunities in relation to the commercial objects. As for another top metric, it was found that Nakornping Hospital station and Chiang Mai Airport station have the same metric (shift) because these stations function as transit points for another vehicle. Rajabhat University station has the compact as the remaining metric due to its location in high-density residential area.

Each metric can be used separately for specific purposes depending on the project planner or decision-maker. For this study, the Airport station was the most potential area to develop first with a total score of 67 points. However, Rajabhat University station was also an interesting station if the developer wants to promote activities together with resilient communities because it scores higher points in compact, mix, and walk metrics.

TOD standard was mainly focused on the area physical data which can be collected before the project construction. This can provide feedback within the project's planning phase. Nevertheless, the TOD standard had difficulty when used with an area larger than a singular project.

The comparison of the metrics used for TOD selection in this study with those of other studies in Thailand [3, 12] found that the TOD standard mainly focuses on urban design and social aspects, while other studies focus on economics and potential. When considering the sub-factors there are few similarities, as shown in Table 3.

Table 3 Comparison of the metrics

TOD standard methods		**Other TOD selection methods**	
Metrics	**Measurement**	**Metrics**	**Measurement**
Densify	- Residential and nonresidential density	Relative Built Form Readiness-BR	*Land use:* - Population Density - Employment Density - Number of shops and facilities
Transit	- The longest walking distance to a transit station (must be less than 1,000 m)		*Station characteristics:* - Distance to nearest transit - Distance to LRT or CBD
Compact	- Transit line options		*Environmentally friendly transit:* - Public Transport Performance
Cycle	- Cycle network - Cycle parking		- Pedestrian-Bicycle Connectivity
Mix	- Percentage of housing that is affordable: - Resident and business preservation - Access to local services	Relative Market Strength	- Percentage of private property - Percentage of undeveloped vacant spaces - Number of plots of land - Average land price per plot

6. Conclusion

Applying TOD standard metric as an analytical tool for TOD selection project planning is beneficial. The strengths and weaknesses of the development station area can be visualized before the construction of the project.

In this study, TOD standard presented the most potential station (Airport station) as the priority developing project. Additionally, this standard could reveal the factors, which should be improved for better performance. TOD standard is considered an effective tool suitable for the context of Thailand. These results may guide the policy makers to contribute to a more efficient city plan.

Health is a critical issue nowadays. Therefore, further research is interested in using TOD to create a healthy environment for the communities. TOD can be combined with other tools for more well-being.

7. Suggestions

1. There may be discrepancies in the physical data collection of some buildings speculated from google Maps due to limited access to private property areas;

2. Each TOD standard principle can be used as a stand-alone indicator of a specific topic.

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