DOCTORAL DISSERTATION

博 士 論 文

A STUDY ON TRANSIT-ORIENTED DEVELOPMENT STRATEGIES IN THE HIGH-SPEED RAIL PROJECT IN THAILAND

タイ国高速鉄道プロジェクトにおける公共交通指向型開発戦略に関する研究

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by

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A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Engineering in transport and urban engineering

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ABSTRACT

Since Thailand is located a hub of land transportation connectivity among ASEAN countries. Thailand agrees with China to promote the strategic partnership through a memorandum of understanding on the cooperation on Thai railways infrastructure development on the strategic framework for the development of Thailand's transportation infrastructure 2015-2022. Thai-Chinese high-speed rail project (phase 1: Thailand's capital Bangkok to Nakhon Ratchasima province) is one of the megaprojects in long-term benefits under the strategic framework by the government-to-government process.

This high-speed rail (HSR) project was approved by the Prayut cabinet in July 2017 and was expected to operate in 2025. There are two primary reasons why Thailand decided to invest in the HSR project. The first reason is to support the strategy of the development of the international railway network and the second reason is to boost the regional economic development along the pathway.

However, a feasibility study of the HSR project was not feasible since the (direct) economic benefit was 8.56 % and financial benefit could not evaluate the value. Both values are lower than the benchmark in economic benefit (12 %) and financial benefit (5 %) based on the Office of National Economic Development Council. This is Thailand's government is facing how to drive it to sustainable development in the long run.

A feasibility study still recommended that if the Thai government utilized the land development around the HSR hubs (or transit-oriented development), an economic benefit would increase from 8.56 % to 11.68 % and approach criterion. Hence, TOD becomes one of the alternative strategies to boost economic value. Yet, Thailand' s government does not have the practical know- how and experience in how to make it happen around the transit stations. Meanwhile, Thailand faced a limitation of land development surrounding the transport station, such as the Town Planning Act 1975, the Constitution of the Kingdom of Thailand 2017, and Expropriation and Acquisition with Immovable Property Act 2019.

This dissertation is originated from a feasibility study of the HSR project and aims to develop a comprehensive study to provide the TOD strategies around the HSR hub toward sustainable development in Thailand. The strategic deliberation is based on the components of TOD in terms of the HSR hub and urban development. The research gap is sixfold: to investigate the barriers of the Thai government for the HSR project, to explore the international policy ideas, measures, and tools to implementation; to describe the change of macroeconomic and indirect economic benefit, to examine the size of the station catchment area, to determine the primary and secondary feeder access mode choice to the HSR hub, and to examine the tension between HSR hub and urban development.

The result shows that TOD plays a significant player among four principle barriers (operation service, TOD, new organization and panel, and fate structure) to drive the HSR project to sustainable development based on the mechanism of the barriers of the Thai government for the HSR project. However, TOD is a combination between transport planning and urban development by improving a relatively high level of transport connections and high-density, mixed-used-use, cycling- and pedestrian-friendly land use surrounding transit stations. Other barriers are necessary for the HSR project and need to solve in the initial phase.

The operation service is the political issue about signaling and telecommunication with track work in the section of Bang Sue and Ban Phachi. If the Thai government determines to use shard tracks in this section, the safety and reliability should perceive for railway passengers in advance. The new organization and panel to drive the HSR project should act for railway

operation and urban development since the HSR is an advanced technology and needs to hire experts to the joint venture (for land development) and hire the private sector (for O&M section). Ministry of Finance and SRT are the joint manager to reduce the financial risk. The fare structure for the HSR project can complete with private transportation and train's first-class and second-class, while other modes of transportation system cannot beat. The developer should provide the marketing measures to support demand.

Meanwhile, urban development involves several components to implementation (e.g. actors, transport and urban planning, and legislation and regulation), but the Thai government does not have the practical know-how to make it happened. An international transferable TOD concept from international viewpoints can be learned the decision-making from the best practices of other governments to promote and support the Thai context (i.e., specific areas for special development, land and community management, positive measure for town planning, organization, investment, and legislation and regulation).

Legislation and regulation are the key factors to drive other factors to successful TOD based on international experience. Thailand has similar development with Japan in terms of legislation and regulation. Yet, Thailand lacks many legislation and regulations such as urban renewal, land collection, and integration between transit stations and urban development when compared with Japan. Besides City Planning Act is related to many acts in different government agencies. It affects the management and decision-making because of viewpoints. On the Thai side, the hard regulation is land expropriation around transit stations and needs revision because the development cannot take benefit to developing commercial areas. Besides, the Thai government does not have the financial tool to support the developers and investors of the TOD project.

At the regional level, the Fukushima Shinkansen station can stimulate the macroeconomic for the long run after the operation. The performance after the operation of the Fukushima Shinkansen station outperforms the performance before the operation of Fukushima Shinkansen station on a small scale, even though the station is a big size and locates on the mainline. Meanwhile, in the case of the short-term, the economy has weak productivity performance in some duration because it receives the risk to endure external factors such as oil crisis, economic bubble, and inflation rate. Hence, policy implementations to regulate transportation demand are a considerable tool for economic activity and social welfare.

In terms of economic development, the development of the Fukushima Shinkansen station is not only generative economic growth but also originates economic development in Fukushima prefecture. Because after the opening of the Fukushima Shinkansen station during 1990-2000, there has been an upward trend in the human development index of 0.33 percent per year due to support factors (longevity factor and standard of living factor), even though the number of outpatients has significantly undergone a rapid change.

At the urban and station-area level, the Fukushima Shinkansen station is evaluated the station catchment area by drawing the circular shape around the station via ArcGIS. This approach does not take geography into account when the area developed at a different time and the researcher cannot grasp the natural obstacle within the station catchment area. A radius of the station catchment area is 12.4 and 17.6 km based on dense network and land value perspective, respectively. The station catchment area (12.4 km) beats only California cities since Fukushima city has a limitation of land to develop for urbanization. The specific results from the case study may not provide all factors affecting land value that influenced change in land value because of lack of sufficient data, namely public investment in infrastructure, change in land-use regulation, and landowner's investment. For these reasons, this research

focuses on only the population and economic factors. The population, primary industry, secondary industry, and tertiary factor are a significant impact on land value from a macro perspective.

Meanwhile, in the case of the Nakhon Ratchasima HSR hub, the catchment area surrounding the city center of NKR is a radius of 5.18. the light rai (LRT) transit project is selected as the primary feeder service in this dissertation.

The survey results on access mode choice indicate the LRT (32.19 %) and songthaew shuttle services (11.76 %) as the primary and secondary feeders. The share of private vehicle use to access the HSR hub is as high as 48.08 %. As a result, it is necessary to convince motorists to switch from private vehicle use to public transport as modes of transport to access the HSR hub. Specifically, in the primary development zone, private vehicle use accounts for the largest proportion of the access mode choice to the HSR hub (78.31 %). In the secondary development zone, the LRT and songthaew shuttle services make up 76.42 %, consisting of 59.97 % and 16.45 % for LRT and songthaew shuttle services, respectively.

The Multinomial logit (MNL) analysis results indicate that the significant variables of the primary feeder are travel distance, travel cost, and the availability of LRT line, while those of the secondary feeder are middle- and high-income brackets, car ownership, travel distance, travel cost, the availability of songthaew shuttle routes, and the availability of LRT lines. The MNL analysis also indicates the travel distance, travel cost, and the availability of the LRT line as the common significant variables for the primary and secondary feeder services.

The Tobit analysis results show that the significant demographic variables are income, car ownership, and motorcycle ownership, given tangible improvements are made to the facilities and infrastructure surrounding the Nakhon Ratchasima HSR hub. The expected willingness to pay of the survey respondents for the primary and secondary feeder services to access the HSR hub is 1.094 USD/trip/person, vis-à-vis the travel costs of songthaew shuttle and LTR service (from the farthest LTR station to the HSR hub) of 0.25 USD and 0.50 USD, respectively. The finding demonstrates that the commuters are willing to pay if significant improvements are made to the facilities and feeder service quality, especially to the songthaew shuttle service.

To redevelopment around Nakhon Ratchasima HSR hub, an extended butterfly model is modified assessment for node and place model. Nakhon Ratchasima HSR hub is located in Nakhon Ratchasima municipality and beside the CBD, but it is classified as an unbalanced node with a moderate node-index score on average (0.40) and a low place-index score on average (0.33), given that the maximum score of node-index and place-index is 1. The classification implies that transportation supply is significantly higher than urban activities of station areas.

With the weighting method for subjective evaluation, a sensitivity analysis is adopted to validate the results and check for the potential uncertainties in weights and data. Sensitivity analysis is calculated with 16 scenarios by changing ± 10 % of weight values of each criterion and indicator at a time. The newest node-index score on average ranges from 0.36 to 0.41, while the newest place-index score on average ranges from 0.32 to 0.37. The results from all scenarios are not significantly affected by sensitivity analysis.

Therefore, this study would be useful to the high-speed rail project in Thailand as well as other cities in developing countries to motivate more TOD strategies in the future and to drive the high-speed rail project to sustainable development.

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CHAPTER 1

INTRODUCTION

1.1 Research background and motivation

The development of high-speed rail (HSR) projects is continuously undertaken by the Office of the National Economic and Social Development Council and the Office of Transport and Traffic Policy and Planning (Office of the National Economic and Social Development Council (NESDC), 1992; Office of Transport and Traffic Policy and Planning (OTP), 2010). It ensures that HSR projects will bring a new era for travel and new experience to passengers and become a competitive economy for regional cities.

Nowadays, Thailand and China have signed a memorandum of understanding (MOU) of the HSR project connecting Thailand's capital Bangkok to the Chinese city of Kunming, running through Laos. The HSR development for regional connectivity on Bangkok-Nong Khai (phase 1: Bangkok-Nakhon Ratchasima) is one of the projects in MOU which was approved in July 2017 by the Prayut cabinet and expected to operate in 2024 (Thai cabinet resolution, 2017). There are two main reasons why Thailand decided to invest in HSR development. The first reason is to support the strategy of development of the international railway network and the second reason is to boost the regional economic development along the corridor.

However, a feasibility study of the HSR development for regional connectivity on Bangkok-Nong Khai (phase 1: Bangkok-Nakhon Ratchasima) is not feasible because the (direct) economic benefit (8.56 %) and the financial benefit (NA) are lower than the benchmark of NESDC (NESDC, 2012; The State Railway of Thailand (SRT), 2017). This is NESDC identifies economic benefit and financial benefit should be higher than 12 % and 5 %, respectively. The Thai government is facing how to drive the HSR project to sustainable development in long run.

Additionally, a feasibility study recommends that if the Thai government uses urban development around the HSR hub (or transit-oriented development), an economic benefit will increase from 8.56 % to 11.68 % and approach a criterion (SRT, 2017). For this reason, TOD is a meaningful strategy to support economic value, but the Thai government does not have practical know-how and experience in how to make it happen surrounding transit stations. Meanwhile, Thailand faces an obstacle in terms of legislation and regulation, especially urban development around transit stations (Chalermpong and Ratanawaraha, 2016; Japan International Cooperation Agency et al. 2017).

1.2 Statement of the problem

According to Yin et al. (2015) and lbraeva et al. (2020), study regarding TOD and HSR in developed countries are mainly concerned with indirect effects (i.e., reduce travel time, the impact of mode share of the railway in the transport market, and towards an integrated transport system) and direct effects in regional level (i.e., regional economic and social development and connection**,** redistribution and relocation along the HSR corridor, reconstruction of the urban-regional system), urban level (i.e., restructuring of urban system and synergy between HSR and urban dynamics), and station-area level (i.e., the definition of HSR station area, the general function of a station area, property development, urban quality, and development of station).

The research challenges are questioned in several viewpoints, e.g., how to develop an integrated system, how to build a sustainable role for the cities along the HSR corridor, respond to the urban development opportunities of HSR, and how to increase the quality of station areas.

Additionally, since the HSR project is an infrastructure-megaproject under the government-to-government deal, there is a lack of study on the obstacles of the HSR project from the Thai government perspective because of suitable and sustainable development (SRT, 2017; Thai cabinet resolution, 2017).

Therefore, this research requires to study more on the issue regarding TOD and HSR in the international and Thai contexts to encourage and attract the HSR travelers to use public transport to support sustainable transportation and support and develop the HSR project for a sustainable economy in Thailand. Given the background, the following sub-section explains the objectives of this study.

1.3 Research objectives

This dissertation is originated from a feasibility study of the HSR development for regional connectivity on Bangkok-Nong Khai (phase 1: Bangkok-Nakhon Ratchasima). This study aims to develop a comprehensive study to provide the TOD strategies with the HSR project towards sustainable development in Thailand. The strategic deliberation is based on the components of TOD in terms of HSR hub and urban development.

The research presents a methodological and a theoretical component that aimed to overcome the research gap of TOD and HSR hub. To identify the TOD strategies and HSR hub in the Thai context, there are six principle ways to be performed as follows.

1. To investigate the existing barrier from the HSR project (the fourth chapter)
2. To explore the international policies, measures, and tools to implementation (the fifth chapter)
3. To describe the change of macroeconomic and indirect economic benefit (the sixth chapter)
4. To examine the size of the catchment area (the seventh chapter)
5. To determine the primary and secondary feeder access mode choice to the HSR hub (the eighth chapter)
6. To examine the tension between HSR hub and urban development (the ninth chapter)

1.4 Scope and limitation of the study

On behalf of this research, Brazil, England, France, Germany, Hong Kong, Japan, South Korea, Taiwan, and USA are selected as an international comparison because of the best practice in TOD (Cervero, 1998; Dittmar and Ohland 2004; Akashi 2007; Jaehak et al., 2015; Suzuki et al., 2015) with the case study in Thailand (Nakhon Ratchasima city). Specifically, chapter 6 and chapter 7 only concentrate on Japan (Fukushima Shinkansen station) due to large gross provincial product, municipality size, travel distance from the origin, ridership (number of HSR passengers), vacant land around the hub, and availability of feeder services (Tissayakorn et al., 2019).

This research has limitations for available data and information from documents, policy reports, and academic literature from the fourth chapter to the seventh chapter. The eighth chapter uses survey data on HSR travel which had a limited time span (i.e., on a single day).

1.5 Outline of the dissertation

There are a total of ten chapters and appendices in this dissertation. This chapter starts to introduce the background and motivation why TOD strategies surrounding the HSR hub are important to study. The remaining chapters are arranged as follows:

The second chapter presents the existing researches of the relevant studies and ideas which were discussed.

The third chapter outlines the existing study area, data collection procedure, and collected data are described. This research design of all analysis processes and methodologies applied in this research is explicated.

The fourth chapter aims to contribute an understanding of the mechanism of barriers of the Thai government for the development of the HSR project on how to drive the HSR project for sustainable development. The objective of this research is fourfold: to classify the operation technique of the first HSR project investment in Thailand, to suggest TOD strategies for development around the HSR hub, to identify the characteristic of the new organization and personnel for the HSR project, and to advice the optimal fare structure for the first-year operation. This chapter is expected to have a significant impact on the direction of transportation policies and sustainable development aiming to increase the use of HSR. The results show that two HSR systems could not operate in the same tracks because of the level of service, operation and maintenance cost, safety, and technology transfer. TOD is the most influential factor in the mechanism because it can generate a financial return, economic return, and social return to the project. Additionally, the components of successful TOD depend on many factors, e.g., city planning, location, regulations, timing, and local government. The new organization and panel to drive the HSR project is the limitation of available information by surfing the internet. The fare structure for HSR travelers can challenge only private transport and train's first-class and second-class. However, it does not compete naturally with another mode of public transportations.

The fifth chapter identifies the critical factor perspective of international TOD policies, measures, and tools to determine the transferable models that could work in Thailand by gap analysis. Specifically, this research focuses on specific areas for special development land and community management, positive measures for town planning, the organization for TOD, and measures and tools for investment from nine countries (Brazil, England, France, Germany, Hong Kong, Japan, South Korea, Taiwan, and USA) which were proven as the best practice. These critical success factors are useful for governments and planners to apply in the Thai context.

The sixed chapter proposes to reveal the economic performance of Fukushima prefecture after the development of the Fukushima Shinkansen station. The objective is twofold: to analyze the short-term and long-term changes constantly of Fukushima prefecture before-after development of the Fukushima Shinkansen station based on time series and to evaluate the indirect (wider) economic benefits and economic development on Fukushima prefecture based on actual data by using comparative analysis with compound annual growth rate. As a result, after the operational Fukushima Shinkansen station, the macroeconomic in Fukushima prefecture outperforms the previous time, even though it faces economic variance in some

situations. Furthermore, the Fukushima Shinkansen station will not originate economic growth but also generate economic development in Fukushima prefecture, as well as the effective factors are the gross prefecture product, elementary school, high school, employee (full time) and unemployment and human development index that can create a capability for Fukushima prefecture. However, the outcome of wider economic benefits in Fukushima prefecture is the maximum value since it is significantly induced the economic impacts of other factors.

The seventh chapter emphasizes evaluating the size of the Fukushima Shinkansen station catchment area by utilizing a dense network and land value and comparing it with the existing studies. The summary of the result is Fukushima Shinkansen station catchment areas are 12.4 and 17.6 km based on dense network and land value, respectively. Therefore, a radius of 12.4 km captures a part of the radius of 17.6 km of the station catchment area. Additionally, it is denser than only California cities because of the limitation of land that led to developing the urbanization. Meanwhile, the population factor and industry factor have a significant impact to drive the change in land value.

The eighth chapter determines the influencing factors of primary and secondary feeder services to access the HSR hub of Nakhon Ratchasima municipality and the willingness to pay for the feeder services. There are three groups of influencing factors: demographics, travel characteristics, and facilities and infrastructure. The current and future modes of transport to access the HSR hub are first examined, and the primary and secondary mass-transit feeders are determined. The study area is the catchment area surrounding the city center of Thailand's northeastern province of Nakhon Ratchasima. The influencing factors of access mode choice to the HSR hub are analyzed by the multinomial logit (MNL) model, and the willingness to pay for the feeder services by the Tobit model. The survey results on access mode choice indicate light rail transit (LRT) and songthaew shuttle service as the primary and secondary feeders. The MNL analysis indicates the travel distance, travel cost, and the availability of the LRT line as the common significant variables for the primary and secondary feeder services. The Tobit analysis reveals that the commuters are willing to pay if significant improvements are made to the facilities and feeder service quality. The findings are expected to provide the local government and concerned agencies with useful insight into the influencing factors that play an essential role in convincing private car users to switch from private vehicles to mass transit services.

The ninth chapter designates strategic transport and land use, which drive the potential for allocation of additional accessibility and urban development. The potential is determined by the extension of transport accessibility and economic development (amenities and tax earnings of the municipality). The modification of the node and place model for the high-speed rail (HSR) hub is first examined and categorized into node- index and place- index, incorporating information about people who access the Nakhon Ratchasima HSR hub and their willingness to pay. With analyzing this HSR hub in the extended butterfly model application, a place- index score on average (0.28) is lower than a node- index score on average (0.40). A score of 0.40 and a score of 0.28 over a maximum possible score of 1 can be considered as a moderate score and low score, respectively. These results clearly show that the HSR hub is classified as an unbalanced node.h

The tenth chapter summarizes the main findings and policy implications and contributes that can guide the transport and urban planning in Thailand and developing countries as shown in Figure 1.1. It also postulates the possible prospects for further research that can enrich the validity of research findings.

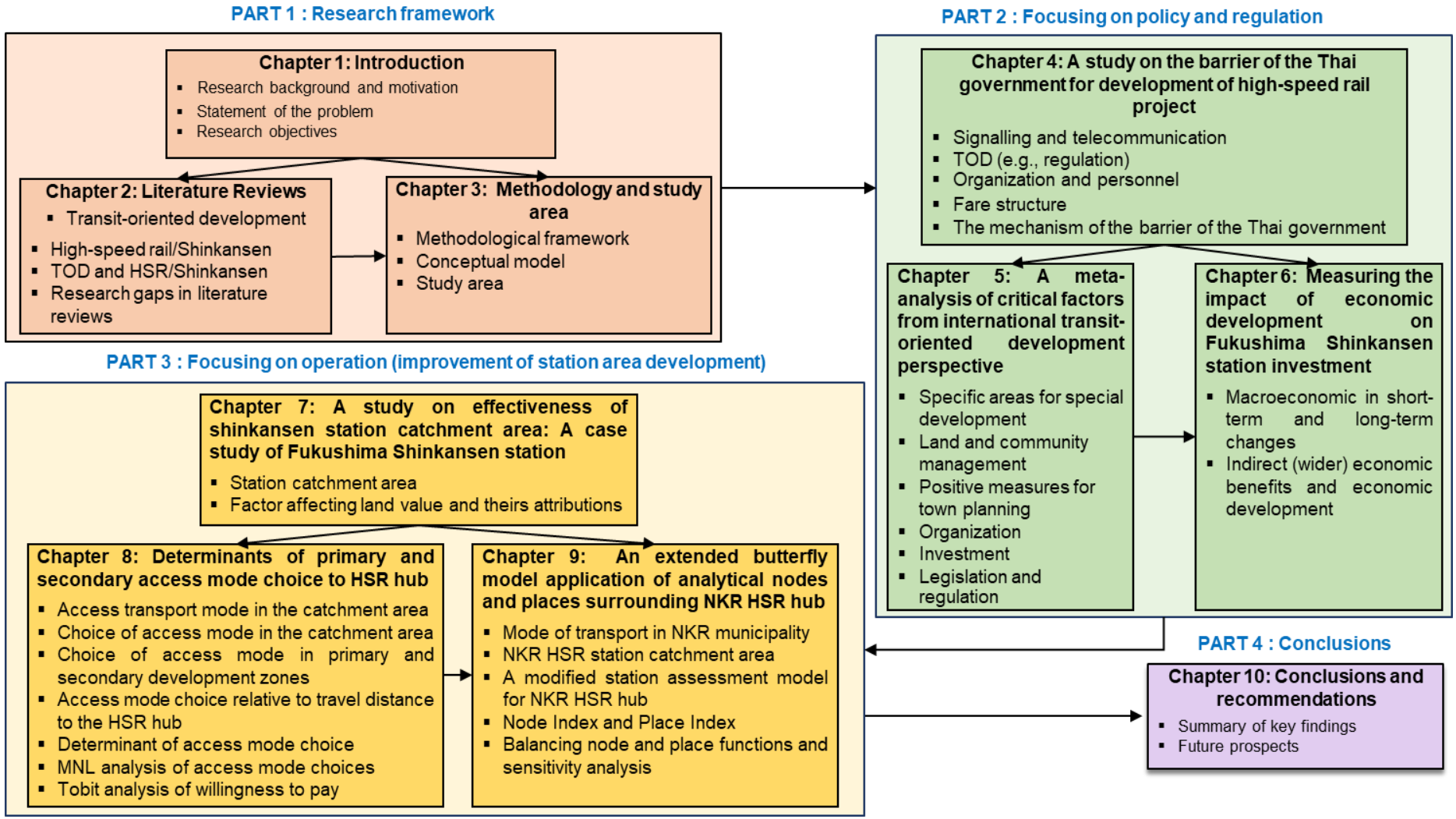

Figure 1.1 The outline of the dissertation

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CHAPTER 2

LITERATURE REVIEWS

The purpose of this chapter is to provide the relevant studies and ideas regarding this dissertation. The chapter begins by providing an introduction of transit-oriented development (TOD) focusing on the previous studies relating to the definition of TOD, the performance of TOD, the scale of TOD planning, and the stakeholders of TOD planning in Chapter 2.1. Then the definition of high-speed rail/Shinkansen and HSR/Shinkansen infrastructure and development are detailed in Chapter 2.2. In Chapter 2.3, the existing researches on TOD and HSR/Shinkansen are detailed. Chapter 2.4 summarizes the research gaps from literature reviews.

2.1 Transit-oriented development

2.1.1 Definition

Transit-oriented development (TOD) is a concept which originally defined as "…a mixed-use community within an average 2000-foot walking distance of a transit stop and core commercial area. TODs mix residential, retail, office, open space, and public uses in a walkable environment, making it convenient for residents and employees to travel by transit, bicycle, foot or private car" (Calthorpe, 1993). A walkable environment plays an important role through access and egress transit stops to reduce private car trips and control the urban sprawl. Hence, Calthorpe (1993) focused on the physical characteristics around transit stops (station catchment area).

The definition of TOD has diverse natural definitions and different researchers have different expectations of TOD so far (Schlossberg and Brown, 1887; Boarnet and Crane, 1997; Cervero and Kockelman, 1997; Ewing and Cervero, 2001; Parker et al., 2002; Dittmar and Poticha, 2004; Hale and Charles, 2006; Hoffman, 2006; Halbur, 2007; Newman and Kenworthy, 2007; Center for Transit-oriented Development (CTOD), 2009; Newman, 2009). TOD is expected to integrate land use and public transportation, convince private car users to switch from private vehicles to public transport services, generate a mix of uses at various densities surrounding transit stations, and promote and support sustainable development (Transit Cooperative Research Program, 2002). Different stakeholders (actors) have different requirements and goals to drive TOD and hence their definitions of TOD should differ.

2.1.2Performance of TOD

TOD should be reserved for projects that achieved five main goals, i.e., location efficiency, rich mix of choice, value capture, place making, and resolution of the tension between node and place (Dittmar and Poticha, 2004).

1. Location efficiency

Location efficiency is important to creating an equitable and efficient region. The communities with affordable housing with easy walk to transit stations could be increased the ability and willingness with limited resources to stimulate the local economy. The key components of location efficiency consist of density, transit accessibility, and pedestrian-friendly. Density is how to increase effective non-motorized transportation (walking and

cycling) around transit stations. Transit accessibility is how to serve the railway users access and egress the destinations easily. Pedestrian-friendly is how to interconnect and scaled to pedestrian network within transit district (Handy et al. , 2005; Gori et al., 2014; Boarnet et al., 2017).

2. Rich mix of choices

The rich mix of choices is a choice and a mix of users. The choice is offered several activities within walking distance, while a mix of users makes the communities more convenient and affordable to complete one trip excluding private car. The fundamental choice provides community residents with a range of housing options, gets around on foot, by cycling, or transit systems to improve mobility service, and offers demand needs such as chopping choices, pubic services, and public assistance.

3. Value capture

It is a portion of the financial benefits received through property value increases. The successful value capture requires frequent and high-quality transit service, good connections between transit and the community, community amenities and a dedication to the place making, and scorekeeping and attention to financial returns. In the case of local government, value capture refers to higher tax revenues from increased sales and property values, while in the case of the transit agency, value capture means revenues from joint development and fare boxes (Gihring, 2009; Li et al., 2013).

4. Place making

Place making inspires a people-centered approach to attractive, planning, design, and management of public spaces as the heart of the whole community. The combination between people and places is maximized the shared value that required to collaborative process more than promoting a better urban perspective. The key elements of existing place are places for people, enrich the existing, multiple transportation options, work with landscape, mix uses and forms, and respect community heritage. However, the development needs to flexible correspond to future changes in demography, lifestyle, and use (Project for Public Space, 2016).

5. Resolution of the tension between node and place

Transit stations (or transit stops) is a node, while urban development is place. The node value not only relies on the transit station's position in the railway network but also its position within the city transport network. Meanwhile, the place value relies on its location in the city, the function of the area surrounding the transit station, and the spatial quality of the transit station. The node value and place should correspond to the tension between both values. The level of accessibility is provided by the node value and corresponded to the accessibility demands located in the place. On the other hand, the travel demands are generated by the activities located in the place should correspond to the transport facilities provided by the node (Bertolini, 1999; Yin et al., 2015; Cast, 2019).

2.1.3 Scale for TOD planning

TOD planning is required to work at regional, urban, and station level and incorporated suitably (CTOD, 2009; Yin et al., 2015). The boundary of TOD to development (station catchment area) is critical. A TOD catchment area is measured by the maximum distance people will willingness to walk to access and egress transit stations The average maximum

walking distance of local people to transit stations falls between 800 m and 1,200 m (Calthorpe, 1993; O'Sullivan and Morrall, 1996; Regional Plan Association, 1997; Halden et al., 2000; Rastogi and Rao, 2003; Vuchie, 2005; Wibowo et al., 2005; Yang et al., 2013; Faniels and Mulley, 2013; El-Geneidy et al., 2014; Wibowo et al., 2015).

However, TOD is important for station plans to merge and integrate into a larger picture at the urban level and regional level. Successful TOD planning requires understanding the role of stations and neighborhoods in the regional network of transit systems. A regional TOD plan is coordination between itself and other existing regional plans for growth to set the common goals and coordination among agencies. Investment should be made in developing projects in key locations throughout to region from conceptual to actual form. Station-area planning is important to understand the pulse of the community to promote economic and social activities because the project investment takes place. Planning TOD should include local politics to ensure the regional priority (CTOD, 2009; Singh et al., 2012; Suzuki et al., 2015).

2.1.4 Stakeholders of TOD Planning

TOD involves several stakeholders in implementation. The transit agency is responsible for maximize monetary return to land, maximize ridership, and capture value in long run. The rider is responsible for generating and high level of parking, improving transit service and station access, increasing mobility choice, developing a convenient mix of uses around transit stations, and maximize pedestrian access. The neighbors are responsible for maintaining property value, minimize traffic impact, increase mobility choices, and improve access to transit stations, jobs, and liability. The local government is responsible for maximizing tax revenue, foster economic vitality, and redevelop underutilized land. The federal government is responsible for protecting the public interest. The developer is responsible for maximizing return on investment, minimize risk, and ensure value long run (Dittmar and Poticha, 2004).

However, the core value of stakeholders is to understanding government projects from nature governance. Government project is complex when each project involves many government agencies. This case has to assign and specific organization among government agencies (Ahola et al., 2014).

2.2 High-speed rail/Shinkansen

2.2.1 Definition

According to Feigenbaum (2013) and the International Union of Railways (2018), high-speed rail (HSR)/Shinkansen was one of the railway transportations that ran significantly faster than conventional railways by using specific rolling stock and dedicated tracks. Meanwhile, the signaling was dependent on operators and did not have an international standard. The speed was greater than 200 km/h on standard gauge tracks.

2.2.2 HSR/Shinkansen infrastructure and development

HSR/Shinkansen infrastructure and development were a significant investment to boost the socioeconomic and integrated spatial domestic and international countries (Aschauer, 1989; Bruinsma and Rietveld, 1993). This is HSR/Shinkansen aimed to promote regional development along the corridor (Vickerman, 1997; Yin et al., 2015), while cities in the pathway

increased accessibility and competitiveness (Vickerman, 1997; Yin et al., 2015; Kim and Sultana, 2018).

HSR station (hub) is a connector that required primary feeder services to integrate into different ranges (Van der Spek, 2003). HSR makes travel easier than other modes of transportation, especially travel distance between 150-800 km (Gleave, 2004). The competitive network of transportation systems reduced travel costs and generated a higher ridership for commuting, business travel, and leisure which promote economic development (Yin et al., 2015).

According to Vickerman (1997) and Chen and Haynes (2015), the HSR network generated a positive economic impact in the major cities, while the negative economic impact in small and peripheral cities where left off the network. The absence of the HSR hub affected the positive effects from the macro perspective (Vickerman, 2015). The location of the HSR hub needed to take into account construction and utilization around the HSR hub with integration primary feeder services (Higgins and Kanaroglou, 2016).

2.2.3 The experience of HSR investment

1. Japan

Tokaido Shinkansen (515 km) was firstly operated from Tokyo to Osaka in 1964. The Japanese government determined to invest this section in order to reduce travel time between two cities and increase alternatives for using modes of transport (Okabe, 1980; Sasaki et al., 1997)). There are nine networks of Shinkansen lines[1] serving 22 of its major cities (Oh et al., 2015). HSR drove economy, especially industrial side but it could not boost the benefits from HSR for long run of regional development (Sasaki et al., 1997; Haynes, 1997; Oh et al., 2015.

2. France

The French TGV Sud-Est (425 km) linking Paris and Lyon was operated in 1981. The French government determined to invest this section based on three concepts which were dedicated line for traffic congestion, compatibility with existing railway network, and high frequency operations with short journey times (Vickerman, 1997; Arduin and Ni, 2005). France was one of the most successful in the financial value and the impact because of the active government (Dunn and Perl, 1994). However, the French HSR made the negative impact on the industries in terms of the number of overnight stays from business travellers (Bonnafous, 1987; Vickerman, 1997; Department of Transport, 2011).

3. Germany

The German InterCity Express (ICE) linking Hamburg and Augsburg was firstly operated in 1991. The German government determined to invest this section because (1) the government required to solve the traffic congestion and improve the connectivity between the North and South and (2) to integrate passengers and freight service for supporting industries (Vickerman, 1997; Ahlfeldt and Feddersen, 2010). The German ICE was used a shared track HSR network to operation rather than upgraded the existing lines. This approach did not have a significant impact on the economic geography (Sands, 1987; Vickerman, 1997), but it made

[1] Akita, Hokkaido, Hokuriku, Joetsu, Kyushu, Snayo, Tohoku, Tokaido and, Yamagata

several questions involved to financial revenue and environmental justification (Albalate and Bel, 2010).

4. Spain

The Spanish HSR linking Madrid and Seville was firstly operated in 1992. The Spanish government determined to invest this section because the government required to use this investment (tool) to promote economic development along the corridor (Givoni, 2006; Vickerman, 1997). The HSR was used a dedicated tract and obtained technology transfer of HSR technology Vickerman (1997). The HSR passengers had a low lever due to the small size of urban agglomerations and the market share of air transportation faced slightly negative impact (Rus and Inglada, 1997; Givoni, 2006; Vickerman, 1997; Coto-Millan et al., 2007). However, Gourvish (2010) reported that Madrid received the benefits from connection to Seville such as a greater centralization of businesses and population in the Spanish capital.

5. China

The Chinese HSR linking Guangzhou and Wuhan was firstly operated in 2009. China is the longest HSR network in the world by using a dedicated track for operation. The HSR made a reduction of travel time from 12 to 3 h in the first operation (Yin et al., 2015). Since this travel time seemed shorter than other countries, many angles of economic benefit (e.g., employment, environment, and urbanization) were generated (Tang et al., 2011; Salzberg et al., 2013; Yin et al., 2015).

6. South Korea

The Korea Train eXpress (KTX) was firstly operated in 2004. This section was determined to investment because the Korean government required to boost regional development and to reduce the traffic congestion along the corridor (Chang and Lee, 2008; Oh et al., 2015). According to Chang and Lee (2008) and Oh et al. (2015), The KTX reduced travel time between major cities (with a two-hour traveling time). The KTX also signed on market shared (Park and Ha, 2006). However, the KTX had a significant impact on transportation rather than socioeconomic (Oh et al., 2015).

7. Taiwan

The Taiwan HSR (THSR) linking Taipei and Kaohsiung was firstly operated in 2007. This section was determined to investment due to the traffic congestion (Cheng, 2010). The government used a build operate transfer model for this section. The funding for THSR came from shareholder equity accounting for 20 % and banking group (Yung-Hsiang, 2010; Oh et al., 2015). If the financial return was failure, the banks would buy back from the system. Therefore, HSR passengers are the key variable for the BOT project.

2.3 TOD and HSR/Shinkansen

2.3.1 Direct effects

1. Journey times and travel distance

The market advantage of railway transportation depends on the speed and reliability of transport mode. Figure 2.1 shows the competitive advantage of HSR. Railway transportation is faster than aircraft for a journey of approximately 150-400 km. HSR becomes a faster mode and makes a significant mode if the journey is farther than 400 km. The aircraft is faster than HSR if the journey is farther than 800 km (Gleave, 2004).

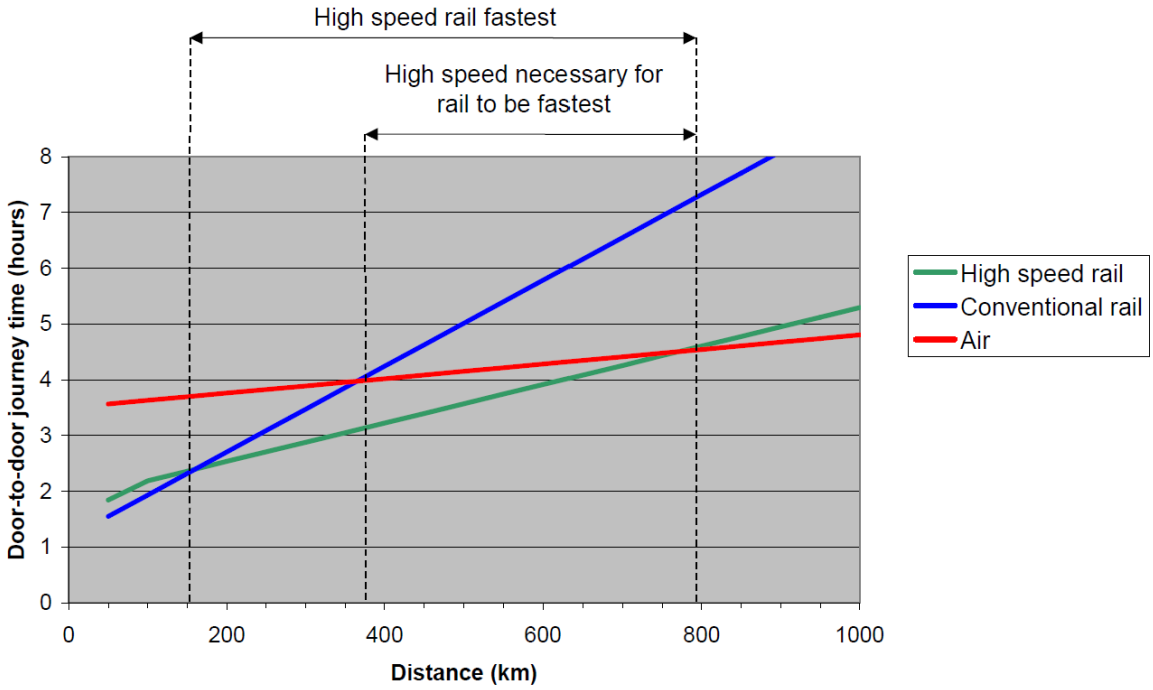

Figure 2.1 Competitive advantage of HSR

Source: (Gleave, 2004)

2. Reduced travel time

Table 2.1 shows the travel time of conventional railway and HSR. Travel times on HSR lines are lower than conventional railways. Fast travel time brings about an important reason for HSR travelers. Most Japanese and Italian HSR travelers take the HSR because of reduced travel time (Sanuki 1980; Casette et al., 2011; Oh et al., 2015).

Table 2.1 Travel time of conventional railway and HSR

Countries (lines)	Journey time (h:min)		Changes (%)	Travel distance (km)
	Conventional time	HSR time		
Japan				
(Tokyo-Shin Osaka)	6:30	4:00	-38.33	515
(Shin Osaka-Hakata)	8:30	4:40	-45.10	554
South Korea				
(Seoul-Busan)	4:10	2:40	-36.00	442
(Seoul-Mokpo)	4:40	2:58	-36.43	414
Taiwan (Taipei-Zuoying)	4:50	1:34	-67.59	345
France (Paris-Lyon)	-	2:20	-	427
Spain (Madrid-Seville)	5:55	2:30	-57.45	535
Germany Frankfurt-Cologne)	2:13	0:59	-55.64	177
Italy (Rome-Naples)	1:45	1:5	-38.10	213

Source: Bonnafous (1987) for France, Sand (1993) for Japan, De Rus and Inglada, (1997) for Spain, Chang and Lee, (2008) for South Korea, Ahlfeldt and Feddersen, (2010) for Germany, Yung-Hsiang, (2010) for Taiwan, and Cascetta et al., (2011) for Italy.

3. Mode split

Table 2.2 shows mode split in different countries based on before-and-after operational HSR lines. The results are clearly shown for comparison of modal share of HSR lines for similar travel distances. For instance, in Spain's AVE, Mode share increased from 14 % to 51 % after two years of operation, while aircraft decreased from 40 % to 13 % and road journey decreased from 40 % to 36 %.

However, the ridership decreased in a short term for Germany, Taiwan, and South Korea (Vickerman, 1997; Cheng and Lee, 2008; Yung-Hsiang, 2010). In Germany, ICE traffic accounted for 28 % of long-distance ridership revenues. 12 % of HSR traffic comes from former road and air ridership and is lower than estimated (Vickerman, 1997). In Taiwan (Cheng and Lee, 2008), the HSR ridership decreased from the estimation value (200,000 trips per day) to actual value (101,000 trips per day). Besides, the integration of transportation modes was weak performance and affects Taiwan HSR.

Table 2.2 Mode split after operational HSR

HSR (lines)	Description
Sanyo Shinkansen line	The ridership grew up 40 % from 1971 to 1975 (the first operational year).
Honam line	Market share of transportation mode decreased during 2003-2004 as follows. ▪ Aircraft decreased from 3.1 % to 1.1 %. ▪ Express bus decreased from 14.3 % to 14.9 %. ▪ Conventional railway decreased from 23.5 % to 9.0 % ▪ Private cars decreased from 59.1 % to 53.8 %.
Taipei-Kaohsiung	▪ HSR serviced in 2007 and has 25.03 % of the market share in April 2007. ▪ In 2008, the market share of HSR increased from 25.03 % to 49.64 % ▪ Market share of other modes changed on this HSR line during 2005-2008 as follows. - Aircraft decreased from 28.73 % to 4.97 %. - The intercity bus service decreased from 35.29 % to 22.28 %. - Conventional railway decreased from 7.76 % to 2.50 %. - Private cars decreased from 28.22 % to 20.61 %.
ICE network	The ridership was fivefold in the first five years of operation.
AVE Madrid-Seville	Market share of HSR increased from 14 % to 51 % after two years of operation while other modes of transportation decreased (e.g., aircraft decrease from 40 % to 13 % and private car and bus decreased from 44 % to 36 %).
Rome-Naples	The market share of HSR increased from 49 $ to 55 %, while the market share of the private car decreased from 51 % to 45 %.

Source: Okabe (1979) for Sanyo Shinkansen line, Vickerman (1997) and Givoni (2006) for ICE network and AVE Madrid-Seville, Cascetta et al., (2011) for Rome-Naples, Chang and Lee, (2008) for Gyeongbu line, Yung-Hsiang, (2010) for Taipei-Kaohsiung

4. Integration of transport systems

HSR hub is a node and wishes to connect with modes of transportation by possible transfer routes and different ranges. The design requires the seamless transfer and reduce transfer resistance (Van der Spek, 2003).

The travel distance between modal transit stops (e.g., bus stops, conventional railway stops, and private car parks) and the travel time for travelers to transfer from one mode to other modes were measured by Tapiador et al. (2009). This study provided a good door-to-door service for commuters and other travelers. The results showed that traffic congestion increased

in the neighboring area. Likewise, the regional bus is a half-mile from the HSR hub and connects local bus are infrequent.

The first and last-mile connectivity focus primarily on the mode of transport to access and egress the elevated and underground train stations (Stringham, 1982; Krygsman et al., 2004; Givoni and Rietveld, 2007; Brons et al., 2009). Yang et al. (2019) focuses on travel time from the origins of the journey to the Chinese HSR hubs and finds that business travelers would choose subway services over other modes of transport to reduce travel time and the private car use is correlated to the number of subway lines.

This section is discussed the direct effects of HSR, especially transport effects. The next section will describe the indirect effects including economics and urban planners.

2.3.2 Indirect effects

1. Regional level

HSR at the regional level can increase mobility and accessibility opportunities. It affects the location of places and leads to a regional spatial redistribution. Among the cities along HSR corridors, there is a redistribution of social, economic, and spatial elements. Murakami and Cervero (2010) compared the population and labor market within 5 km from Shinkansen stations on Tokaido lines. The intermediate Shinkansen stops (Odawara, Shizuoka, Hamamatsu, Gifu-Hashima, and Maibara) are less attractive for business passengers and less profitable for the privatized Shinkansen company. The size of the city and its metropolitan area, network location, and travel distance from the central city can be found to determine an HSR service's potential impact on intermediate and secondary cities (Yin et al., 2015).

2. Urban level

- Restricting of the urban system

HSR is a stimulation for the restricting and reshaping of urban systems. Hall (2009) mentioned that locations of HSR hub influenced three kinds of urban impacts as shown in Figure 2.2. The first type is when the HSR hub was located near or inside the central business district (CBD). This improves or reinforces the CBD attractions as the place for commercial investment such as King's Cross-St Pancras in London and Lille. The second type is when the HSR hub was located on the edge of cities. This can help develop complementary sub-centers such as Kassel-Wilhelmshöhe in Germany. The last type is when the HSR hub was located in an edge city on the urban periphery. This is the use of a new station as the basis for the new commercial area such as Shin-Yokohama in Japan.

The transformation of the mono-centric city into a poly-centric urban region is promoted by the second type and the third type. That is to say, the development of more urban centers and more nodes connecting the urban pattern and the infrastructure networks together (Priemus, 2008).

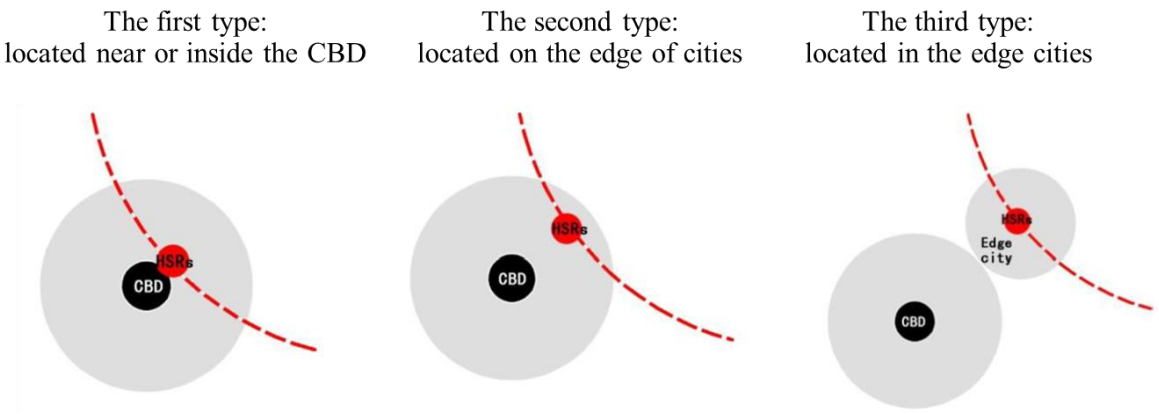

Figure 2.2 Three kinds of HSR hub location

- Economic impact

The economic impact in Sanyo Shinkansen (Osaka-Hakata) was examined by Okabe (1979). The result showed many viewpoints on local communities along the corridor (i.e., a saving of the value of time, a competitive aircraft (when the distance between cities was less than 500 km), an increase in population, an increase in offices, cloth fashions, tourists, hotels, an increase in land prices and wages). This impact did not affect in the short time to lead the growth of the business sector since the policies were the important key to the redevelopment of the station area. However, only small and medium-sized cities along the Sanyo line expanded the areas of activities.

The performance of Tokaido Shinkansen in terms of economic and social impact was declared by Okada (1994). The geography and society obtain the positive effect on Japanese business (stores and hotels), economy (reduced travel time), urban development surrounding Shinkansen station (employment, industrial shipments, tourists, and conference rooms), and environment (reduced air pollution). These performances resulted from the superiority of the Shinkansen over other meant of transportation in terms of speed, safety, and punctuality.

The impact of the Shinkansen network on spatial dispersion of economic activities and population was analyzed by Sasaki et al (1997). The result showed that the expansion of the Shinkansen network would not necessarily contribute to regional dispersion. However, the development of Shinkansen could not resolve the problem of excessive agglomeration. Lee (2017) argued with the impacts of HSR on socio-economic perspective. Specifically, the regional development generated a higher population density, Gross Prefectural Product (GPP) in Tokyo, Nagoya, and Osaka, and a sustainable environment.

The international comparison on (Japanese, Taiwanese, and Korean) HSR impact and station area development was studied by using policies and performances (Oh et al., 2015). The result showed many economic and social impacts. For economic development around the station, the researchers expressed that it depended on strategies and the location of stations. For instance, Shin-Yokohama station affected the population in Kohoku district where was located in the residential area. The business market of shops and sales around Karuizawa station was expanded after Tohoku Shinkansen operated in 1997. Around Nagoya station was developed with more floor space and a higher amount of sales. On the other hand, there was a smaller impact on the number of employees.

3. Station-area level

- HSR station area

HSR station catchment area was defined as the zone within an urban design (the service area or core area) that had a willingness to travel to and from the station and the transportation modes available (Giannopoulos and Boulougaris, 1989). However, willingness to travel varies by person, trip purpose, travel time, travel cost, gender, age, climate, land use, and income.

The size of the geographical catchment area is created by a circle surface with a radius of the maximum distance. It influences the travel demand to determine the ridership that used the stations in different radius, as well as involved land value (Quade and Douglas, 1996; Guerra et al., 2012; Sung et al., 2014; Upchurch et al., 2014; Jun et al., 2015). The net benefit from the station depends on station characteristics, the income of the people, and station catchment area (Bowes and Ihlanfeldt, 2001). The researcher can discuss the catchment area in terms of its radius.

Railway transportation in Japan is operated by various private companies. The ridership has a crucial factor for financial return. Railway companies (operators) must realize the station catchment area concept as much capacitance as possible, whereas the users the people who worked or resided within the station catchment area. For this reason, attractive people to work or reside in the station catchment area can take part in one of the strategies in railway companies.

Station catchment areas were proved by a few studies on urban transit and often defined a radius of 400-800 m from the station (Vuchic, 2005; Guerra et al., 2012). However, the HSR station catchment areas differed from that and had larger accessibility because of inter-city travel Catz and Christian, 2010). In addition, the previous investigations have examined a reasonable HSR/Shinkansen station catchment area that fell in the radius range of 5-25 km, depending on feeder systems (Murakami and Cervero, 2012; Zhong et al., 2014).

- Accessibility

Accessibility was defined as ease in which people could reach destinations and activities (Hansen, 1959; Song et al., 2017). Investment in transportation (high quality and efficiency) led to better accessibility of the area. This change in accessibility impacted land value and usage (Alonso, 1964; Goldberg, 1970; Mulley, 2014; Suzuki et al., 2015)

The transportation systems not only enhanced the accessible range but also brought about more efficient land-use patterns for minimizing travel distance (Litman, 2012). Travelers derived a good deal with the transportation systems that benefited from easier access to transportation modes.

- Land value (or land price)

The land value was defined as the fair market value of land and excluding buildings. Change in land value is often defined in the same way. The change was caused by population growth, economic development, public investment in infrastructure, change in land-use regulation, and landowner's investment. While the land value increased, the government applied the public financing method (land value capture) to solve this point (Suzuki et al., 2015). Accessibility can be utilized as an alternative approach to transportation systems and service evaluation. Not only increased land value but also land-use changes the result from increased accessibility.

- General functional of station

HSR hub areas and railway station areas are similar general functions. Most of the researchers defined station areas as a combination of transport and land use perspective (Bertolini, 1996; Bertolini, 1999; Bertolini and Dijst, 2003; Reusser et al., 2008; Zemp et al., 2011; Ivan et al., 2012; Chorus and Bertolini, 2014; Kamruzzaman et al., 2014; Vale, 2015; Lye et al., 2016; Singh et al. 2017; Caset et al., 2018; Kim et al., 2018; Papa et al., 2018).

Bertolini (1996) created the conceptual framework for analyzing station areas as a node-place model. This model aims to explore the underlying relationships at station areas. The basic idea is to improve the transport perspective (or node value) of a location to set the conditional redevelopment of the location by improving accessibility. Meanwhile, the development of a location (or an increase in place value) improves the conditional favorable to further development of transport system owing to the demand side of the transportation system.

Figure 2.3 shows the five typical situations, conceptual node-place model. The first situation of the node-place model (balance) is an intensive area for transportation and economic activity and can be seen as a key dynamic in the development of the station catchment area. The second situation of the node-place model (dependence) is little demand for land use and less service for transportations. The third situation of the node-place model (stress) is a high supply of transportation and intense beneficial land-use development. The fourth situation of the node-place model (unbalance node) is high development in transportation service but weak role from economic activity. The fifth situation of the node-place model (unbalance place) is high economic activity but the insufficient supply of rail transportation.

According to redevelop station area, both unbalanced location types are expected to switch to a more balance location type. The realization of this potential is not a certainty, but it may affect other factors.

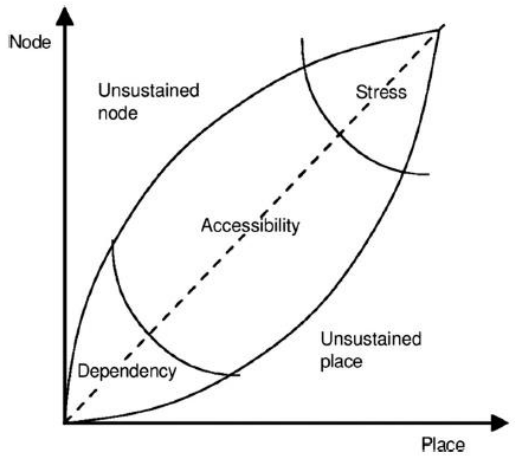

Figure 2.3 The conceptual node-place model
(Source: Bertolini, 1999)

Many researchers apply the node-place model to subways and bus rapid transit in different geographical contexts (e.g., Bertolini, 1999; Value, 2015; Lyu et al., 2016; Singh et al. 2017; Caset et al., 2018). The definitions of goals differ for all studies and several works of literature approach to set the TOD typologies and enhance the assessment of the transit stations

in each dimension. The common TOD typologies allow policy makers and planners to design the strategies by supplementing the quantitative analysis (Reusser et al., 2008)

- Development of station area

The development of the station area is a complex process and includes spatial, temporal, financial, management, and policy issues (Bertolini, 1998; Dittmar and Poticha, 2004; Thomas and Bertolini, 2014; Tomas et al., 2018). The actors play an important role to organize different contexts for the development process. The actors include transit agency, rider, neighbors, local government, the federal government, and developer/lender. Each group has its responsibilities and goals. If some countries have complex organizations, they will affect the development of station areas. Additional concerns are legislation and regulation and uncertain risks which are challenged in the association of spatial planning (Bertolini and Spit, 1998).

2.4 Research gaps in literature reviews

The infrastructure-megaproject such as for TOD components is often made without understanding the existing situation and possible international TOD policies, measure, or tools (specific areas for special development, land and community management, positive measure for town planning, organization (involves in the development of TOD), investment, and legislation and regulation.) to the transferable concept in long run.

For regional level and urban level, there is a lack of research in aggregate demand (macroeconomic) perspective based on time series and wider economic related-parameters based on agglomeration economy. For the station-area level, there is a lack of a size of the HSR station catchment area for the first year of operation to understand the boundary and take a benefit to fulfill development. At the station-area level, the HSR hub should be an integrated primary feeder service to access and egress the HSR station for cities or municipalities with large catchment areas. There exists very limited research on the mode of transport to access and egress HSR hub.

More specifically, to the redevelopment of the station area, the node-place model focused primarily on developed countries with mass transits, walkable entities, metropolitan area, high-capacity transport services, high population density, and after operation of transit stations There exists very limited research on how to recognize and balance the node- and place-index of HSR station area in a Thai context to designate strategic vision for future development before operational HSR hub.

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CHAPTER 3

RESEARCH METHODOLOGY AND STUDY AREA

This chapter begins by providing the methodological framework is adopted in this research thoroughly data collection and the analytical tool. Then the overview of three models (Multinomial logit model, Tobit model, and Node-Place model) is detailed. After that, this research explains why Nakhon Ratchasima HSR hub and Fukushima Shinkansen station were selected as case studies.

3.1 Methodological framework

The methodological framework was developed to achieve the goal of research which is sustainable development in providing and improving TOD strategies with the HSR project in Thailand (NKR municipality). Figure 3.1 describes the processes which had been done. A brief explanation of the research structure is as follows.

First, a review on TOD, HSR, and relevance of TOD and HSR studies had been done to better understand the components of TOD and HSR studies (See more detail illustrated in the second chapter).

Second, the research regarding the barrier of the Thai government for the development of the HSR project had been done by both academic literature, document, and policy report and drawing mechanism on how to drive the HSR project to sustainable development (For more detail, see the fourth chapter).

Third, an internationally transferable policy concept was conducted by focusing on specific areas for special development, land and community management, positive measures for town planning, organization, investment, and legislation and regulation with meta-analysis. Hong Kong, Japan, South Korea, Brazil (Curitiba), England (London), France (Lille), Germany (Munich), USA (New York and Washington DC) were the best-practice experience in TOD implementation from international case studies to develop contextually appropriate public policy. The screening of countries is a preliminary selection of shortlists for TOD around transit stations for the long run based on available information on transport and urban policies from documents, policy reports, and academic literature. (For more detail, see the fifth chapter).

Fourth, an impact on transportation economics and policies around Fukushima Shinkansen station was focused by analyzing the macroeconomic in short-term and long-term changes constantly of Fukushima prefecture before-after opening of Fukushima Shinkansen station based on time series and evaluating the indirect (wider) economic benefits and economic development on Fukushima prefecture. An empirical analysis with compound annual growth rate method was used as a methodology, while the actual data were obtained from international websites such as e-stat, World Bank, and Ministry of Land, Infrastructure, Transport, and Tourism (For more detail, see the sixth chapter).

Fifth, the Fukushima Shinkansen station catchment based on geographic information system approach with dense network and land value perspective was focused by evaluating the size of the Fukushima Shinkansen station catchment area and comparing it with the existing studies. This analysis does not attempt to estimate the land value change in Fukushima prefecture whether public policies may be able to harness and leverage these trends to induce greater land value benefits. The data were obtained from the basic survey of city planning in

Fukushima city and Geographic Information System shapefile that provided by e-stat and Ministry of Land, Infrastructure, Transport, and Tourism website. (For more detail, see the seventh chapter).

Sixth, the determinants of primary and secondary access mode choices to the NKR HSR hub were focused on by investigating the influential factors of primary and secondary feeder services to access the Nakhon Ratchasima HSR hub and willingness to pay for the feeder services. The influencing factors are categorized into three groups: demographics; the purpose of HSR travel and travel characteristics of primary and secondary feeders and private vehicles; and facilities and infrastructure based on questionnaire survey (stated preference survey). The influencing factors of access mode choice to the HSR hub are determined by the multinomial logit model and the willingness to pay by the Tobit model. The pattern modes of transport to access the HSR hub are first examined and the primary and secondary mass-transit feeders are determined (For more detail, see the eighth chapter).

Seventh, the resolution of the tension between node value and place value was focused by balancing the node- and place-index of NKR HSR hub to designate strategic transport and land use which drive the potential for allocation of additional accessibility and urban development. A modified assessment model for the NKR HSR hub is first examined to match the station area and HSR characteristics. The data were obtained from primary data (from the stated preference survey in the eighth chapter) and secondary data (from government statistics and company websites) (For more detail, see the ninth chapter).

Finally, the significant findings in the relevance of TOD and HSR are revealed. Then the recommendation regarding important policies and the improvement of TOD strategies and the HSR project will be developed to support sustainable development in the NKR municipality (For more detail, see the tenth chapter).

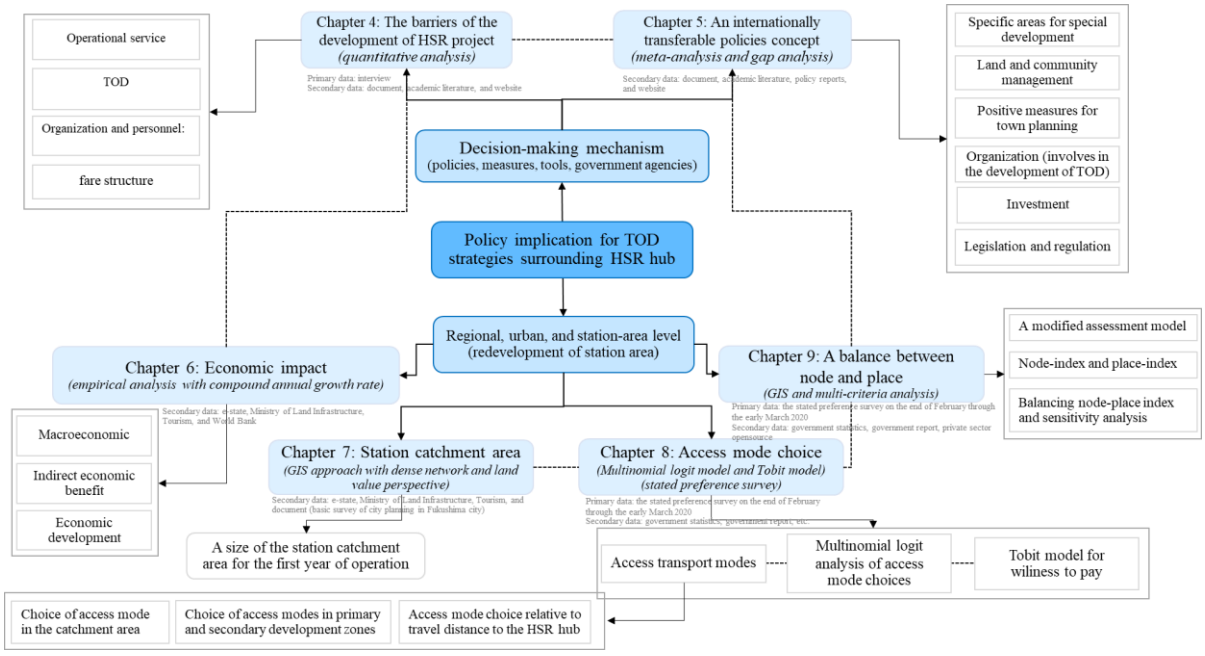


Figure 3.1 The methodological framework of this research

3.2 Conceptual model

3.2.1 Multinomial logit model

1. Assuming the independence of irrelevant alternatives

A major limitation of the multinomial logit (MNL) model is that the construction necessitates that alternatives do not violate the assumption of the independence of irrelevant alternatives. The assumption for the independence of irrelevant alternatives is explained by Luce and Suppes (1965). "Where any two alternatives have a non-zero probability of being chosen, the ratio of one probability over the other is unaffected by the presence or absence of any additional alternative in the choice set". As can be seen, in the MNL case the ratio:

$$\frac{\mathbf{P_j}}{\mathbf{P_i}} = \mathbf{exp}\{\beta(\mathbf{V_j} - \mathbf{V_i})\} \text{ is indeed a constant independent of the rest of the options.} \quad (1)$$

2. Multinomial logit model (Condition logit model)

A more general model may be obtained by combining the multinomial and conditional logit formulations, so the underlying utilities $\boldsymbol{U_{nj}}$ depend on characteristics of the individuals as well as attributes of the choices, or even variables defined for combinations of individuals and choices (such as an individual's perception of the value of a choice). The basic utility equation for individual n choosing alternative j an MNL model is shown below.

$$\mathbf{U_{nj}} = \mathbf{V_{nj}} + \varepsilon_{\mathbf{nj}} \quad (2)$$

The systematic component of the utility function is given as:

$$\mathbf{V_{nj}} = \mathbf{Z_n}\gamma_{\mathbf{j}} \quad (3)$$

Therefore,

$$\mathbf{U_{nj}} = \mathbf{Z_n}\gamma_{\mathbf{j}} + \varepsilon_{\mathbf{nj}} \quad (4)$$

γ_j is a vector of alternative-specific parameters, i.e., the parameters are subscripted by j. These parameters relate the characteristics of a respondent (Z) to the respondent's utility for the j^{th} choice. They are individual-specific characteristics. This means that the effect of the independent variables will vary across all of the choices. In other words, there will be a separate coefficient on each independent variable for each possible outcome. For example, if the age of the individual were an independent variable, then the effect of age on choosing alternative 1 would be different from its effect on choosing alternative 2, alternative 3, etc. Z_n is a matrix of individual or case-specific characteristics. Estimation of this model is relatively easy since the log-likelihood function is globally concave. To specify the likelihood, first, define $d_{ni} = 1$ if individual n chooses alternative i, $d_{ni} = 0$ otherwise. This means that there are J lots of d_{ni}, each indicating a choice. These indicators are then used to select the appropriate terms in the likelihood function. Therefore, the likelihood function for individual n is:

$$\mathbf{L_n} = \mathbf{R_{n1}^{dn1}} \times \mathbf{R_{n2}^{dn2}} \times \mathbf{R_{n3}^{dn3}} \times \ldots \times \mathbf{R_{nj}^{dnj}} \quad (5)$$

Where P_{ni} is the probability that individual n chooses alternative i. The likelihood function for the entire sample is:

$$\mathrm{L_n} = \prod_{\mathrm{n=1}}^{\mathrm{N}} \left(\mathrm{P_{n1}^{dn1}} \times \mathrm{P_{n2}^{dn2}} \times \mathrm{P_{n3}^{dn3}} \times \ldots \times \mathrm{P_{nj}^{dnj}}\right) \quad (6)$$

Therefore, the log-likelihood function is just:

$$\mathbf{In\ L} = \sum_{\mathbf{n=1}}^{\mathbf{N}} \sum_{\mathbf{i=1}}^{\mathbf{j}} \mathbf{d_{ni}}\ \mathbf{In}\left(\frac{\mathbf{e}^{\mathbf{x_{n_i}\beta}}}{\sum_{\mathbf{j}}^{\mathbf{i}} \mathbf{e}^{\mathbf{x_{n_i}\beta}}}\right) \quad (7)$$

3.2.2 Tobit model

The empirical willingness to pay (WTP) model for a quality improvement can be expressed in Equation 8, where α is a coefficient vector, β is a lone coefficient, $\boldsymbol{x_{1i}}$ is a vector of independent variables, $\boldsymbol{q_i}$ is perceived current quality, and $\boldsymbol{i}$ is individuals ($1, \mathbf{2}, \ldots, \boldsymbol{n}$).

$$\mathbf{WTP} = \boldsymbol{\alpha}'\mathbf{x_{1i}} + \beta\mathbf{q_i} + \boldsymbol{\varepsilon_{1i}} \quad (8)$$

Equation 9 is described the omission of the current quality variable, where the new error term ($\boldsymbol{e_{1i}} = \beta\boldsymbol{q_i} + \boldsymbol{\varepsilon_{1i}}$) is not independent of the explanatory variables.

$$\mathbf{WTP} = \boldsymbol{\alpha}'\mathbf{X_{1i}} + \boldsymbol{\varepsilon_{1i}} \quad (9)$$

An independent variable brings about endogeneity bias. The level of quality is a subjective measure and depends on perceptions. Equation 10 can be described as follow, where $\boldsymbol{q_i}$. is quality, $\boldsymbol{\gamma}$ is a coefficient vector, $\mathbf{X_{2i}}$ is a vector of variables, and $\boldsymbol{\varepsilon_{2i}}$ is a normally distributed error term.

$$\boldsymbol{q_i} = \boldsymbol{\gamma}'\mathbf{X_{2i}} + \boldsymbol{\varepsilon_{2i}} \quad (10)$$

Equation 10 is substituted into Equation 8 (as shown in Equation 11). The correlation in error terms will generate in the quality variable and WTP, especially the coefficient on quality. The positive correlation will bias the positive coefficients, while the negative correlation will bias the negative coefficient.

$$\mathbf{WTP_i} = \boldsymbol{\alpha}'\mathbf{x_{1i}} + \beta(\boldsymbol{\gamma}'\mathbf{X_{2i}} + \boldsymbol{\varepsilon_{2i}}) + \boldsymbol{\varepsilon_{1i}} \quad (11)$$

Equation 12 is described the technique to avoid the endogeneity bias. The WTP variable is continue and censored at zero, where *WTP** is the unobserved true willingness to pay**.**

$$\mathbf{WTP} = \begin{cases} \mathbf{WTP}^* & \mathbf{if}\ \ \mathbf{WTP}^* > \mathbf{0} \\ \mathbf{0} & \mathbf{if}\ \ \mathbf{WTP}^* \leq \mathbf{0} \end{cases} \quad (12)$$

The testing and correction for endogeneity bias are implemented with a simultaneous equations model (Equation 13-Equation 15) in which quality and WTP are jointly estimated.

$$\mathbf{WTP_i} = \boldsymbol{\alpha}'\mathbf{x_{1i}} + \beta\mathbf{q_i} + \boldsymbol{\varepsilon_{1i}} \quad (13)$$

$$\mathbf{q_i} = \boldsymbol{\gamma}'\mathbf{X_{2i}} + \beta\mathbf{q_i} + \boldsymbol{\varepsilon_{1i}} \quad (14)$$

$$\boldsymbol{\rho} = [\boldsymbol{\varepsilon_{1i}}, \boldsymbol{\varepsilon_{2i}}] \quad (15)$$

The estimation method is maximum likelihood with the normal distribution (in error terms, $\boldsymbol{\rho}$). The test for the homogeneity of $\boldsymbol{q_i}$ in the independent WTP model is a t-test for $\boldsymbol{\rho}$ = 0 (Smith and Blundell, 1986; Greene, 2002). $\boldsymbol{X_{1i}}$ and $\boldsymbol{X_{2i}}$ have a high explanatory in the quality term, but have a low explanatory in the WTP and error term. A Bassman-type identification is tested for the final stage. The error terms are regressed from the estimated WTP as shown in Equation 16.

$$\hat{\boldsymbol{\varepsilon}}_{\mathbf{1i}} = \boldsymbol{\delta}'\mathbf{X_{2i}} + \boldsymbol{\nu_i} \quad (16)$$

Where $\hat{\boldsymbol{\varepsilon}}_{\boldsymbol{1i}}$ are the residuals, δ is a vector of coefficients and $\boldsymbol{\nu_i}$ is a normal distribution of error term.

The test statistics can be expressed in Equation 17. It is the product between the sample size and the $\boldsymbol{R^2}$ value and distributes chi-squared with degrees of freedom equal to the number of variables in the $\boldsymbol{X_{2i}}$ vector, *j*, minus the number of variables in the $\boldsymbol{X_{1i}}$ vector, $\boldsymbol{k}$, minus 1.

$$\boldsymbol{x^2 = n \times R^2(df = j - k - 1)^n} \quad (17)$$

3.2.3 Node and place model

According to Dittmar and Ohland)2014(, TOD projects need to achieve five main goals of 36 location efficiency, a rich mix of choices, value capture, placemaking, and resolution of the tension between node and place. To achieve these goals, it is important to ensure the urban development interacts with the transit system. The node-place model is applied and modified in diverse objectives and contexts. The balance between node functions and place functions is a crucial mechanism within catchment area (Bertolini, 1999).

Figure 2 shows overview of the polar graph of node and place modeling visualizations. The kite model included criteria for transit ridership and the presence of services (Stadsregio Arnhem Nijmegen, 2011). The node- place- experience model was similar kite model and included some indicators which reflected the travellers experience, i.e., comfort, ambient elements, and personnel presence (Groenendijk et al., 2018). Based on TOD concept (Cervero and Kockelman, 1997), design criterion should include and consider for walkability of the built environment. The web diagram measured walkability and bike ability with additional criteria such as user- friendliness and passenger load (Singh et al., 2018). The butterfly model is the last development by Province of North Holland Noord- Holland and Deltametropool Association (2013). This model included proximity criterion which reflected the distance of the station to the nearest urbanized settlement.

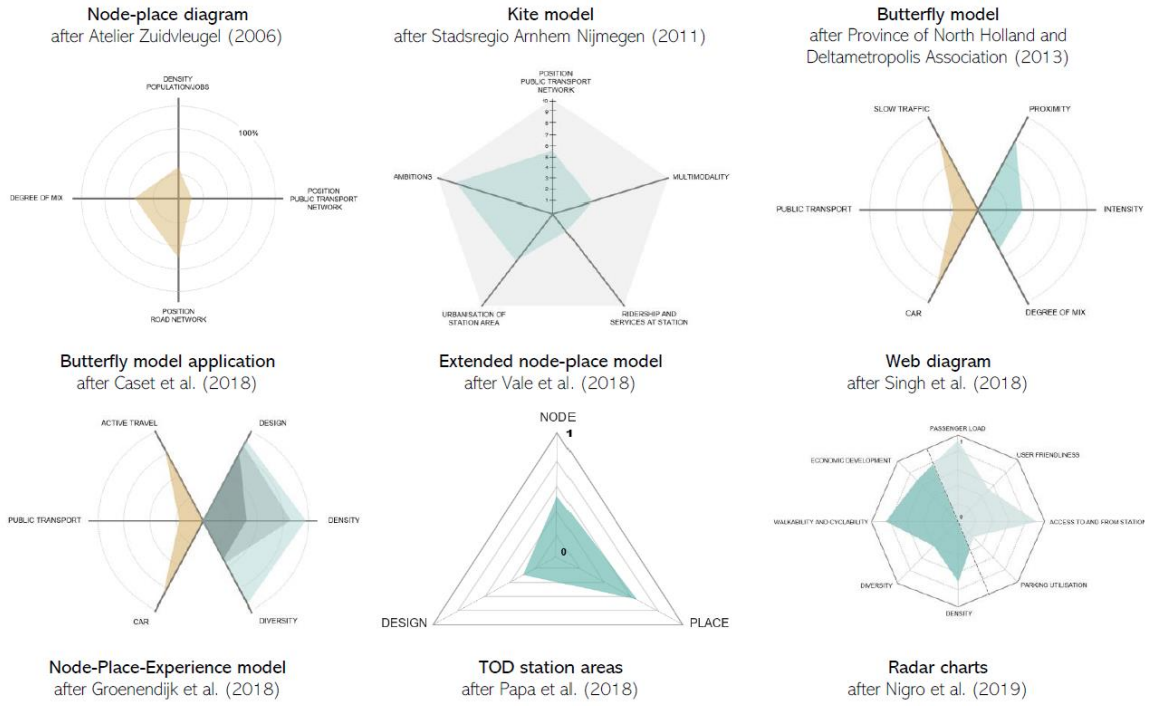


Figure 3.2 Overview of the polar graph of node and place modeling visualizations

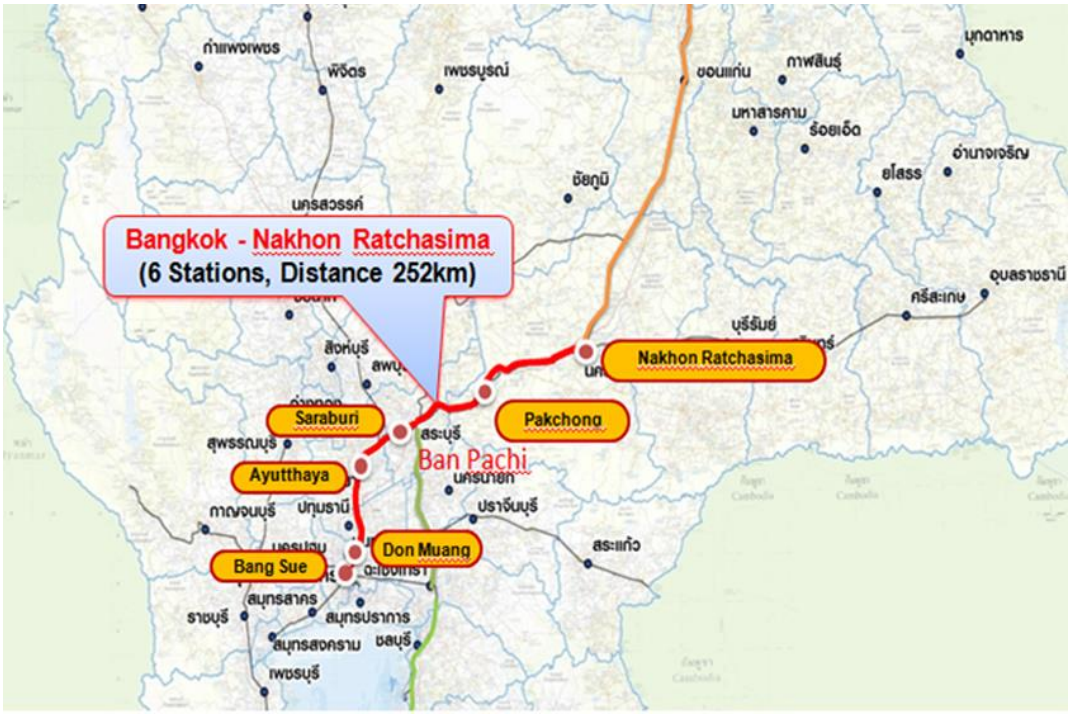
Source: Caset (2019)

3.3 Study area

3.3.1 Nakhon Ratchasima HSR Hub

Figure 3.3 shows the HSR hubs of the HSR project. There are six HSR hubs, namely Bang Sue, Don Mueang, Ayutthaya, Saraburi, Pak Chong, and Nakhon Ratchasima (NKR). Bang Sue and Don Mueang HSR station are located in the capital city of Thailand (Bangkok), while others are placed in the regional area. This research merely focuses on five HSR stations excluding the Bang Sue HSR hub because this hub was studied under urban redevelopment in the Bang Sue area project by Japan International Cooperation Agency et al. (2017).

Figure 3.3 HSR hubs of the HSR project



Source: MAA Consultants Co.

The screening of HSR hubs is a preliminary selection of shortlists for TOD surrounding HSR hubs. TOD around the HSR hubs will be chosen from the high, medium, and low levels of station selection. It is based on an assessment of the importance of HSR stations in terms of the potential and necessity of development. The criteria and data are charitably obtained from various sources, namely gross provincial product (GPP) from NESDC, size of the city from Department of Public Works and Town and Country Planning (DPT), availability of feeder services from OTP, travel distance from the origin from SRT, land use around HSR hub within 200 m from DPT, vacant land around the hub from SRT, and ridership (number of HSR passengers) from SRT. The criteria are shown in Table 3.1 and the results are summarized in Table 3.2.

Table 3.1 Criteria for assessing the importance of HSR hubs in terms of potential and necessity of development

Criteria	High	Medium	Low
GPP (USD)	> 31,807	3,181-31,807	< 3,181
Size of the city*	a very large-sized city or a large-sized city	a medium-sized city	a small-sized city or a very small-sized city
Availability of feeder services (types)	> 3	1-2	0
Travel distance from origin (km)	150-800	100-150	< 100
Land use around HSR hub within 200 m	commerce/resident	community	agriculture/park/ industry
Vacant land (km^2)	> 1	0-1	< 1
Ridership (trip/day)	> 1,000	500-1,000	< 500

Note: *a very large sized city (more than 65,001 people), a large sized city (40,001-65,000 people), a medium sized city (20,0001-40,000 people), a small sized city (8,001-20,000 people), and a very small sized city (lower than 8,000 people)

Table 3.2 The results of the assessment of the importance of HSR stations in terms of potential and necessity of development

Criteria	Bang Sue	Don Mueang	Ayutthaya	Saraburi	Pak Chong	NKR
GPP (USD)	132,835	132,835	11,800	6,775.26	7,829	7,829
Size of the city*	-	-	A very large-sized city	A very large-sized city	A very large-sized city	A very large-sized city
Availability of feeder services (types)	▪ Commuter Train - Blue line (operated) - Red Line (2022) ▪ Bus	▪ Commuter train (Red Line (2022)) ▪ Bus	▪ Songthaew shuttle ▪ Tuk-tuk	Motor Tricycle	Songthaew shuttle	▪ Light Rail Transit (2024) ▪ Songthaew ▪ Tuk-tuk
Travel distance from the origin (km)	-	14.74	63.61	105.79	172.46	253
Land use around HSR hub within 200 m	Community	Community	Agriculture	Agriculture	Agriculture	Downtown
Vacant land (km^2)	NA	NA	-	-	0.87	0.44
Ridership (trip/day)	1,780	680	840	580	250	1,180

The results summarized in table 3.2 indicate that the NKR HSR hub was the highest potential and necessity of development among the HSR hubs. Additional information from the Twelfth National Economic and Social Plan (NESDC, 2017a), NKR municipality is the socioeconomic center of Thailand's northeastern province of NKR. The province is the land transportation hub and serves the gateway to other northeastern provinces. The province of NKR has the largest gross provincial product (8.10 billion USD) of the northeastern region (NESDC, 2017b). In this research, the NKR HSR hub is selected as a representative HSR hub

in Thailand. Figure 3.4 shows the country map, regional map, and locality map of NKR municipality.

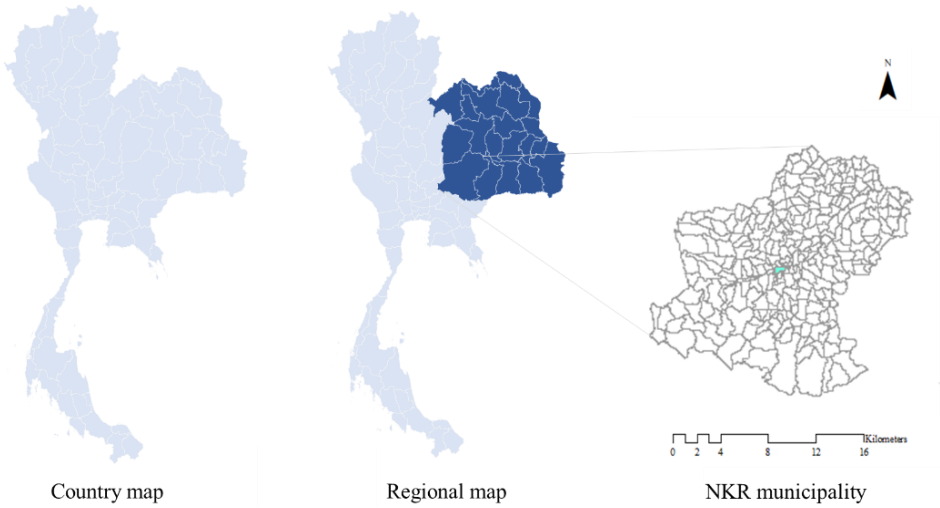


Figure 3.4 The country map, regional map, and locality map of NKR municipality

A 2020 study by A21 Consultant Co. on the current modes of transportation of residents in NKR municipality. Of a total of 1,800 respondents, private vehicles accounted for the largest proportion of the transport mode in the municipality (90.5 %), consisting of 42.5 % and 48 % for cars and motorcycles, respectively. The current modes of public transport in the municipality comprised songthaew shuttles (2.4 %), taxi and motorcycle taxi (1.1 %), chartered van (0.8 %), and others (0.6 %) including tuk-tuk, conventional diesel-run train, and tricycle rickshaw. Non-motorized transportation (walking and bicycle) accounted for the rest (4.6 %). Songthaew shuttles are covered pickup trucks with rows of seats in the back that transport people along set routes, and a tuk-tuk is a three-wheeled motorized vehicle used as a taxi in Thailand. Figure 3.5 illustrates the modes of transportation of residents in NKR municipality.

The large disparity between the use of private and public transport in the municipality could be attributed to low levels of service of songthaew shuttles, e.g., low number and frequency of vehicles (OTP, 2016). Another reason was the accommodative policy on car ownership and subsidized fuel prices (Vikitset, 2014; Patanakorn and Pornchaiwisetgul, 2015; Noparumpa and Saengchote, 2017; Muthitacharoen et al., 2019).

Figure 3.6 shows the current and future modes of public transport in NKR municipality, consisting of songthaew shuttle, tuk-tuk, taxi service, motorcycle taxi, tricycle rickshaw, and conventional diesel-run train, light rail transit (LRT), and HSR.

There are 363 songthaew shuttles serving the residents of the NKR municipality (Department of Land Transport (DLT), 2020a). The songthaew service covers 20 routes with service time between 6 a.m. to 8.30 p.m. daily. The fare is flat (0.25 USD/trip), and passengers can conveniently access the shuttle service. However, the number of songthaew shuttles has been declining due largely to the accommodative policy on car ownership and subsidized fuel prices, resulting in lower levels of service of songthaew shuttle (DLT, 2020a).

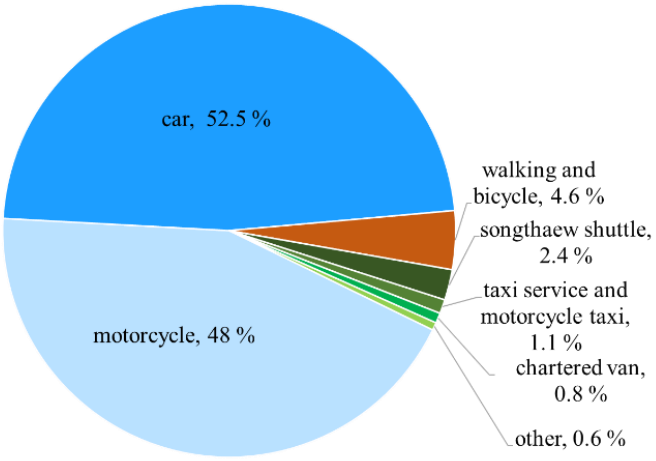


Figure 3.5 Current modes of transportation of residents in Nakhon Ratchasima municipality

Note: Other includes tuk-tuk, conventional diesel-run train, and tricycle rickshaw.

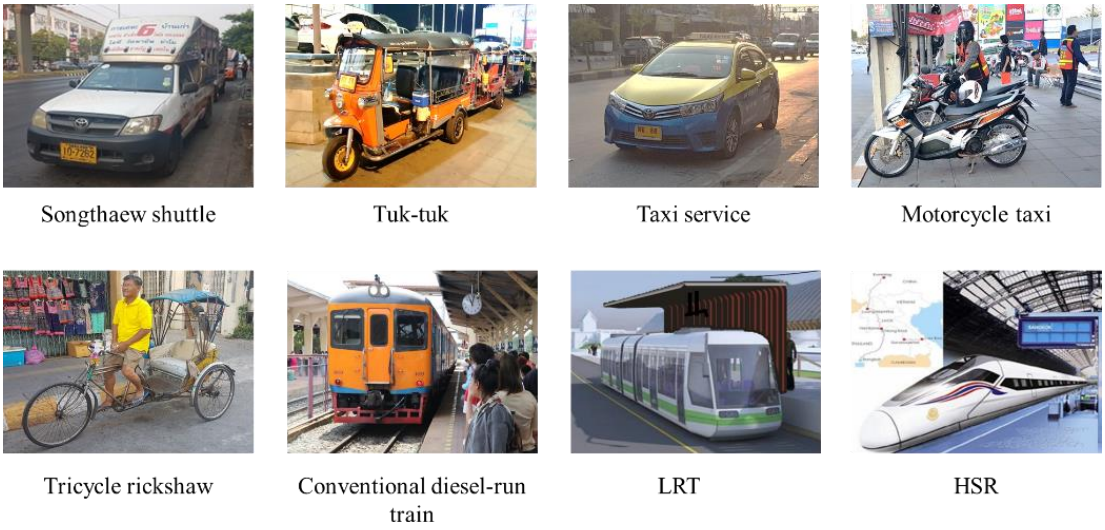


Figure 3.6 Current and future modes of public transport in Nakhon Ratchasima municipality

Source: A21 Consultant Co. for the light rail transit (LRT) image and OTP for HSR image

Due to the accommodative car ownership policy, there are only 20 tuk-tuks for the entire municipality, with a starting fare of approximately 1.30 USD. There are 10 registered taxis serving the municipality, while the rest (118) are ride-sharing vehicles. The travel cost is distance-based and the starting fare is 1.30 USD. In addition, there are more than 2,000 motorcycle taxis serving the municipality, and most motorcycle taxi stops are located near the songthaew shuttle stops. The motorcycle-taxi fare is distance-based with a starting price of 0.80 USD. There are fewer than 10 tricycle rickshaws serving local residents and tourists traveling a short distance. The fare is distance-based with a starting price of 0.70 USD (DLT, 2020b; Ministry of Transport (MOT), 2016; MOT, 2017).

The NKR municipality has two conventional diesel-run train stations: Thanon Chira Junction railway station (orange color) and Nakhon Ratchasima railway station (light blue color), as shown in Figure 4. The train fare between the two stations is around 0.05 USD and the travel time is four minutes (State Railway of Thailand, 2020). The Nakhon Ratchasima

railway station (light blue color) is located near (less than 30 m) the Nakhon Ratchasima HSR hub (purple color).

The green-line light rail transit (LRT) project, currently in the detailed design phase, is expected to complete in 2024, which is the same year as the HSR project (A21 Consultant, 2020). The LRT fare is distance-based and the fare structure is USD 0.33 + (0.033 × travel distance). The LRT service hours are from 6 a.m. – 11 p.m. and the frequency is every 10 minutes during peak hours (7.30 a.m. – 9 a.m. and 4.30 p.m. – 6 p.m.) and every 20 minutes during off-peak hours. The Nakhon Ratchasima LRT station is located around 50 m from the main entrance of the Nakhon Ratchasima HSR hub.

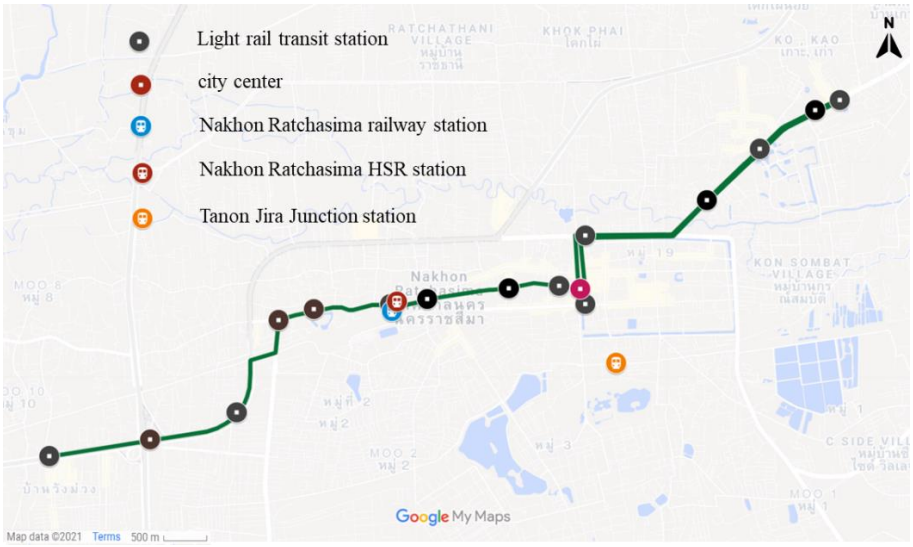


Figure 3.7 Rail transport and rail station locations in NKR municipality

Source: A21 Consultant, (2020)

3.3.2 Fukushima Shinkansen station

Shinkansen (or bullet train) has a network of High-Speed Rail (HSR) in Japan and also builds to reduce the overall travel time of the journey between the two cities and promote nation-wide economic growth by improving passenger mobility along the corridor. The Tokaido Shinkansen line (Tokyo to Shin-Osaka section) is the oldest Shinkansen network and is operated in 1964, just in time for the Tokyo Olympics. Then, the Shinkansen system is well known in both domestic and foreign countries, whereas it combines high safety and reliable transportation with high quality and capacity.

Currently, the Shinkansen network is 3,294 km in length and is consisted of nine pathways which are two types of tracks: Shinkansen tracks exclusively for Shinkansen (Tokaido, Sanyo, Tohoku, Joetsu, Hokuriku, and Kyushu Shinkansen) and conventional tracks (Yamagata and Akita Shinkansen). Meanwhile, all Shinkansen lines are operated by Japan Railways Group (JR's Group) that takes over their assets and operations of the government-owned Japanese National Railway on April 1st, 1987 (See Table 3.3 and Figure 3.8).

Shinkansen investment expands the economic activities and allows people to spend more time at their destinations and increase their chances to the business cycle. Thus, Shinkansen is a tool to make significant business effects throughout its service area. The success of the first

Shinkansen line has encouraged the national plan to construct the Shinkansen projects for regional development in the next phase.

Table 3.3 Summary of the Present Status of Shinkansen

Shinkansen line	Origin and destination	Operating distance (km)	The number of stations	Operator (JR's Group)
Main lines				
Tokaido Shinkansen	Tokyo–Shin-Osaka	552.6	17	JR Central
Sanyo Shinkansen	Shin-Osaka–Hakata	622.3	19	JR West
Tohoku Shinkansen	Tokyo–Shin-Aomori	713.7	23	JR East
Joetsu Shinkansen	Tokyo–Niigata	240.0	12	JR East
Hokuriku Shinkansen	Tokyo–Kanazawa	450.5	18	JR East/ JR West
Hokkaido Shinkansen	Shin-Aomori– Shin-Hakodate-Hokuto	148.8	4	JR Hokkaido
Kyushu Shinkansen	Hakata– Kagoshima-Chuo	288.9	12	JR Kyushu
Mini lines				
Yamagata Shinkansen	Fukushima–Shinjo	149.0	11	JR East
Akita Shinkansen	Morioka–Akita	127.0	6	JR East

Figure 3.8 Shinkansen networks

Source: International High-Speed Rail Association (2018)

Since the Thai government does not have practical know-how and experience in how to make it happen, this research has to study the lesson learned from the best practice and outcome by using international comparison.

Japan is the best role model to generate TOD for sustainable development. Likewise, the Fukushima Shinkansen station on the Tohoku Shinkansen line is the optimal case study in Japan among others because it is a similar NKR HSR hub in terms of station type, station size, travel distance from the capital city, and travel time. Although the city policy and the surrounding area of the station have the difference, this research will point out how to increase the potency before-after the operational HSR project in the future (see Table 3.4).

Table 3.4 Comparison between NKR HSR hub and Japanese Shinkansen stations

HSR hub (Operating year)	HSR/ Shinkansen line (Operator)	City (Province)/ City (Prefecture)	Station type*	Station size**	Travel distance from the capital city to the hub (km)	Travel time from the capital city to the hub (h)
A case study in Thailand						
Nakhon Ratchasima (2024)	Northeast (NA)	Nakhon Ratchasima (Nakhon Ratchasima)	Type 1	Big	253	1:01 (Fuxing)
The candidate case studies in Japan						
Fukushima (1982)	Tohoku Shinkansen (JR East)	Fukushima (Fukushima)	Type 1	Big	255.1	1:06 (Yamabiko)
Iiyama (1997)	Hokuriku Shinkansen (JR East)	Iiyama (Nagano)	Type 1	Small	255.9	1:38 (Hakutaka)
Nagaoka (1982)	Joetsu Shinkansen (JR East)	Nagaoka (Nagano)	Type 1	Big	245.1	1:02 (Toki)
Hamamatsu (1964)	Kodama Shinkansen (JR Central)	Hamamatsu (Shizuoka)	Type 1	Big	238.9	1:19 (Hikari) 1:24 (Kadama)
Tsubamesanjo (1982)	Joetsu Shinkansen (JR East)	Sanjo (Niigata)	Type 1	Small	268.7	1:12 (Toki)

Note: *There are three types of Shinkansen stations which are the first type of Shinkansen station: development of a new Shinkansen station in the area with existing/conventional railway, the second type of Shinkansen station: an expansion of the existing station in the area with a conventional railway, and the third type of Shinkansen station: developing a new Shinkansen station with new urban development (Oh et al., 2015)

**Station size is asked from Thai and Japanese experts in railway for more than 10 years.

Figure 3.9 shows the locations of the Tohoku Shinkansen line which connects the Tokyo metropolitan area and Aomori city. This Shinkansen consists of 23 Shinkansen stations[2] and is the longest Shinkansen line in Japan (675 km). This area also has two mini Shinkansen lines (Akita and Yamagata Shinkansen) which built tracks over the existing narrow-gauge railway lines and unlike the regular Shinkansen lines.

[2] Tokyo, Ueno, Omiya, Oyama, Utsunomiya, Nasu-Shiobara, Shin-Shirakawa, Koriyama, Fukushima, Shiroishi-zao, Sensai, Furukawa, Kurikoma-Kogen, Ichinoseki, Mizusawa-Esashi, Kitakami, Shin-Hanamaki, Morioka, Iwate-Numakunai, Ninohe, Hachinohe, Shichinohe-Towada and Shin-Aomori Shinkansen station

Figure 3.9 Tohoku Shinkansen Line (dark green line)

Source: International High-Speed Rail Association (2018)

The Tohoku Shinkansen line was operated in June 1982 (Omiya-Morioka Shinkansen station) and opened between Ueno Shinkansen station and Omiya Shinkansen station in March 1985. Then, Japan National Railways (JNR) split privatization, the Tohoku Shinkansen became the route of the East Japan Railway (JR East) and the Tokyo Shinkansen station to Ueno Shinkansen station worked in June 1991.

Meanwhile, the section of Morioka city to Aomori city was published in 1972 by the "Basic plan to determine the route of Shinkansen railway to start construction". Construction was temporarily frozen due to the financial deterioration of JNR. After that, it was started as a public project and local government between Morioka–Shin-Aomori area and function in December 2002 (Morioka-Hachinohe Shinkansen station) and on December 2010 (Hachinohe–Shin-Aomori Shinkansen station).

Fukushima prefecture is the third-largest area in Japan where locates in the South of the Tohoku region in the Northern part of Honshu island. It is also characterized by the magnificence of nature and the category of unique goods. This prefecture currently consists of 13 cities and 13 districts including Fukushima city is a capital city. It takes approximately 1.5 hrs by Shinkansen or 3 hrs by private car to Tokyo Shinkansen station. Furthermore, the Fukushima Shinkansen station is located in Fukushima city, Fukushima prefecture. At present, there are six railway lines that operate in the Fukushima station and consist of Tohoku Shinkansen, Yamagata Shinkansen, Tohoku main line, Ou main line, Abukuma Express line, and Iizaka line (International High-Speed Rail Association, 2018).

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CHAPTER 4

A STUDY ON THE BARRIERS OF THE THAI GOVERNMENT FOR DEVELOPMENT OF HIGH-SPEED RAIL PROJECT

4.1 Introduction

The development of the railway as the major public transportation system will create a sustainable mode of transportation, which is economically viable in the long run. In Thailand, the development of the HSR system is continually and carefully undertaken since studied by the Office of the National Economic and Social Development Council (NESDC) in 1992 (NESDC, 1992) and the Office of Transport and Traffic Policy and Planning (OTP) in 2010 (OTP, 2010). This is to ensure that the HSR system will transform public transportation in Thailand in the future. The HSR system will bring a new era for travel and new experience to passengers. It will be also an important key to national development as it will decentralize growth and prosperity countrywide. The HSR will pave the way for connectivity with the neighboring countries in the ASEAN Economic Community. In addition, it increases the various value-added such as the distribution of economic to regions, the competition to other transportation modes, and developing industries of the country.

The main purpose of this paper is to contribute to making the mechanism of barriers from the first HSR project. This research is expected to have a significant impact on the direction of transportation policies and sustainable development aiming to increase the use of HSR. As a case study, the development of High-Speed Rail for regional connectivity between Bangkok and Nong Khai (Phase 1: Bangkok-Nakhon Ratchasima) is selected because it is the first HSR project investment and expects to operate in 2022. Furthermore, the objective of this paper attempts to (1) classify the operation technique of the first HSR project investment in Thailand, (2) suggest TOD strategies for development around the HSR station, (3) identify the characteristic of the new organization and personnel for the HSR project and (4) advise the optimal fare structure for the first year operation as well as this research has 4 hypotheses that are essential to HSR in Thailand consist of (1) two HSR systems (Japanese system and Chinese system) can operate between Ban Sue and Ban Phachi section, (2) TOD is effective to the sustainable development of HSR stations in Thailand, (3) what characteristic of the new organization and panel to drive the HSR project and (4) HSR fare structure is competitive in other public transportation systems. Moreover, the methodology of this paper is based on the interview, document review, literature review, and website review of the HSR project.

4.2 The HSR master plan for development in Thailand and the current situation

The initial plan for HSR in Thailand was created by the Ministry of Transport (MOT) in 2009 under the Abishit cabinet. This strategic planning was to connect neighboring countries, which will contribute to economic revitalization, domestic and international, and national development of Thailand. Afterward, the Yingluck cabinet who came into power in 2011, concentrated on the HSR project as the highlight of its transportation infrastructure improvement project and it was approved by her government in 2013 inclusive on March 27, 2015, the Prayut cabinet approved the principle of Thailand's transportation infrastructure development strategy 2015-2022 and transportation infrastructure investment action plan 2017

that had included four pathways for HSR development project. The HSR networks development based on the following criteria:

4.2.1 Compliance with national policies/strategies and international cooperation

The pathways are aligned with national policies and strategies; one of them will be the route to support the development of the Eastern Special Economic Zone and link the 3 major airports of the country (Don Muang-Suvarnabhumi-U-Tapao). Subsequently, the Northeastern line (Bangkok-Nong Khai route) in which is the path of the Thai-Chinese cooperation based on Memorandum of Understanding (MOU) to support the standard gauge railway network linkage to Laos and China. Consequently, the North line (Bangkok-Chiang Mai route) is a cooperation project between Thailand and Japan based on the Memorandum of Cooperation (MOC). Last, the Southern Bangkok-Padang Besar route, which has the potential to develop interconnections to Malaysia and Singapore in the future. It is consistent with low policies and strategies levels.

4.2.2 Project Availability

When the projects have a feasible economic and financial return and affirm the environmental impact assessment (EIA), their projects will reasonably approve by the cabinet and construction of the projects in the next stage. Table 4.1 shows the development of HSR projects (Fist stage). Two projects were approved by the cabinet which was the development of High-Speed Rail for regional connectivity between Bangkok and Nong Khai (Phase 1: Bangkok-Nakhon Ratchasima) and the High-Speed Rail Linked 3 Airport Project (Don Muang-Suvarnabhumi-U-Tapao). Those projects are in rush development and considering the projects are in line with the country's high-level development policies and strategies. Meanwhile, the Bangkok-Phitsanulok route, Japan side has contemplated how to create regional development planning along the corridor and the Thai side has also verified the feasibility project by MOT, Thailand inclusive it is expected to submit to the cabinet approves in 2019. As well as Bangkok-Hua Hin route is still a feasibility study by private investments in state undertakings Act, BE 2561 (2018).

Table 4.1 The development of HSR projects (Fist stage)

Order	Route	Economic Benefit (%)	Wider Economic Benefit (%)	Financial Benefit (%)
1	Bangkok-Nakhon Ratchasima	8.56	11.68	NA
2	Don Muang-Suvarnabhumi-U-Tapao	10.09	13.96	7.37
3	Bangkok-Chiang Mai	7.2	14.7	2.35
4	Bangkok-Hua Hin	NA	NA	NA

Note: Benchmark for economic and financial return is 12% and 5%, respectively

4.3 The barrier of the Thai government

4.3.1 Operation service on Bang Sue and Ban Phachi section

As the original plan of Thailand, Bang Sue station has three layers' structure that composes of the first floor is concourse, the second floor provides for meter gauge (long-distance lines and red lines) and the third floor arranges for HSR lines and airport link. Moreover, there are six tracks allot to the North HSR Line and Northeastern HSR line to operating a shared track on the third floor. Figure 4.1 shows a Cross-section of the Bang Sue station (modified design).

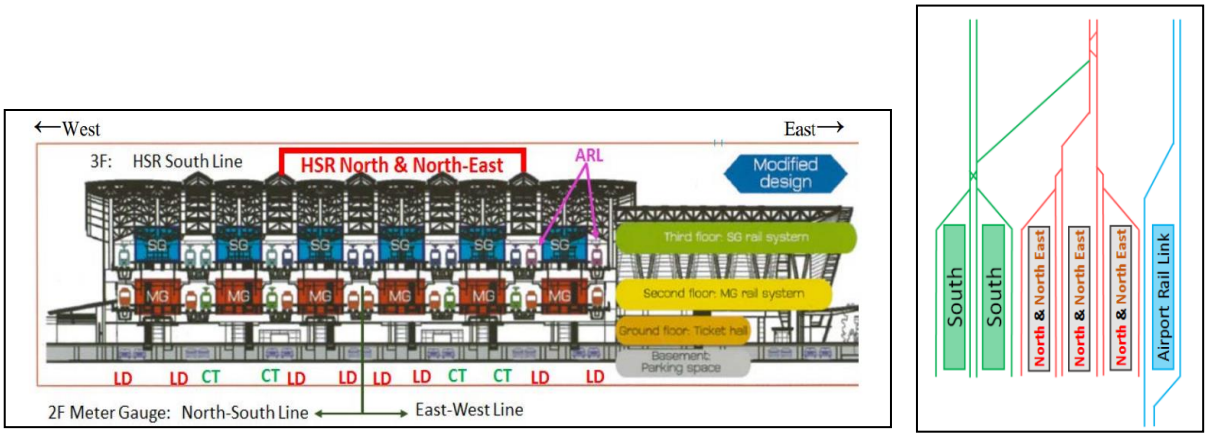

Figure 4.1 Cross-section of Bang Sue station (modified design)

Figure 4.2 shows the plan for the development of the HSR network in Thailand. The cabinet of Thailand approved 57,000 billion USD for the development of the HSR project on July 17th, 2017. The signaling and telecommunication use Chinese train control system via GSMR network (frequency band 900 Hz) and China side would like to operate it on a dedicated track. Meanwhile, the development of the HSR North line (Bangkok to Chiang Mai, phase 1: Bangkok-Phitsanulok) is currently considered by MOT, Thailand and this project uses the Shinkansen system that is based on the Memorandum of Cooperation (MOC) dated May 27th, 2015. In particular, a new MOC agreed with H.E. Arkhom, MOT of the Kingdom of Thailand, and Mr. Ishii, Minister of Land, Infrastructure, Transport and Tourism of Japan on August 6th, 2016 to operated it on a dedicated track because of Shinkansen technology.

Therefore, the original plan of HSR operation is different from the current situation due to political issues. Moreover, we review the HSR operations in the previous experience (Japan, Spain, France, China, Taiwan, and South Korea) that most countries use the dedicated tracks to avoid conflict with safety and reliability except for German and Italy have mixed operation between HSR and conventional trains together in some parts (Pouryousef et al., 2010). The alternative way is Bangkok-Nakhon Ratchasima section and Don Muang-Suvarnabhumi-U-Tapao section should use the same signaling and the government should change the structure at Bang Sue station.

Figure 4.2 The plan for the development of the HSR network in Thailand

Note: the blue line, red line, green line, and yellow line are Bangkok-Phitsanulok, Bangkok-Nakhon Ratchasima, Don Muang-Suvarnabhumi-U-Tapao, and Bangkok-Hua Hin respectively in their HSR development project.

4.3.2 TOD

The feasibility study of the HSR project was evaluated by Thailand's government. The result showed that this project had negative outcomes over 30 years. It was currently in progress and expected to operate in 2022. On the other hand, if The Thai government did not start the development of the HSR project, it would lose several opportunities to the regions because the project is a part of the development of the Trans-Asian railway network.

From a planner perspective, the TOD strategy is one of the tools to promote and support sustainable development in catchment areas. Many previous studies demonstrate that TOD has a significant role in regional development (e.g., Krause, 2010; Oh et al. 2015). However, TOD had a variety of factors and elements to make its effect and cause to their land uses. Meanwhile, Thailand's government has misunderstood the general TOD concept, has never had an experience on how to utilize TOD around the transportation hubs and TOD in Thailand has a problem with policy-linkage in each level (national, regional prefecture, and local level) including Thailand has the limitation in the current regal system that relates to expropriation and utilization of land use.

As the new Thailand's constitution requires the expropriation of property to be done by using the mandatory provision. However, when the researcher consider the constitution of mandatory provision determine the cores and conditions for the enactment of the property expropriation law must be composed of (1) identification of the purpose of the expropriation, (2) specify the duration of the property to use, (3) when expropriated for any purpose, it must be used to the purpose, (4) if the property does not expropriate within the timeframe, it will return to the original owner or heir at law and (5) the expropriation of the immovable property should do only necessary to be used for the purposes.

In this regard, the expropriation of the immovable property can be done only by the implementation of the constitution or expropriation and acquisition with immovable property Act, BE 2562 (2019) as well as the scope of use is to public benefits (see Table 4.2). Hence, if the Thai government has a policy to immovable property expropriation for development in TOD, we suggest that the objective of the immovable property expropriation will include in the development of immovable property in the station area of public transportation systems. However, this specific law is not extended to develop real estate around the station of public transportation systems.

Next, the important reason to consider is land use for public benefits in expropriation and acquisition with immovable property act, BE 2562 (2019) (see Table 4.3). If land development is developed by using the national model scheme, it will able to solve the economic, social, and environmental issues. Thus, it can promote TOD as a tool to drive them around the station area of the public transportation system.

The third point is a mechanism according to the town planning act, BE 2518 (1975) to determine the land use (see Table 4.4). It is classified the business into a plan for transportation planning, public utilities, and environmental conservation to advance to a guideline for the development of the area around the station of the public transportation system in the TOD viewpoint. It can operate since it is an activity control or the utility of land and is not necessary to use specific town planning which must be enacted.

Therefore, based on the limitation of TOD in Thailand, we propose an approach for achieving their issues as follows: First, the Thai government should be explicitly specified the railway transportation investment projects that will be the main public transportation system or alternative of the public transportation system for users. Second, Thailand's government

could have the national model scheme for TOD around the station area of the public transportation systems and relate to the spatial plan at each level. As well as it indicates the direction of how to develop and shows the outcome after development all of them including opportunity cost if we did not develop. Third, a financial tool for supporting the development of the TOD project (tax measure and soft loans) like Japan and USA to support operator whom operate the public transportation system and assist financial aid. Fourth, encourage the local government to participate and develop the TOD in each province, and Fifth, propose a proposal TOD around the station area of the public transportation system for a new law or change to an existing law that related to expropriation.

Table 4.2 Outline of Constitution of the Kingdom of Thailand, BE 2562 (2019)

Content	The basic principles and laws of a nation that determine the powers and duties of the government and guarantee certain rights to the people
Objective	Section 37: People have property rights and inheritance ▪ The immovable property expropriation will not be done, except by the virtue of the provisions of the law enacted for public utility, national defense or natural resources, or other public benefits. As well as, they need to pay fair compensation within a reasonable time for the owner by taking into account the public interest impact on expropriation including the benefits that the expropriation may receive from the expropriation. ▪ The expropriation of the immovable property shall be done only as necessary to be used for the purposes provided in paragraph three. Exception for expropriation to bring the expropriated property to compensation and unfairness to the owners. ▪ The property expropriation law must specify the purpose of expropriation and specifying the duration of access to the property. If it is not used for that purpose within the specified duration or there are surplus properties after utilization, the original owner or heir at law wishes to return to the previous owner or heir at law.

Table 4.3 Outline of Expropriation and Acquisition with Immovable Property Act, BE 2562 (2019)

Content	Land preparation land for infrastructure project investments
Objective	▪ Section 7: when the government has to acquire the necessary land in the public utility, national defense, natural source, or other public benefits or compensation for the unfairness of landowners who are expropriated under this act when they do not agree to transfer otherwise. ▪ Public benefits under Section 1 (Article 7) include the city plan, promoting and maintaining environmental quality, agriculture development, land reform, land readjustment, conservation of the historic and historical site, industry, and the development of special economic zones
Definition	▪ “Expropriation” means the acquisition of land or other immovable property which does not belong to the government under the condition specified in this Act. However, it excludes the acquisition by the trading method under Section 33 (2), 38, and paragraph 4 (the acquisition of immovable property by trading method). ▪ “Immovable Property” means land, building, perennial or other properties that are attached to land for permanent or constitutes the same land.

Table 4.4 Outline of Town Planning Act, BE 2518 (1975)

Content	Preparation and implementation of the comprehensive plans and specific plans
Objective	▪ To control the development of infrastructure investment and land use ▪ To the implementation of urban renewal and development projects
Definition	“Town planning” means the preparation and implementation of a comprehensive plan and a specific plan to develop a new town or redevelop a damaged town.

4.3.3 The new organization and personnel

In 2017, SRT had 950 million USD of net loss and also had problems related to personnel availability because it had limited personnel management that was the result of the cabinet resolution on July 28th, 1998, SRT could accept only 5 % of retirement for the new employees. The performance was under the standard until it is one of the state's enterprises for rehabilitation by the State Enterprise Policy Office.

Moreover, the cabinet resolution of the project had raised this issue to prevent/regulate the operational project to effective performance and the new organization might have the agility and suitability for HSR operation[3]. The project could determine the measure or guidelines for supporting both budget and personnel so that project could continue to operate, train, and reduce the risk in the future within 2018.

Currently, the Thai government just had the conceptual framework for settlement the special organization, also could pay attention to do them carefully and kept time to other processes would not receive the effect in the future. Furthermore, it might be the demo special organization to drive another HSR project in Thailand as well.

Based on the academic literature, the possible way for the new organization and personnel in the Thai context consists of railway operation and land development (see Figure 4.3). The operation corporation is divided into the operation and maintenance (O&M) section and the land development (TOD) section. O&M section is required to hire private sector to responsibility because of knowhow and experience, while TOD section is a joint venture between the government and private sector for cooperation because of the limitation of legislation and regulation. The management includes SRT and the Ministry of Finance to reduce the financial risk.

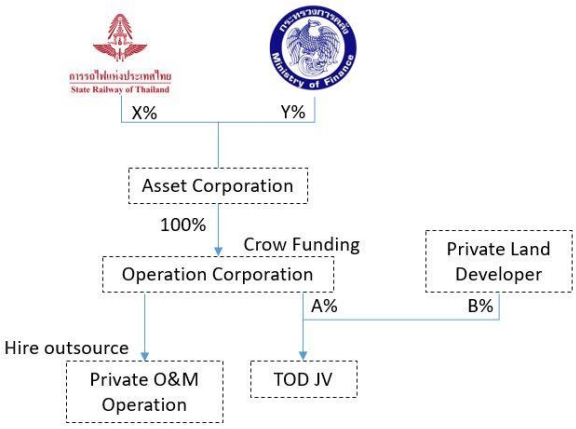

Figure 4.3 The new organization and personnel

[3] The lesson learned in Thailand, Airport Rail Link (ARL) (Bangkok) was under controlled by SRT and the process approved by board of the state railway of Thailand. Therefore, it affected the flexibility for purchasing trains/cars and spare parts so far.

4.3.4 Fare structure

As the feasibility study, a fare structure was 2.54+0.06 USD/km, which would be the highest revenue when compared with other fare rates in Table 4.5. While the authors compare with other public transportations between Bangkok to Nakhon Ratchasima route (252 km) described that the fare structure of the project was 17 USD/trip and could compete with private transportation and public transport (train's first-class and second-class). However, it was not able to compete with other public transportation modes such as buses and vans, even though an advantage in the value of time.

Table 4.5 Comparative fare structure among mode of transportation systems (Bangkok-Nakhon Ratchasima)

Transportation mode	Fare rate (USD/trip)	Remark
Private car	20-42	Including depreciation and fuel cost
Van	6	Observation result
Bus (first class)	7	Department of Land Transport
Bus (second class)	5	
Train (first class)	26-32	Car seat and air-conditioned sleeper
Train (second class)	13-20	
Train (Third class)	10-13	Air-conditioned chair car
	5-8	Fan chair car
	3-6	Fan chair car (Fast/Express)

When we considered the fare structure of the project and GDP per capita of the other countries, it explained that the fare structure (when the distance adjusted approximately to 500 km) had approximately the proportion of 0.44 % of GDP per capita. It is closed to South Korea and Taiwan's HSR fare structure because their HSR systems could challenge the other forms of public transportation.

Table 4.6 Comparative HSR fare in various countries

Program	Japan	China	South Korea	Taiwan	Thailand
First HSR route	Tokyo-Osaka	Beijing-Tianjin	Seoul-Busan	Taipei-Zuoying	Bangkok-Nakhon Ratchasima
Fare for the first year of operation	3,000 Yen	55 Yuan	44,800 Won	1,490 Taiwan dollar	536 Baht
Fare for 500 km per GDP per capital (first year of service)	1% (1964)	0.64% (2011)	0.32% (2004(	0.38% (2007(	0.44% (2017)

Meanwhile, China and Japan had determined the fare rate per GDP per capita that was higher than 0.64-1 of GDP per capita because Japan did not have the financial support policy for the service provider (JR's) besides infrastructure investment. However, the cheap fare structure per GDP per capita might cause the service provider to making financial risks, especially in the case of low passenger liked the lesson learned from Taiwan. Hence, the Taiwan government had to participate in financial support for private concessionaires so that the service provider could continue to services. On the other hand, when the researcher considered the journey between HSR and aircraft, aircraft had the advantage among the mode of transportations during 150-800 km/trip (Gleave, 2004).

4.4 The mechanism of the barriers of the Thai government

From the previous section, there are four barriers that impact the HSR project investment and consist of the level of service (operation service), TOD, the performance of organization and staff (the new organization and personnel), and fare structure. Subsequently, the researcher attempts to make the mechanism among the relationship of the factors based on how to drive the HSR project for sustainable development in Thailand.

As Figure 4.4, it can be explained that TOD is the most influential factor in the mechanism because it has the highest joints and generates a financial return (demand and financial freedom), economic return (GPP and activities), and social return (quality of life and welfare) to the project. In addition, the components of successful TOD depend on the city planning, location, regulations, timing, and local government as Korea, Japan, and Taiwan experience (Oh et al., 2015).

The performance of the organization and staff is the second influential factor because it concentrates mainly on financial value (outcome) and technical to convince and courage the number of passengers who travel by HSR. It also relates to TOD in terms of how to develop income.

The third and the fourth-ranking influential factors are fare structure and operation service, respectively. Fare structure relates to the decision-making of the mode of transportation and direct economic benefit. Operation service has a low impact on the diagram given it involves only the safety and financial return (operation and maintenance cost and demand).

However, some external factors do not appear in the mechanism such as political issues, timing, social-economic characteristics, and technology since the researcher cannot change or modify the individual characteristics of the users.

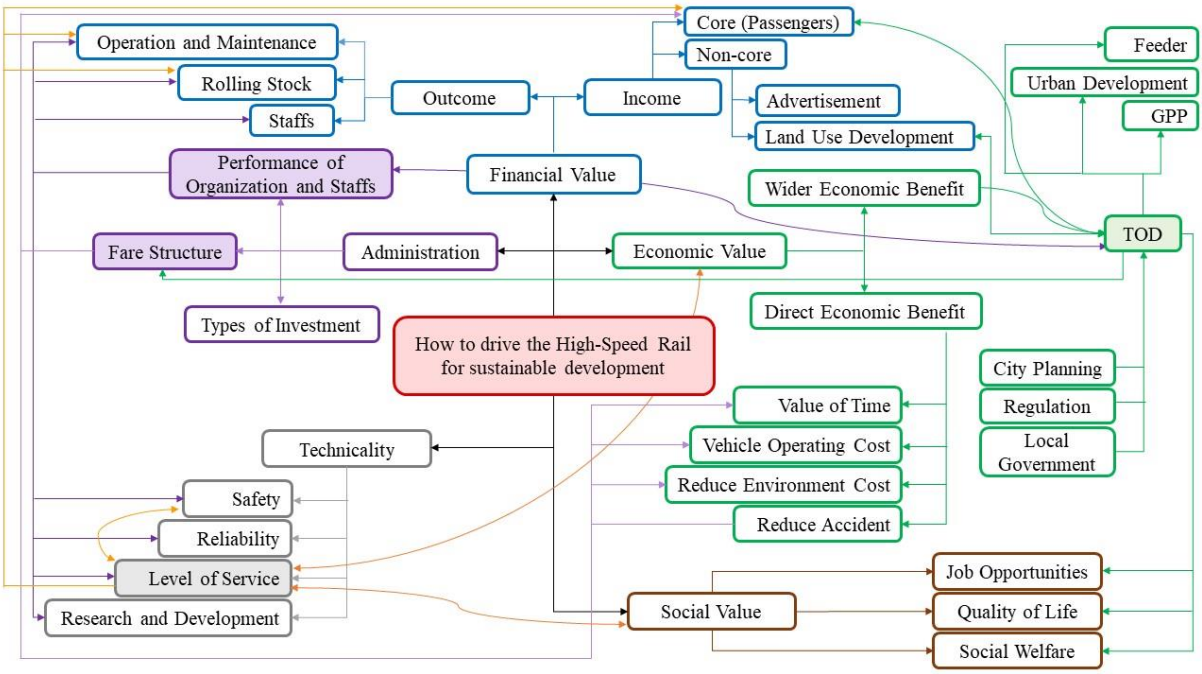

Figure 4.4 The mechanism of the barriers of the Thai government for the HSR project

4.5 Conclusion

Thailand is the latest country to the development of the HSR project, like an important tool for economic development in their regions. As a result of the feasibility study, it is not feasible, is going on to construction, and expects to operate in 2022. Meanwhile, there are several barriers that the Thai government could consider to drive the HSR project to sustainable development.

This research analyzes and makes the mechanism of the barriers of the Thai government for the first HSR project. Four main barriers consisted of operation service on the section between Bang Sue and Ban Phachi, TOD, the new organization and personnel, and fare structure. The four hypotheses are considered to achieve the objectives as follows.

Using different signaling cause a political issue and there has never had the experience to combine the different HSR systems (signaling and telecommunication) by shared track. However, if the Thai government requires to use mixed operations with two systems, the government could consider safety and reliability. On the other hand, the alternative way is Bangkok-Nakhon Ratchasima section and Don Muang-Suvarnabhumi-U-Tapao section should use the same signaling and the government should change the structure at Bang Sue station.

TOD is a potential tool and useful to making sustainable development as it interacts between public transports and land use development by increasing the activities and accessibility. However, the development of land use is a variety of factors and Thailand has a limitation for TOD. The researcher proposes an approach for achieving their issues as follows: First, the Thai government should be explicitly specified the railway transportation investment projects that will be the main public transportation system or alternative of the public transportation system for users. Second, Thailand's government must have the national model scheme in TOD around the station area of the public transportation systems and relate to the spatial plan at each level. As well as it indicates the direction of how to develop and shows the outcome after development all of them including opportunity cost if we did not develop. Third, a financial tool for supporting the development of the TOD project (tax measure and soft loans) like Japan and USA to support operator whom operate the public transportation system and assist financial aid. Fourth, encourage the local government to participate and develop the TOD in each province, and Fifth, propose a proposal TOD around the station area of the public transportation system for a new law or change to an existing law that related to expropriation.

This research proposes the possible way for the new organization and personnel in the Thai context consists of railway operation and land development. The operation corporation is divided into the O&M section and TOD section. O&M section is required to hire private sector to responsibility because of knowhow and experience, while TOD section is a joint venture between the government and private sector for cooperation because of the limitation of legislation and regulation. The management includes SRT and the Ministry of Finance to reduce the financial risk.

The pricing can challenge only private transport and train's first-class and second-class. However, it does not compete naturally with other modes of public transport.

In addition, the researcher also investigates the factors that influence the first HSR project in Thailand. The result shows that the TOD factor is the most impact to drive the HSR project sustainable development. Because it integrates land use development and public transportation systems inclusive it produces a wealth of benefits, especially concerning demand increase and improve economic return surrounding public transportation hub. Meanwhile, other factors, the

performance of organization and staff, fare structure, and operation service has significant importance to approach and achieve as well.

Further research issues should be studied with the factors that influence the Nakhon Ratchasima HSR station, consider the characteristics of TOD typologies for the HSR station, and discusses how to connect the building integration.

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CHAPTER 5

A META-ANALYSIS OF CRITICAL FACTORS FROM INTERNATIONAL TRANSIT-ORIENTED DEVELOPMENT PERSPECTIVE

5.1 Introduction

Transit-oriented development (TOD) is often defined as a mixed-use development and density around transit stations and vastly influenced among actors, institutions, policies, and legislation and regulation (Dittmar and Ohland, 2004). Many case studies of TOD are shown a research strategy in the discipline of urban planning and implemented a conceptual idea in practical application (Curtis et al., 2009). This condition results in policymakers' require to seek an example of an international road map and transfer effective policies to their environment (Tan et al., 2014).

Policy transfer is how governments can learn decision-making (knowledge) from the experience of other governments (Rose, 1993; Dolowitz and Marsh, 2002). However, it differs from policy transfer analysis such as diffusion, emulation and harmonization, and learning (Evans, 2004). The transferable knowledge composes of policy goals, policy content, policy instruments, policy programs, institutions, ideologies, ideas and attitudes, and negative lessons, depending on the situation (Dolowitz and Marsh, 2002).

In this research, (national and local planning) policy is a development framework that made the decisions on planning applications. The measure is a way to develop or act to achieve the goals or outcomes. The tool is a method that leads to solving the problems (Ministry of Housing, 2021; Gabrielle Garton Grimwood, 2021).

Meta-analysis becomes an increasingly popular and valuable tool in transferable TOD policy (Thomas and Bertolini, 2014; Thomas and Bertolini, 2017; Thomas et al., 2018) since this tool can provide the common factors in the policy transfer and obtains the idea accepted from various lessons (Deacon et al., 1997). These efforts attempt to compare the specific conditions (plans and policies, actors, and implementation) under the findings in developed countries. The results show many factors complicating policy transfer that softer transferable lessons (e.g., good actor relationships, information sharing) are much more difficult to transfer than harder technical tools in the Dutch context.

There exists very limited research on measures in terms of specific areas for special development, land and community management, town planning, organization (involves in the development of TOD), investment, and legislation and regulation. Since TOD is a policy concept and wishes to implement in multi-layers and several stakeholders, this research questions the previous measures developed and developing countries can support and apply in the Thai context by using a meta-analysis through a gap analysis.

The objective of this research is to analyze international TOD policies, measures, and tools from developed and developing countries' perspectives for transferable Thai context (Nakhon Ratchasima) with gap analysis. Specifically, this research investigates the lesson learned from developed and developing counties where have the best-practices experience in TOD implementation to develop contextually appropriate public policy. The selected countries to comparison with Thailand are first examined.

5.2 Selection of case studies

5.2.1 Single case study

Single case studies have limited ability to provide an adequate and affordable solution for validity, cannot report issues of construct validity that reliability and replicability of various forms of analysis, and is the issue of external validity or generalizability (Willis, 2013). However, the government perspective is relatively focused on multiple-case studies to define lessons learned in policy development, especially an obstacle to the implementation of key policies (Niehaves and Krause, 2010).

Several case studies may not require the statistical samples to research (Schofield, 1993). Comparison of multiple-case studies is proposed for more generalized theory (Yin, 1994) and more sustainable mobility in urban planning and development (Naess, 2004).

5.2.2 Multiple cases studies

The challenge of integration of multiple-case studies is how to integrate the different types of data. This technique offers the researchers to determine the mutual influence of factors and approach data in a systematic between cases (Cervero and Murakami, 2005). There are many TOD case studies that incorporated the best approach around the world, e.g., Hong Kong, Japan, South Korea, Brazil, and USA (Bertolini, 1995; Cervero, 1998; Sorensen, 1999; Tang et al., 2004, Sorensen et al., 2009; Knowles, 2012; Turner and Morgan, 2012; Cullingworth and Caves, 2014; Suzuki et al., 2015; Oh et al., 2015; Yin et al., 2015; Japan International Cooperation Agency (JICA) et al., 2017, Matsui et al., 2017, Pojani and Stead, 2018). The next phase in the integration of multiple case studies through meta-analysis could be researched to determine common policies measures, and tools to promote and implement in the Thai context.

5.3 Data and methodology

This research uses meta-analysis with nine international countries for TOD implementation. Most countries include TOD strategies in transport and urban planning and require the cooperation of several local actors across the cities and regions. The screening of countries is a preliminary selection of shortlists for TOD around transit stations for the long run based on available information on transport and urban policies from documents, policy reports, and academic literature.

Hong Kong, Japan, South Korea, Taiwan, Brazil (Curitiba), England (London), France (Lille), Germany (Munich), USA (New York and Washington DC) are proven approaches and matched from the available information. Critical (success) factors from multiple-case studies (specific areas for special development, land and community management, positive measures for town planning measure, development for the organization, investment measure, and legislation and regulation) are analyzed by using meta-analysis and gap analysis for Thai context.

5.4 Case synthesis and results

5.4.1 Specific areas for special development

1. Japan

Land-use regulation, urban facilities, and urban development in city planning are the principle concept of the planning system which was received from the French planning system and German planning system (Flachennutzungs Plan (F-Plan) and Bebauungs Plan (B-Plan)). New residential Area Project and expansion of the Area Division are conducted together with urban facilities development**.** Land use is controlled by zoning regulations for development progresses. Besides, the zoning regulations in the district plan function independently. Given specific areas, they will be a framework for practical implementation with various measures and tools under zoning, land readjustment, and Urban Renewal Act (Sorensen, 1999; Sorensen et al., 2009; Turner and Morgan, 2012; Akashi, 2007; JICA, 2017; Matsui et al., 2017;).

2. Hog Kong

A comprehensive development area (CDA) is a measure to facilitate urban restructuring and phase out incompatible development and non-conforming uses. The purpose is to comprehensive development and redevelopment and design by using development parameters (e.g., maximum gross floor area, building height, and site coverage) (Mile and Huberman, 1994; Cervero, 1998; Tang et al., 2004).

3. Germany

German planning system uses Flachennutzungs Plan (F-Plan) and Bebauungs Plan (B-Plan). F-Plan is a principle land-use plan and covers all municipalities. This plan can create with many municipalities and should include 10 elements, e.g., general land use, areas for public facilities, and regional transportation allocation. B-Plan is a resolution of assembly and resolution of regulation at the district level (Wenget, 1975; Cervero, 1998; Akashi, 2007).

4. France

French planning system uses Schéma de Corrence Territoriale (SCOT) and Plan Local d'urbanism (PLU) as two policies to development. SCOT is a medium- and long-term (20-30 years) policy for land use. This policy covers not only land use but also economic, environmental, and other macro policies. It is determined by two or more municipalities through consultations with stakeholders such as residents and public opinion hearings.

PLU is set by the municipality through consultations with residents and public opinion hearings. This policy covers land use, road adjacency condition, building height, and criteria for building appearance (Akashi, 2007).

5. England

The structure plan is the master plan to explain the long-term policy at the national level and the local plan is the policy and set by the district for the land-use plan at the local level. Meanwhile, the unitary development plan is the metropolitan plan (London special district and six metropolitan areas) which covered the structure plan and the local plan (Akashi, 2007).

6. USA

Planned unit development is a policy for specific zoning processes and permits a greater flexible regulatory. Specifically, building development is designed for various types of land uses with a lower development cost (Turner and Morgan, 2012; Cullingworth and Caves, 2014).

5.4.2 Land and community management

1. Land readjustment

Land readjustment is a measure that began with a formal decision from a private sector or a public sector. The local government is the key player to implement the land adjustment. This measure is firstly applied in Tokyo in 1923 to develop a new town and renew the old town for improving the urban structure with infrastructure investment by Urban Renaissance (UR). This approach differs from the original concept in the German planning system because it is not isolated designed for either the public or the private sector (Wengert, 1975; Larsson, 1997; Sorensen, 1999; Home, 2007; Sorensen et al., 2009; Turner and Morgan, 2012; Cullingworth and Caves, 2014; Matsui et al., 2017; Souza et al., 2018; The Hong Kong Institute of Surveyors, 2018; Krabben et al., 2020).

Figure 5.1 shows land adjustment based on Japanese system. The primary mechanism consists of the change of location, form, and area of land to achieve the projects. The transformation process is formed by land readjustment agencies, private sector, and government agencies (nation, prefecture, and local) under Land Readjustment Law. The expectation is every piece of transformed private land will be smaller than the original one because of the significant increase in public spaces. The value of land will be higher than the original one because of added facilities (e.g., Larsson, 1997; Sorensen, 1999; Home, 2007; Sorensen et al., 2009; Matsui et al., 2017; Souza et al., 2018).

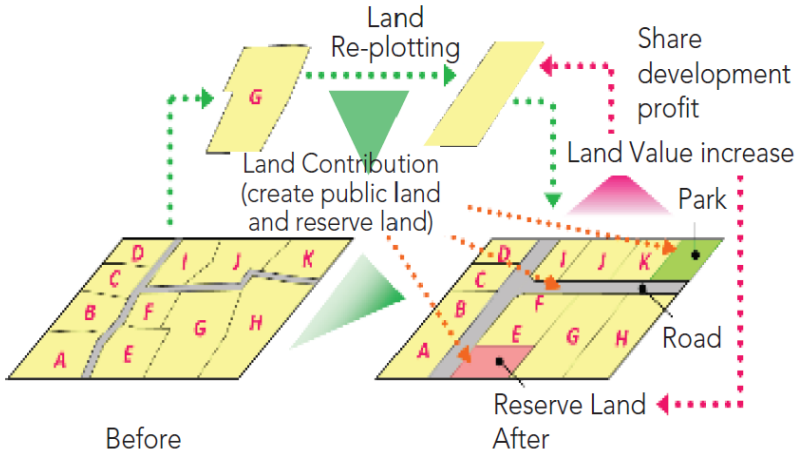

Figure 5.1 Land readjustment

Source: Matsui et al. (2017)

Table 5.1 shows the different international experiences related to land readjustment. Several countries (e.g., Japan, South Korea, France, and Brazil) use different forms of land readjustment from the basic functions to the most complex processes by governance and urban planning (e.g., Souza et al., 2018; The Hong Kong Institute of Surveyors, 2018; Krabben et al., 2020).

Table 5.1 The different international experiences related to land readjustment

Country	Similar form	Reference
Japan	Tochi kukaku seiri	▪ City Planning Law ▪ Land Readjustment Act

Country	Similar form	Reference
South Korea	Tojiguhoegjeongli	▪ Colonial Urban Planning Act ▪ Land Readjustment Act ▪ Urban Development Act
Taiwan	▪ Tudi Zhong hua Shi di Zhong hua	▪ Land Act ▪ Equalization of Land Rights Act ▪ Urban Land Readjustment Regulation ▪ Farmland Readjustment Act ▪ Rural Community Land Readjustment Act
USA	Land assembly	Planning and Compulsory Purchase Act
Germany	Baulandumlegung	Federal Building Code
France	Remembrement urbain	Spatial Planning Law
Brazil	▪ Reajuste de Terrenos ▪ Reparcelamento do Solo	Sao Paulo Municipal Master Plan

2. Land banking

Land banking is a measure to assist limitation of land use and agriculture land tenure by the purchase of a pre-developed land or required purchase and pre-emption (Loue, 2006). Land banking is created in USA in 1971 to acquire tax-foreclosed properties that remained unsold at sheriff sales (Alexander, 2015). In 2009, the land bank is announced by the U.S. Department of Housing and Urban Development as the best measure for communities with effects of real estate market (Department of Housing and Urban Development, 2009).

The purpose is to buy large tracts of undeveloped land to sell at a higher price after development. Many case studies in the world showed the driving land bank opportunities, e.g., France, England, Sweden, and USA (Loue, 2006; Department of Housing and Urban Development, 2009; Atmer, 1987; Dijk and Kopeva, 2004; Haila, 2000). However, the creation of land banks is concerned with five major obstacles (psychological, legal, structural and operational, administrative, and financial obstacles), especially, structural and operational characteristics of land-banking agencies (Enders, 1985).

5.4.3 Positive measure for town planning

1. Japan

Floor area ratio (FAR) bonus and FAR transfer are tools to stimulate the density criterion of TOD around the transit stations. FAR bonus can be developed a higher value than the standard of the City Planing Act if public facilities are provided such as public space and park. Additional FAR is applied in the specific areas by Urban Renaissance. The FAR transfer is an additional FAR within station catchment area by transferring FAR from other locations where do not require to utilize the maximum FAR (Akashi, 2007; Sorensen et al., 2009; Suzuki et al., 2015; Thomas and Bertolini, 2017; Thomas et al., 2018; Kidokoro, 2019; Thomas and Bertolini (2020).

2. Hong Kong

There are two policies (outline zoning plan and development permission area plan), one measure (comprehensive development area), and two tools (FAR and FAR transfer) for a positive town planning system in Hong Kong.

Outlined zoning plan is allowed when development permission area plans are approved and accorded with zoning. Development permission area plan is prepared for an area not previously covered by outlined zoning plan. Both types are used for rural areas (with

development and non-development areas) which is provided by Urban Renewal Authority (Tang et al., 2004; Cervero and Murakami, 2008).

The Town Planning Board is the organization where the developed project in a comprehensive development area (CDA). CDA is used for urban areas when it requires to encourage an intensive approach to urban design and development areas with stakeholders to use public space and local community facilities (Town Planning Board, 2021).

FAR is the key basic to guide and improve the development density in the zoning areas. Although each zone in the Metroplan area and new towns has different maximum FAR, most Metroplan areas are higher FAR than new towns because of socioeconomic factors. Meanwhile, the FAR transfer is an increase in FAR around the areas but the total density is the same. This approach is often used for building conservation because it faces the limitation to development (Suzuki et al., 2015).

3. Germany

Regional planning incentives, compact, urban, and green city, and promoting green forms of transport are policies to assist and develop station areas. Regional planning incentive is a strategy and visionary for incentive zoning and land-use controls by local governments. The original plan adopted the concept of transportation and urban planning to promote the investment in S-Bahn and U-Bahn systems. However, the plan was challenged the overspill development into mixed-use town centers. The regional association set the condition on housing, commercial, and industrial development could develop surrounding transit stations.

Compact, urban, and green cities develop a radius of 600 m from all U-Bahn and S-Bahn stations (station catchment area). The station catchment area is divided into two zones which were the primary zone and the secondary zone. The primary zone is a radius of 150 m from transit stations and aims to develop a commercial area. The secondary development zone is a radius of 151 to 600 m from transit stations and aims to develop housing communities.

Promoting green forms of transportation aims to switch people from private vehicles to public transportation or non-motorized transportation. Besides the transit facilities and services are upgraded to support travelers for green modes (non-motorized transportation). The important developments are the construction of pedestrian overpasses and underpasses at a busy crossing, provision of bicycle parking lots around transit stations, separate signal phase and turning phase for cyclists, and redesign of intersections and use of street and speed bumps to slow through traffic (Cervero, 1998).

5. England

Planning obligations under Section 106 of the Town and Country Planning Act 1990 are used as a measure for an acceptable mechanism in planning terms. The purpose is to bring development in line with sustainable development as articulated through the relevant local, regional, and national planning policies. This planning obligation is flexible to private developers who do not have a comply with existing urban planning requirements. For instance, the private developers will receive a higher FAR if they will trade in funding, construction of infrastructures, and affordable housing. This offer requires the purpose of local governments for consideration. However, this process is criticized by some for delaying the planning process and for reducing its transparency, certainty, and accountability (Suzuki et al., 2015).

6. USA

Planned unit development is a policy and zoning, FAR bonus, inclusionary housing, and transferable development right are tools to assist and develop station area.

Planned unit development is a principle policy of a city for future direction. This policy is integrated regulation of land-use zone and regulation of land-use subdivision. Private developers will propose a project for specific area development and exchange the fundamental infrastructures. This policy is flexible to develop TOD because TOD projects are included in the master plan to develop.

Zoning is a tool to specify the size of buildings constructible in a zone predetermined by subdividing the city area. Private developers will receive a higher density in terms of FAR if there is an exchange in providing space for public benefits. FAR consists of three types (FAR bonus, inclusionary housing, and transferable development rights) based on objectives.

FAR bonus in the station catchment area can be developed a higher FAR than standard of the city (or town) planing law. The private developers will receive a higher FAR if they share their areas or provide higher spaces (e.g., public space, walkway, and community service). This is an increase of FAR depends on the size of spaces.

Inclusionary housing (or inclusionary zoning) is defined as a set of government-imposed mandates on private (residential) developers to guarantee a new development, including a mix of prices and types of affordable to diverse income households. These include financial offsets (e.g., subsidy, density bonus, and fee waivers) that reduce costs of building the below-market rate. Many cities create at least 10 % of new housing be affordable in response to the law. The key factors are the availability of housing units, long term investment, location, and a range of developers incentives

Transferable development right (or FAR transfer) is allowed the transfer of development from one zone of land to another. The zone of land is called the sending zone because the development right sends out of it, while the receiving zone is developed more intensively than existing permitted in the zoning ordinance. Many elements for transferable development rights require implementation such as the local government, the zoning ordinance, allocation rate, density bonus, and necessary (Akashi, 2007; Walls and McConnell, 2007; Wiener and Barton, 2013).

7. Brazil

There are two policies (transit-supportive housing policies and parking policies) and one tool (transferable development rights) for the planning system.

The housing development is provided for some 20,000 low-income people and built around transit stations based on Municipal Housing Fund Act. This system brings about the higher density bonuses in some zones (ZR 2, ZR 3, and ZR 4 zones) which belong to the dsitance of the transitway.

Parking policy is important in Curitiba city because the private vehicles can park for a short period. The governments seek the solution about levying higher registration fees and import fees to overcome private vehicle ownerships.

Transferable development rights are permitted to sell and transfer their development rights to property developers in Curitiba city. This tool aims to protect heritage and transfer densities to places where generate benefits as much as structural axes. Because the characteristics around structural axes are mixed-used development and receive bonuses of density transfers (Cervero, 1998).

5.4.4 Organization

1. Japan

Urban Renaissance (UR) and local government are two organizations to push forward for TOD projects. UR is a semi-government organization to address urban and housing issues with the private sector and government sector. UR needs to build attractive cities and create a good environment and community by focusing on the urban rejuvenation field, living environment field, disaster redevelopment field, and suburban environment field (Urban Renaissance Agency, 2016).

Local government is an initial driver for many TOD projects since they have the high density in some places, solve the problem of degraded areas with mixed-use, generate the additional income (of taxes) for local government. The local government still gets an opportunity to receive the grant from the federal government (central government) if the development area is announced to special area based on the law on spatial measures for UR (Urban Renaissance Headquarters, 2004).

2. Hong Kong

Metro planning committees, rural and new town planning committees, and MTR are key players to drive TOD projects. Metro planning committees focus on a legal framework for renting space and the condition of benefit sharing. Planning committees prepare outline zoning plans and development permission areas plans and approve master layout plans revise comprehensive development areas. MTR is the operator management for negotiating private agencies and builds residents and commercial properties around the transit stations (Cervero and Murakami, 2008; Suzuki et al., 2015).

3. South Korea

The federal government is a legislator to define the special development area where required the development and strategy from the public hearing. The local government is the leader to do the master plan and seek the source of funds to develop public assistance and public service.

Korea Railroad Corporation is the operator of the national railway and Korea Rail Network Authority is the maintenance technician of the national railway (Oh et al., 2015).

4. Germany

The federal government is the legislator to define the special development area where required the development and strategy from the public hearing. The local government is the leader to do the spatial development plan and district plan and seek the source of funds to develop public assistance and public service. Deutsche Bahn is the railway operator and does improve the station area (Cervero, 1998; Akashi, 2007).

5. France

The federal government is a legislator to define the special development area where required the development and strategy from the public hearing. The local government is the leader and the public institution of development (EPA) is the source of fund for government investment (Minister of Territorial Development, 2021)

Local government is a determinant to the specific principle of passenger and goods transport as well as parking and needs to adjust with SCOT and PLU (Akashi, 2007).

Operational international interest (OIN) is a planning organization for urban planning, especially the legal system of special areas because of the major interest of land or state. OIN aims to spread the prosperity of succeeding in the regional areas to set the provision of privileges for strategic conditions (Organisation for Economic Co-operation and Development, 2017).

Railway operator is French National railway Company which aimed to responsible refurbish and develop facilities of railway station and research and development urban design and railway engineering (French National Railway Company, 2021).

5.4.5 Investment

1. Japan

Grant-in-aid and tax incentives are two tools to support investment measures for support TOD projects. Grant-in-aid is federal government specifies the portion of grant-in-aid for infrastructure development to local government. Tax incentives are provided the reduction of fees for (income, purchasing land, real estate) tax (Akashi, 2007; Suzuki et al., 2015).

2. Hong Kong

Rail + property development program is applied around Mass Transit Railway (MTR) railway stations. There are three factors for this program: (1) private developers buy 50-years leases tat granted property development rights through the tenders, (2) The government provides development rights of stations to MTR over the land above and around new stations and depots at the full market, excluding the presence of the new railway lines, and (3) MTR adopts private developers based on the full market value, including the presence of the new railway lines. The difference of value is enough to funding gaps estimated by the company and by external project assessors (Suzuki et al., 2015).

3. Germany

The federal government is the legislator to define the special development area where required the development and strategy from the public hearing. The local government is the leader to do the spatial development plan and district plan and seek the source of funds to develop public assistance and public service. Deutsche Bahn is the railway operator and does improve the station area (Cervero, 1998; Akashi, 2007).

5.4.6 Legislation and regulation

1. Japan

The primary registration and regulation are Urban Renaissance Law, while the secondary registration and regulation are Deep Underground Utility Law and Barrier Free Law (Urban Renaissance Headquarters, 2004; Akashi, 2007; JICA et al., 2017; Ministry of Health, Labour and Welfare of Japan, 2021; Ministry of Land, Infrastructure, Transport and Tourism, 2021). The primary registration and regulation aim to compact the development of scattered cities, promote the development of advanced industrial and people's quality of life, and set the targeted area districts (based on government policy) and priority areas.

2. Hong Kong

As the Basic Law (Hong Kong Special Administrative Region Government, 1997; Haila, 2000), the government will lease land to the private sector for development within 50 years.

The land rental is approximately 3 % of the appraised value and is an increase based on the period of land tenure. Both ways are particularly beneficial to the development of TOD projects because of the range of period and price of the land rental.

3. South Korea

The station area development is involved many acts (i.e., The Act of National Integrated Transport System Efficiency, The Act of Housing Development Promotion, The Act of Urban Development, and The Act of Station Area Development Promotion).

The Act of National Integrated Transport System Efficiency is legislated to coordinate several transport facilities and modes of transport. The main purpose is to improve the traveler's movement and to boost national economic development.

The Act of Housing Development Promotion is legislated to solve the urgent housing shortage problem. The main purpose is to stabilize people's housing and to enhance people's welfare.

The Act of Urban Development is legislated to pursue planned and systematic urban development. The main purpose is to create better urban circumstances and to enhance the public interest.

The Act of Station Area Development Promotion is legislated to pursue efficient and systematic development for station areas. The main purpose is to support financial tools and processes to developers (Oh et al., 2015).

4. Germany

The federal building code (Baugesetzbuch) is a legal measure that controlled the use of land for relative buildings or others within a municipality. Many amendments in the measure are defined the principle component of TOD. In particular, in the 5th amendments, land-use plans shall preserve a sustainable urban development and a more humane environment such as the general requirement for living and working conditions, the housing requirements of the population, the social and cultural needs of the population, and the requirements of Churches and religious organizations (German Law Archive, 2021).

5. France

OIN has the regulation to create an urban community for the special area and needs to achieve the national benefit. EPA is similar to OIN, but it focuses on the special area where had joint venture and made the regional benefit (Organisation for Economic Co-operation and Development, 2017; Public institution of development, 2021).

7. England

Planning obligations under Section 106 of the Town and Country Planning Act 1990 is a measure to permit the huge urban development project and affect the urban and conflict with the condition of current urban form (Lord et al., 2020; Department of Communities and Local Government, 2006).

8. Brazil

Zoning law permits the first two floors to extend to property lines for exclusive busways and auxiliary lanes. This leaves 1.5 m between buildings and street curbs for sidewalks. Zoning law also requires at least 50 % of the ground and second floors to be devoted to retail-commercial uses such as shops and restaurants (Cervero, 1998).

9. Taiwan

As zone expropriation, the government can acquire the station area land and promote the development of station district plans. The land owners can exchange 40 % - 50 % of their expropriated area in principle without loss of their rights (Oh et al., 2015)

5.4.7 Summary of critical factors from international TOD perspective

Table 5.2 shows the summary of critical factors from the international TOD perspective. Specific areas for special development aim to set the potential area for development through the national plan. Land and community management aim to collect the land for practical development using land readjustment and land banking. Town planning aims to improve urban planning to induce developers to invest by exchanging the benefit (e.g., FAR bonus, FAR transfer, and zoning). The organization aims to modify the regulation to establish the special organization and assist the local government by knowledge transfer. The investment aims to modify the supportive investment for a developer with the condition. The developers will invest in public assistance and public service and the government will reduce the tax or give additional loans. Legislation and regulation are the key players to drive other factors.

Table 5.2 Summary of critical factors from international TOD perspective

Countries	Specific areas for special development	Land and community management	Positive measures for town planning	Organization	Investment	Legislation and regulation
Japan	√	√	√	√	√	√
Hong Kong	√	NA	√	√	√	√
South Korea	NA	√	NA	√	NA	√
Germany	√	√	√	√	NA	√
France	√	√	NA	√	NA	√
England	√	NA	√	NA	NA	√
USA	√	√	√	NA	√	NA
Brazil	√	√	√	NA	NA	√
Taiwan	√	√	NA	NA	NA	√

As a comparison between the international TOD perspective and the current Thai perspective, Thailand (Nakhon Ratchasima) faces many gaps to consider for TOD projects.

1. Specific areas for special development

This is a primary factor in development for TOD projects because it can provide policy, measure, and tool to implement and support transit stations. In general, the node-place model is an application to classify the typology of places and understand each place within the station catchment areas (Bertolini, 1999). The score of the node-place model and TOD index can assist the government (Department of Public Works and Town Planning and Ministry of Transport) to set the potential areas and priority areas in the country and town planning for development based on Town Planning Act 2019.

2. Land and community management

This factor is an alternative way to collect individual lands with different stakeholders and improve the potential land value. Land readjustment is the most efficient and fair land

consolidation method for TOD development. Because whole landowners jointly organize a new plot of land through the sacrifice of some common areas in proportion to the original land plot fairly. As a result, a plan of development that responds to the utilization of the land to its full potential and has appropriate public services and facilities according to the TOD component.

Land banking is mostly accumulated to obtain personal benefit and not the collective by private investors. This way results in injustice or transparency because of a high land price in land development.

3. Positive measures for town planning

This factor contributes to create mixed use and density through the measures (FAR bonus and FAR transfer) surrounding transit stations. FAR bonus is included in Section 2 under Town Planning Act 2019, while the FAR transfer is still under consideration by the committee. Many civic and economic centers in the capital city (Nakhon Ratchasima) uses FAR bonuses in terms of creating mixed-use and density, while the regional cities use FAR bonuses to control the height of the building. Nevertheless, the government does not only have the know-how to apply town planning for potential transit stations.

4. Organization

Based on international experience, policy agencies, local governments, and private developers should work together for TOD projects. In the case of Thailand, the federal government is the main player to do the TOD projects and the private sector will follow the command or announcement. The local government has a limitation of responsibility to the TOD projects because the Thai management uses a centralized government. Additionally, the limitation of monetary is a concern in the regional cities to develop infrastructure projects.

In recent years, many cities in Thailand establish developing companies (including Nakhon Ratchasima) to participate in the urban planning in each city. Nevertheless, these companies face barriers to the development of the commercial area around transit stations based on the legislation and regulation (e.g., Expropriation and Acquisition with Immovable Property Act 2019).

5. Investment

Development between transportation and urban development and urban development after transport development are two groups to investment.

Development between transportation and urban development can apply TOD at the full level, while urban development after transport development can apply TOD at the partial level. The land bank is used as a concession for railway development and urban development such as the R+P model (for large size of the land bank from the government) and joint venture (for large size of the land bank from the private sector). If there is no land bank in the area development, the government will support developers to develop infrastructure projects.

Both ways have a good mechanism for the local government to develop infrastructure projects and the developers can rent the land for the long run (more than 30 years). The property price is affordable to live and rent/buy. However, there are some weak points. For example, the federal government has the limitation of budget to decentralize local government. There are not any financial incentives (measures and tools) for developers, especially real estate.

6. Legislation and regulation

Thailand is a similar development to Japan in terms of legislation and regulation. Japan starts with the announcement of new legislation and regulation in terms of urban development (e.g., Land Readjustment Act, City Planning Act, and Act on the Urban Renaissance Agency). Meanwhile, transport development (Japan National Railway) is privatized and broken up into six regional railways and a nationwide freight train operator to make profitable and efficient. Universal design is raised to implement for travelers.

Thailand has only the City Planning Act and positive measures of town planning to support TOD in the practical approach. Therefore, Thailand lacks many legislation and regulations such as urban renewal, land collection, and integration between transit stations and urban development when compared with Japan. Besides City Planning Act is related to many acts in different government agencies. It affects the management and decision because of viewpoints.

5.5 Conclusion

This chapter aims to identify critical success factors in TOD lessons to assist overcome gaps in TOD implementation in Thailand (Nakhon Ratchasima province) by using a transferable international perspective. The meta-analysis is successfully proven in critical success factors which focused on specific areas for special development, land and community management, positive measures for town planning, organization, investment, and legislation and regulation.

The comparison between the cross-case studies shows the unique policies, measures, and tools to TOD implementation to align stakeholder goals. This research attempts to collect the ideas from international contexts and adapts the preferable route which challenged the gaps. Legislation and regulation are the common approach (but not all) rather than other factors to promote and support TOD.

For specific areas for special development, the government (Department of Public Works and Town Planning and Ministry of transport) needs to evaluate transit stations by using the node-place model within the station catchment area and classify the potential of transit stations. Then the government assigns the potential of transit stations in the national plan, regional plan, and province plan based on the Town Planning Act 2019.

For Land and community management, the government should collect land for development (e.g., land readjustment) and improve the quality of life of residents and improve the potential of lands. In general, the legislation and regulation do not allow for the land collection and use for TOD. If the government has the master plan for TOD (national plan, regional plan, and province plan), it is possible to waive the process.

For positive measures for town planning, specific town planning is an alternative tool to make the master plan for TOD projects around the transit stations, and the stakeholders need to follow this master plan to implementation. Meanwhile, the relative people should understand the town planning to create the strategy and plan.

For organizations, the federal government should provide two divisions which were policy and strategy division and driver division to implement the national viewpoint. The policy and strategy division needs to set the national and strategic policy, measure, tool, budget, and decision making for the developers. Driver division needs to evaluate the TOD projects, knowledge transfer, cooperate with the developers and government. Meanwhile, the local government should provide two divisions which were operator division and developer division

to implement local viewpoint. Operator division encourages developing companies, local government agencies, and local people to brainstorm about specific town planning. The developer division focuses on management before and after operational TOD projects.

However, the challenging point in the organization is which government agencies could act at a policy level to support and promote the TOD projects and how to transfer the knowledge to the stakeholders. Because the Thai government agencies have several units and do their tracks.

For investment, the federal government should provide the financial measures and tools to support developers such as tax and the range of land loans.

For legislation and regulation, they are the most important factor among critical factors from the international TOD perspective to drive others to the goals. However, the current legislation and regulation do not support TOD in many angles, e.g., land expropriation for commercial areas around transit stations by government agencies, and the developers use the different goal from land expropriation (Chalermpong and Ratanawaraha, 2016).

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CHAPTER 6

MEASURING THE IMPACT OF ECONOMIC DEVELOPMENT ON FUKUSHIMA SHINKANSEN STATION INVESTMENT

6.1 Introduction

Several infrastructure projects in Thailand are approved by Thailand's Prime Minister Prayuth Chan-Ocha, especially the development of the Thai-Chinese High-Speed Rail project (phase 1: Bangkok-Nakhon Ratchasima). It is developing a transportation network across the country to provide multimodal interconnection for more convenient travel and encourage economic development along the corridor.

This High-speed Rail (HSR) project is still constructed and expected to operate in 2022; however, the feasibility study is not feasible and it takes the risks of financial and economic return. In other words, Thailand's government is facing how to drive the HSR project for sustainable development in long-term operation and maintenance. As figure 1 shows, TOD (Transit-Oriented Development) is the most influential factor to drive the HSR project for sustainable development because it integrates land use development and public transportation factors (Tissayakorn et al., 2019). Hence, Thailand could apply TOD around the potential HSR stations (including Nakhon Ratchasima HSR station) to improve the urban infrastructure in a meaningful way.

Since Thailand does not have experience in TOD, HSR in Japan (Shinkansen) is the best-case study for all countries to learn how to make effective TOD. Shinkansen also can expressly facilitate the new towns/communities along the corridor by comprehensive national and regional development levels. That is to say, without Shinkansen, the economic impact will not accomplish the outcomes. In addition, the past studies have clearly shown that HSR investment is expected to enhance economic growth and economic productivity such as Tokaido, Sanyo, Tohoku, Kyushu Shinkansen line, and some prefectures in Japan. However, there is a lack of studies in (1) aggregate demand (macroeconomic) perspective in Fukushima prefecture based on time series and (2) the previous studies display almost the effective parameters and have some limited indicators to analyze and consider. Therefore, we attempt to collect the gap of wider economic-related parameters and set the framework based on agglomeration economy.

This research is expected to have an impact on transportation economics and policies so that we will understand the potential factors when investing in the Fukushima Shinkansen station. The objectives of this study are composed of (1) to analyze the macroeconomic in short-term and long-term changes constantly of Fukushima prefecture before-after opening of Fukushima Shinkansen station based on time series and (2) to evaluate the indirect (wider) economic benefits and economic development on Fukushima prefecture as well as it also has two hypotheses which are (1) operational Fukushima Shinkansen station will impel the economy in Fukushima prefecture based on aggregate demand angle and (2) Fukushima Shinkansen station investment effects to which factors in wider economic benefit and economic development. Furthermore, the methodology of this paper is mixed analysis (quantitative and qualitative analysis) by using empirical analysis with the compound annual growth rate method.

6.2 Research methodology and data source

6.2.1 Lesson learned from the previous studies

The most important lesson from Japanese case studies is the significance of making an evidence base in calibrating and validating the predictive models. Especially, the models have been mainly based on the socio-economic impacts and have been designed to uncover some information such as a hotel (ryokan), house, educational institute, and employment (part-time) because their parameters influence land use and community facilities. Moreover, they did not collect related time-series data on HSR impacts and analyze the long-term and short-term changes.

To address the above challenge, it seems critical to collect the assessment framework for wider economic benefit. Therefore, we attempt to consider all parameters based on three information which are productivity, investment, and land use, and labor market factor (Graham, 2007; Venables, 2016; Department of Transport, 2018) to identify the changes that are attributable to the HSR station service.

6.2.2 Methodology

This study endeavors to complete its objectives which are (1) to analyze the short-term and long-term changes constantly before-after development of the Fukushima Shinkansen station based on time series trend data and (2) to evaluate the indirect (wider) economic benefit and economic development based on actual data. To understand the impacts more precisely, more analyses need more detailed data in this study.

The design of the investigation has been proposed from the perspective of macroeconomic, wider economic benefit, and economic development data by using empirical analysis with a compound annual growth rate (CAGR) method[(4)] because it is one of the most accurate ways to calculate and determine returns for anything. These data need to reflect in the indicators with the key assumptions are productivity, investment and land use, and labor market viewpoint on Fukushima prefecture.

6.2.3 Data source

This analysis does not try to estimate the economic parameters on Fukushima prefecture whether public policies may be able to harness and leverage these trends to induce greater economic benefits. On the contrary, we attempt to collect the actual data from reliable sources in Japan, other international websites such as e-stat, World Bank, and MLIT (Ministry of Land, Infrastructure, Transport, and Tourism), but we have limitations in data access. In other words, this study uses secondary data to analysis and they are mainly on the websites; however, some old data do not store in the database of their websites and we also contract to the international affairs division, Fukushima prefectural government, but until now we did not receive the data. Thus, this paper use as much information as possible to conservative and underestimate the analysis in economic parameters.

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(4) CAGR is the geometric average per year calculates from the growth rate over multiple years and the formula is as follows:

$$CAGR = \left[\frac{Ending\ value}{Beginning\ value}\right]^{\frac{1}{Number\ of\ years}} - 1$$

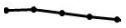
6.3 Results

6.3.1 Analyze the macroeconomic in short-term and long-term changes constantly based on time series

Table 6.1 shows the economic transformation in Fukushima prefecture during 1975-2014. The empirical characteristic of the macroeconomic (Gross Prefecture Product: GPP) with actual data is divided into 8 sections to further examine the economic trends for the short term. At this point, we attempt to consider the support factors and risk factors that bring about economic transformation as shown following:

Table 6.1 Economic transformation in Fukushima prefecture during 1975-2014

Duration	Detail	Trend
1975-1979	▪ Since the oil crisis was fallen in 1973, the oil price was a tendency to increase and was caused by a high inflation rate. The initial phase is described as a recession. ▪ Next, this was the upsurge in the economic situation that did not spread through the entire economy to encourage the economy thanks to some support factors such as the number of commercial establishments, the number of commercial employees, the number of employees, and the number of employees, especially a rise of consumer price index, income and labor market and a decline of the exchange rate (USD-JPY); thus, during 1978-1979 was the sign of the mature return of demand.	
1980-1984	▪ These durations liked the second oil crisis and offered high interest and exchange rate variance. In other words, they degenerated economic performance and caused an imbalance in business performance. ▪ In 1982, the business sectors and labor sectors were grown to support the Tohoku Shinkansen line (Omiya Shinkansen station to Morioka Shinkansen station, include Fukushima Shinkansen station). ▪ The government promoted the development of transportation technology and innovation.	
1985-1989	▪ An economic bubble in which rental houses, real estate, commercial establishments, and stock market prices were greatly inflated until some commercial establishments closed and laid off the commercial employees. Therefore, the number of employees (full-time) was a trend to decrease, but the number of employees (part-time) was a trend to increase to save the fixed cost and risk management. ▪ Meanwhile, the Tohoku Shinkansen line connected Ueno Shinkansen station to Omiya Shinkansen station; hence, it could service from Ueno to Morioka Shinkansen station in March 1985 and public transportation received the benefits from reduced fuel costs in that time.	
1990-1994	▪ These spans, the business sector was stimulated by promoting regulatory reforms, tax reforms, and technology development. ▪ Tohoku Shinkansen line linked Tokyo Shinkansen station and Ueno Shinkansen station; thus, it could service from Tokyo Shinkansen station to Morioka Shinkansen station in 1991. It brought about the business sector (retail establishments) and labor sector (employee (full-time)) growth continues to grow, as well as the number of properties (houses and apartments) was likely to increase to accommodate the number of people who had moved in. ▪ East Japan Railway Company was listed on the Tokyo Stock Exchange in October 1993, the first sale of stock among the seventh JR's Group. ▪ However, Fukushima society was facing a decreasing number of births and an increasing number of deaths.	

Duration	Detail	Trend
1995-1999	▪ This duration was a sustainable recovery phase thanks to an increase in infrastructure projects investment, business/commercial establishment, low-interest rate, inflation rate, and negative impact of the exchange rate. ▪ An aging society was a trend to grow and the number population and births drop by 4,592 and 809 people, respectively. Therefore, it took a risk to labor productivity and the property market in the future.	
2000-2004	▪ Japanese Prime Minister set up a central government to play for the structural reform because (1) to strengthen the function of the cabinet, (2) to reorganize the central government, (3) to make the administration more transparent, and (4) to streamline the government. ▪ The economy was deteriorated out because it was a decline in investment, value-added manufacturing, residential market, population, and jobs including Bank of Japan declared a zero-interest-rate policy to protect the deflation situation. ▪ Meanwhile, the Tohoku Shinkansen line serviced Morioka Shinkansen station to Hachinohe Shinkansen station; therefore, it could operate from Tokyo to Hachinohe Shinkansen station in December 2002. It boosted the number of wholesale establishments and new employee recruitment.	
2005-2009	▪ Although there were risk factors such as exchange rate and the number population, the prefecture suffered the trading volume. ▪ Meanwhile, the population, the first baby boomer, employee, and employment were the trend to decline. These issues contributed to how to improve and replace the quality of the labor force to increase productivity in the future. Thus, the government announced human potential in policy for strengthening in terms of the various vocational training and school education. ▪ An average property price tended to climb due to the influx of foreign tourists, high-interest rates, and future development plans.	
2010-2014	▪ Prices of oil products rose in line with an increase in crude oil prices during 2010-2011. ▪ The Tohoku Shinkansen line operated Hachinohe to Shin-Aomori Shinkansen station; therefore, it could service from Tokyo to Shin-Aomori Shinkansen station in December 2010. It encouraged the business and labor sector in a short time before facing a natural disaster in 2011. ▪ An increase in the number of companies and residential markets stopped owing to an earthquake and Daiichi nuclear power plant accident in 2011. Afterward, the government proclaimed a plan for revitalization in Fukushima prefecture which aimed at sustainable development. ▪ In addition, there was the creation of new industries and jobs for demand in areas such as environment, energy, medical and nursing care as well as investments in intangible assets were mainly investments in innovative property including R&D investment.	

The effective macroeconomic results in Fukushima prefecture illustrate in Figure 6.1. As figures 6.1 shows, Fukushima prefecture's economic outlook is likely to improve after the opening of Fukushima Shinkansen station services. Meanwhile, we also have considered the impact of operational Fukushima Shinkansen station that is measured by the number of support factors and risk factors on the compound annual growth rate of macroeconomic-related parameters after the operation of Fukushima Shinkansen station in 1982. For this approach, Figure 6.1 shows, the impact on macroeconomic has a short-term by Fukushima Shinkansen station and four phases have a stronger impact on the Shinkansen station more than other

external factors because the number of support factors outperforms the number of risk factors. That is to say, the support factor in phase 1-4 is the investment factor and risk factors in phase 1-4 are the inflation rate, interest rate, and exchange rate factor, except in 1996 takes a risk factor only inflation rate and exchange rate factor (see Figure 6.2).

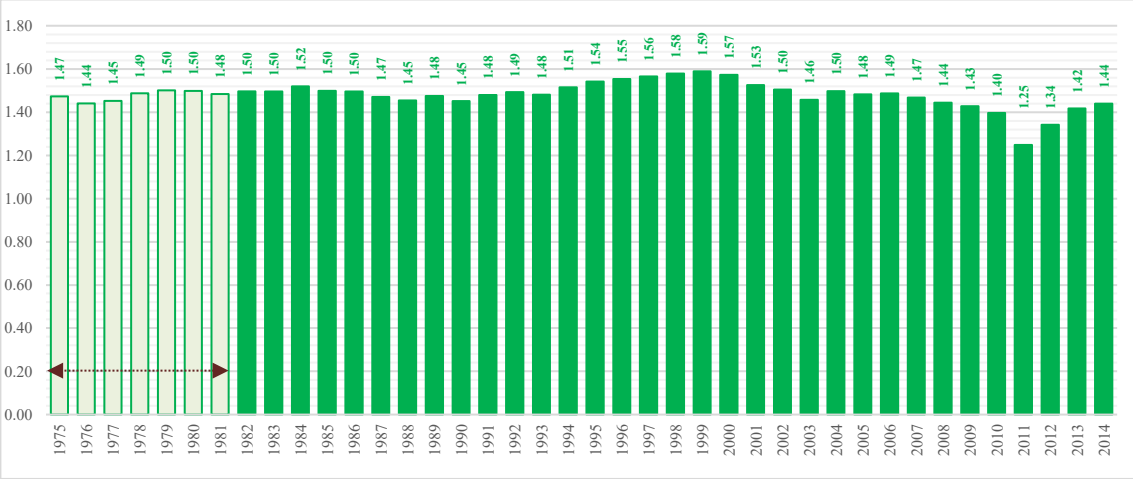


Figure 6.1 GPP in Fukushima prefecture (%)

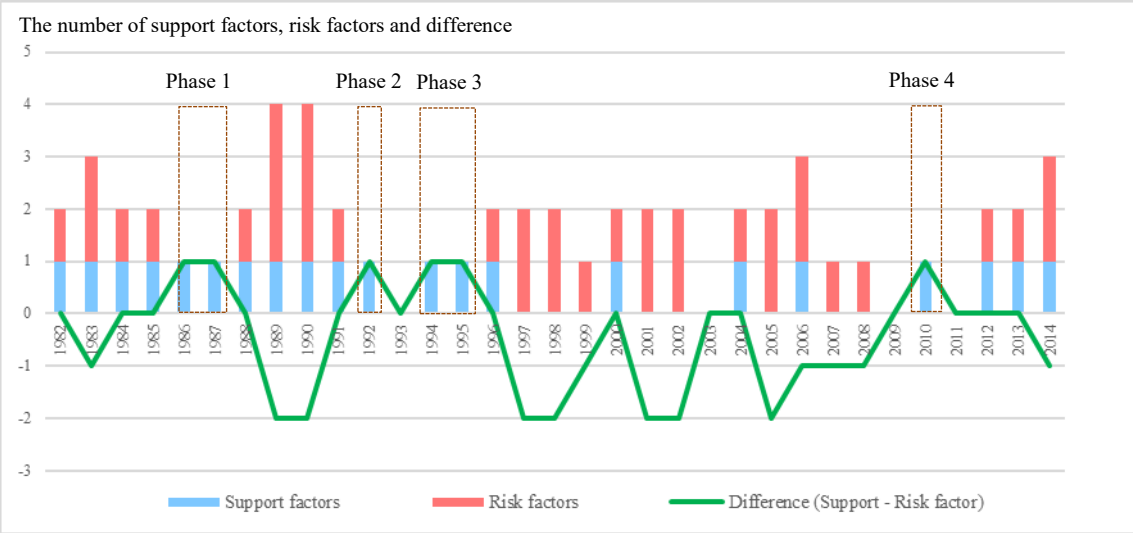


Figure 6.2 The effective phase in macroeconomic viewpoint in Fukushima prefecture

Remark: Support factors consist of investment, import, and export factor and risk factors consist of inflation rate, interest rate, and exchange rate factor

The main finding of this section can be summarized as follow: First (in case of long-term), GPP in Fukushima after the opening of Fukushima Shinkansen station is better than without Fukushima Shinkansen station investment on a small scale, even though the station is a big size and is located on the mainline. Moreover, the impact on macroeconomic has a short-term by Fukushima Shinkansen station and there are four phases (1986-1987, 1992, 1994-1995, and 2010) that have a stronger impact on the Shinkansen station more than other external factors. Each phase has an investment factor as a support factor and has inflation rate, interest rate, and exchange rate factor as a risk factor, except in 1996 takes a risk factor only inflation

rate and exchange rate factor. Second (in the case of short-term), the economy has weak productivity performance in some duration because it receives too risky to endure such as oil crisis, economic bubble, inflation rate. Nevertheless, the results of the study are the base case due to the limitations of data access.

6.3.2 Evaluation of wider economic benefit and economic development

The development of HSR is a megaproject investment that delivered fast and efficient transportation; therefore, passengers can save the vehicle operation, travel time, energy consumption, and environment (Ministry of Transport, 2016). HSR also completes with aircraft with a distance between 150-800 km (Gleave, 2004). Furthermore, it stimulates the revitalization of cities/prefectures by encouraging high density and mixed-use around the high-speed rail station with optimal catchment area. Nonetheless, it does not instantaneously grow up to change/development, to support economic activity/development based on wider economic benefit in terms of agglomeration economy along the corridor (Graham, 2007; Venables, 2016; Department of Transport, 2018).

Nowadays, none of the organizations, institutes, and authors declares the official wider economic and economic development indicators. The researcher attempts to accumulate the related parameters at the impact of transport improvements based on a viewpoint of productivity, investment and land use, and labor market. However, in this section, we have limitations in data access because some old data are not stored in the database of the Japanese government website and others. In this case, we also contact the international affairs division, Fukushima prefectural government, but did not receive the support information anything.

1. Wider economic benefit

A result, as shown in Table 6.2, it indicates that after operational Fukushima Shinkansen station is reflected in only five effective factors (GPP, elementary school, high school, employee (full time), and unemployment), as well as there are seven phases, in which is an increase of effective phase in compound annual growth rate (CAGR) of wider economic benefit factors. Therefore, we determine ways to approach their factors based on the demography and labor market, whereas they are basic to comprehend how to business growth in the prefecture. Their factors are vital keys to drive the urban growth and urban development to change in each situation as follow:

- **Demography**

Fukushima prefecture has a low CAGR of the population (0.61 percent per year) during 1975-1981 because it is a trend to decrease the number of births and immigration, but the number of deaths and the number of old people increase. In other words, the number of people (0-4 years old) tends to decline (or CAGR of population slow down (-0.79 percent per year)) and the number of people (55 years old or older) trends to increase (or CAGR of population grow up (3.34 percent per year)) that directly affect the number of deaths. Besides, the number of immigration (move-in) and the number of immigration (move out) are still low level due to the dropping number of unemployed persons and increasing the number of hires at the same time. Afterward, the Tohoku Shinkansen line (including Fukushima Shinkansen station) operates in 1982, CAGR of the population is dropped by 0.21 percent per year from 1982-2015. Because the first reason is a decline in births rate and immigration (move-in), but the number of death and number of old persons is the trend to increase, the second reason is the economic bubble impact and government policy such as zero interest rate that influences the business sector and academy sector (excluding university), the third reason is an increase

in the number of natural disasters and property value (residential) and the last reason is low level in life expectancy and slightly grow the number of outpatients. That issues reflect on (1) the business sector such as a hotel (ryokan), industry and hospital and (2) academy sector (excluding university) to close down or temporary closing and (3) it brings about to generation gap despite the fact Japanese's government endeavors to urge a system to help finance giving birth policy.

- **Labor market**

In the past, Japan (Fukushima prefecture) has suffered a recession and deflation which honestly influence the labor market such as employee, employment, and production value. That is to say, the CAGR of the population among working-age (25-54 years old) is a downward trend due to the outcome of the number of the birth issue since 1978. That reason, the companies try to recruit and hire employees with two types which consist of (1) residents in other prefecture and (2) part-time jobs as well as replace humans with robots in some parts over the period so that business sector proceeds to efficiency.

When the Fukushima Shinkansen station is closely operated in 1982, the number of employees (full time), retail and wholesale are increased to support the economic activity and economic growth; however, after the initial phase economic activity and economic growth gradually decelerate. Because the prefecture does not have a strong policy/strategy to regulate the proper demand side and supply side for sustainability as well as prepare and protect the risk management for external factors such as technology and natural disaster. Meanwhile, in case of long-term, CAGR of the business sector, academic sector (exclude university), the number of employed persons and part-time job are diminution when compare with before operational Fukushima Shinkansen station owning to (1) a low level of investment stimulation, (2) a slight fall of the number of population, (3) recessionary gap, (4) a growing up with technology and innovation and (5) several natural disasters. On the other hand, the CAGR of the number of employment and unemployed persons grows up to enhance economic and social development in the prefecture.

Table 6.2 Change in the economic situation

Indicators	CAGR of indicators* (%)		Percent Change (%)
	Before 1982	After 1982	
Productivity			
GPP	1.47	1.48	0.68
Investment and land use			
▪ Apartment	NA	3.88	-
▪ Hotel (Ryokan)	0.90	-1.19	-232.22
▪ House	NA	0.01	-
▪ Elementary school	-1.27	-0.97	23.62
▪ High school	-0.86	-0.03	96.51
▪ University	0	2.92	-
▪ Industry	NA	-2.11	-
▪ Retail	1.08	-1.70	-257.41
▪ Wholesale	1.64	-0.29	-117.68
▪ Hospital	1.95	-0.60	-130.77
▪ General clinic	1.15	0.40	-65.22
▪ Dental clinic	2.75	1.53	-44.36
▪ Property price (residential)	NA	0.45	-
▪ Property price (commercial)	NA	-1.27	-
▪ Tourist (stay overnights)	NA	2.39	-
▪ Tourist (do not stay overnights)	NA	6.98	-

Indicators	CAGR of indicators* (%)		Percent Change (%)
	Before 1982	After 1982	
Labor market			
▪ Population	0.61	-0.22	-136.07
▪ Employee	0.90	-0.30	-133.33
▪ Employment (full time)	0.28	1.04	271.43
▪ Employment (part time)	17.97	12.96	-27.88
▪ Unemployment	2.30	2.89	25.65
▪ Minimum wage system	NA	1.88	-
▪ Product value**	NA	-0.43	-

Remark: *Fukushima Shinkansen station has operated since 1982

**production value does not only include physical production (agriculture and manufacturing) but also service production (commerce, financial insurance, and public affairs)

The main finding of this section can be summarized as follows: First, the distribution of Fukushima prefecture demonstrates a clustering spatial distribution. The main causes of shrinking the Fukushima prefecture urban include depletion of production value, a decline of the population, and an employee. Second, based on the CAGR of wider economic benefit indicators before-after operational Fukushima Shinkansen station, there are five effective factors which are GPP, elementary school, high school, employee (full time), and unemployment. Third, the opening of the Fukushima Shinkansen station can mightily accelerate the total wider economy in terms of investment, land use, and the labor market in a few spans (1976-1980, 1982-1983, 1987, 1993, 1995, 1998, and 2003). In other words, the CAGR method proves that the operational Fukushima Shinkansen station has caused a significant negative impact on the Fukushima prefecture encountering population and production value decline.

2. Economic development

The advancement and modernization of transportation systems are joined together with whole economic development. Transportation development is a necessity to improve in the sector of economic, social, and policy of people. In this section, we do not attempt to demonstrate the detail in deep economic analysis, but the purpose is to acquaint the important facts and role of the transportation and economic development process. We focus on the link between transportation and economic development at a macro level because the micro-level is related costs and benefits of individual transportation projects.

We compile the related economic development factor and Human Development Index (HDI) is an optimal measurement because it is a measure of development using an index that includes three main dimensions (life expectancy at birth, knowledge, and education, and standard of living)[(5)]. HDI in Fukushima prefecture is 0.89 in 1990 that ranks in the middle prefecture in Japan (27 out of 47 prefectures) and increases 0.90 and 0.92 in 1995 and 2000, respectively. As a result, HDI in Fukushima prefecture is risen 0.33 percent from 1990 to 2000, whereas the first factor is an increase of life expectancy (longevity) by 0.35 per year and the

[(5)] This method is used by the United Nations Development Program until 2010. HDI combines three dimensions which are (1) life expectancy at birth, as an index of population health and longevity, (2) knowledge and education, as measured by the adult literacy rate (with two-thirds weighting) and the combined primary, secondary, and tertiary gross enrollment ratio (with one-third weighting) and (3) standard of living, as indicated by the natural logarithm of gross domestic product per capita at purchasing power parity. Moreover, an index of 0–0.49 means low development, an index of 0.5–0.69 means medium development, an index of 0.7–0.79 means high development and above 0.8 means very high development.

second factor is the growth of GPP (standard of living) by 0.81 per year. These facts lead us to assume that economic development in Fukushima prefecture is very high, even though the number of outpatients has significantly undergone a rapid change (1.73 percent per year).

6.4 Conclusion

Shinkansen is the most visible from modern technology and environmentally friendly based on the economy. Likewise, it is not only a complex construction but also a difficult calculation for economic benefits. In Japan, the objective of Shinkansen investment is to reduce the travel time between two cities and increase opportunities in the transportation mode and promote mobility demand in the pathway. However, investment in Shinkansen projects cannot instantly change and develop economic effects after operation. In this paper, the authors endeavor to garner the economic-related parameter based on a viewpoint of macroeconomic, wider economic benefit (productivity, investment, and land use and the labor market) and economic development indicators, as well as we consider two hypotheses to accomplish the objectives as below:

H_1 (operational Fukushima Shinkansen station will impel the economy in Fukushima prefecture based on aggregate demand angle): First (in case of long-term), macroeconomic in Fukushima after the opening of Fukushima Shinkansen station outperforms a previous without Fukushima Shinkansen station investment on a small scale, even though the station is a big size and locates on the mainline. Moreover, there are four phases (1986-1987, 1992, 1994-1995, and 2010) that have a stronger impact on the Shinkansen station more than other external factors, as well as their phases have investment factor as a support factor and have inflation rate, interest rate, and exchange rate factor as a risk factor, except in 1996 takes a risk factor only inflation rate and exchange rate factor. Second (in the case of short-term), the economy has weak productivity performance in some duration because it receives too risky to endure such as oil crisis, economic bubble, and inflation rate. Hence, we recommend implementing policies to regulate transportation demand are a considerable tool for economic activity and social welfare.

H_2 (Fukushima Shinkansen station investment effects to which factors in wider economic benefit and economic development):

Case 1 (wider economic benefit): First, the distribution of Fukushima prefecture demonstrates a cluster of spatial distribution. Shrinking urban in Fukushima prefecture includes depletion of production value, a decline of the population, and an employee. Second, based on the compound annual growth rate of wider economic benefit, there are five effective factors (GPP, elementary school, high school, employee (full time), and unemployment) that have a higher performance than without the development of Fukushima Shinkansen station. Third, the opening of the Fukushima Shinkansen station can mightily accelerate the total wider economy in terms of investment, land use, and the labor market in a few spans (1976-1980, 1982-1983, 1987, 1993, 1995, 1998, and 2003). In other words, the compound annual growth rate method proves that the operational Fukushima Shinkansen station has caused a significant negative impact on the Fukushima prefecture encountering population and production value decline.

Therefore, based on the understanding of the potential negative effects of the opening of the Fukushima Shinkansen station on shrinking the Fukushima prefecture, the local government should make suitable strategies and plans, as well as test the post-evaluation with the negative factors. Besides, in the case of the planner perspective, we suggest that the planners should have to consider the underlying factors (population) before developing

urbanization to use consistent with existing resources and challenge the right direction (Johnson, 1999; Peterson, 2017) and land use allocation could depend on the relationship between geographical land-use types and principles of development in surrounding areas. However, the outcome of wider economic benefit in the Fukushima prefecture is the maximum value to receive since it induces the economic impacts of other factors.

Case 2 (economic development): the development of the Fukushima Shinkansen station is not only generative economic growth but also originates economic development in Fukushima prefecture. Because after the opening of the Fukushima Shinkansen station during 1990-2000, there has been an upward trend in the human development index of 0.33 percent per year due to support factors (longevity factor and standard of living factor), even though the number of outpatients has significantly undergone a rapid change.

In addition, this research is meaningful in terms of the impacts on the development of Nakhon Ratchasima High-Speed Rail station in Nakhon Ratchasima prefecture, Thailand. In other words, related agencies such as the Ministry of Interior, local government in Nakhon Ratchasima prefecture, and private sectors in the project area could prepare the initial plan that focuses on the development of the area around the high-speed rail station and prefecture area. As well as set the conditions for determining the area utilization plan in the prefecture. It brings about the urban land use planning and challenge to change travel behavior to the High-Speed Rail system which will urge economic growth and economic development in the future.

A specific limitation of this research is the aged data and database because of whole data based on secondary data. Hence, this paper use as much information as possible to conservative and underestimate the analysis in economic parameters. For further research, we would like to study how to define the High-Speed Rail station area and how to achieve synergy between High-Speed Rail and urban development, whereas it can be appropriate for discussion about development opportunities and various functions around the station.

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CHAPTER 7

A STUDY ON EFFECTIVENESS OF FUKUSHIMA SHINKANSEN STATION

7.1 Introduction

Since Thailand has located a hub of land transportation connectivity among ASEAN countries, China and Thailand have jointly desired to promote the strategic partnership through the memorandum of understanding on the cooperation on Thailand's railways' infrastructure development on the strategic framework for the development of Thailand's transportation infrastructure 2015-2022 (B.E. 2558-2565). HSR development for regional connectivity on Bangkok-Nong Khai (phase 1: Bangkok-Nakhon Ratchasima) is one of the significant implementations in long-term benefits under the strategic framework. The project will be done on a government to government basis.

The HSR project was approved by the Prayut cabinet in July 2017 and was expected to operate in 2024. There have had two main reasons why Thailand decided to invest in HSR development. The first reason has supported the strategy of development of the international railway network and the second reason has boosted the regional economic development along the corridor. It has brought about mobility choice, regional economic growth, and environmental benefits.

Nevertheless, a feasibility study of the HSR project was not feasible. Because the direct economic return was 8.56% and financial return could not evaluate, therefore, they had lower than the benchmark in economics (12%) and finance (5%) based on the office of the National Economic and Social Development Council (NESDC) criteria. In other words, Thailand's government has been facing how to drive it to sustainability in the long term.

Likewise, a feasibility study has recommended that if the government will have utilized the land development surrounding the HSR stations (or TOD), an economic return would have increased from 8.56% to 11.68% and it has approached a criterion. For this reason, TOD has become one of the alternative strategies to boost economic value, but Thailand's government has not had the practical know-how and experience in how to make it happen around the public transport stations. Meanwhile, Thailand has faced a limitation of land development surrounding the transport station, such as the Town Planning Act, BE 2518 (1975), the Constitution of the Kingdom of Thailand, BE 2560 (2017), and Expropriation and Acquisition with Immovable Property Act, BE 2562 (2019).

Regarding the TOD issues in Thailand, they have mainly concerned with what kind of a policy framework and regulation for a TOD?, what are the characteristics of TOD?, and what is the role of weather, built-environment, and geographical characteristics in influencing users?. Additionally, the previous studies have clearly shown the potential TOD and the station catchment area for transit service, for example, land-use change, economic benefits, and environmental benefits.

Meanwhile, the previous investigations have lacked a size of the HSR/Shinkansen station catchment areas when it was opened. Hence, our study has attempted to consider the size of the Shinkansen station catchment area in Japan to identify the radius of the Shinkansen station catchment area and recommendation on how to apply and develop on Nakhon Ratchasima HSR station based on the lesson learned from the Fukushima Shinkansen station.

The objectives of this research have consisted of twofold: (1) to evaluate the Fukushima Shinkansen station catchment area when Fukushima Shinkansen station was operated based on dense network and land value angle and (2) to compare the Fukushima Shinkansen station catchment area with the prior HSR/Shinkansen station catchment areas. The hypotheses have comprised of (1) what is relevant with the Fukushima Shinkansen station catchment areas based on dense network and land value perspective? and (2) factors that contribute to the Fukushima Shinkansen station catchment area.

7.2 Methodology and data approach

7.2.1 Lessons learned from the existing researches

The valuable lesson learned is how to evaluate the size of the HSR/Shinkansen station catchment areas. It is the key point for transport planners, urban planners (or operators), and architects to maximize the benefits as far as possible.

The previous investigations justify the HSR/Shinkansen station catchment areas in diverse areas by using a dense network approach from the feeder systems (Murakami and Cervero, 2012; Zhong et al., 2014). Nevertheless, the results imply that they looked perhaps rough and did not determine the accurate radius. Their empirical studies also did not consider the exact HSR/Shinkansen station catchment area when the HSR/Shinkansen station was operated or the original HSR/Shinkansen station catchment area before an operation. This is why it will face the loss of opportunities cost for the cities.

Then we endeavor to concentrate on the original HSR/Shinkansen station catchment area, but it is difficult to judge when it happened. In addition, we have a limitation of information to find historical data. For these reasons, our scope is to evaluate the HSR/Shinkansen station catchment area when it was operated by using the dense network approach. On the other hand, this analysis examines the parameter that had the consistency of transport and land-use theory and had to cover long-term panel data; hence, the land value parameter is an alternative indicator to measure the station catchment area as well. At least, our article looks more accurate than prior studies by utilizing one decimal place of circle surface.

7.2.2 Research methodology

The analysis is done by following the process depicted in Figure 7.1. To begin, this study has identified the definition of the station catchment area for HSR/Shinkansen station. The representative HSR station in Thailand has then assessed the importance of HSR stations in terms of potential and necessity of development.

Following this, we collate the representative HSR station from Thailand with the candidate for Shinkansen stations in Japan by utilizing station type, station size, distance, and travel time as criteria whereas Japan is a famous and well-known TOD for its excellent mobility and sustainability. An international comparison is important for the HSR station catchment area in Thailand, where became the first developing country to invest and require to achieve sustainable development in the future.

After that, for grasping what range is required to be developed about land-use under the premise of the access by dense network and land value. Therefore, we utilize ArcGIS software version 10.6.1 as a tool to overcome the station catchment area by addressing the city center (Fukushima Shinkansen station) and boundary (Fukushima city).

Since our focus concentrates on the inter-city railway station, we consider the reasonable HSR/Shinkansen station catchment area that fell in the radius range 5-25 km, depending on the feeder systems20, 23). For these reasons, we draw a circle shape with a specified radius (0.1-25.0 km) surrounding Fukushima Shinkansen station. In addition, we insert four railway networks (Abukuma express line, Tohoku mainline, Iizaka line, and Ou mainline) that linked the Fukushima Shinkansen station in 1982, including land value.

In the final stage, the first method based on a dense network and the second method based on land value is proposed and applied for evaluation of the Shinkansen station catchment area at the accessible range around Fukushima Shinkansen station in Fukushima city.

Nevertheless, In the case of the land value perspective, we have a more sensitive process than the dene network perspective. That is to say, after drawing a circle shape, we have to merge the current and prior circle shape and then add the land value data (1983-1999), but we face the incompleteness of the (data on) the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) website in 1982 (the opening of Fukushima Shinkansen station). Thus, the compound annual growth rate (CAGR) method is our alternative way to solve this point. After that, we select the summary statistics function in Arctoolbox for calculation.

Finally, we examine the involved size of the Fukushima Shinkansen station catchment areas from two points of view and collate them with the existing studies. In the meantime, our consider factor affecting the land value in each factor (population growth and economic growth (industry)) during 1975-1986 based on the basic survey of city planning in Fukushima city.

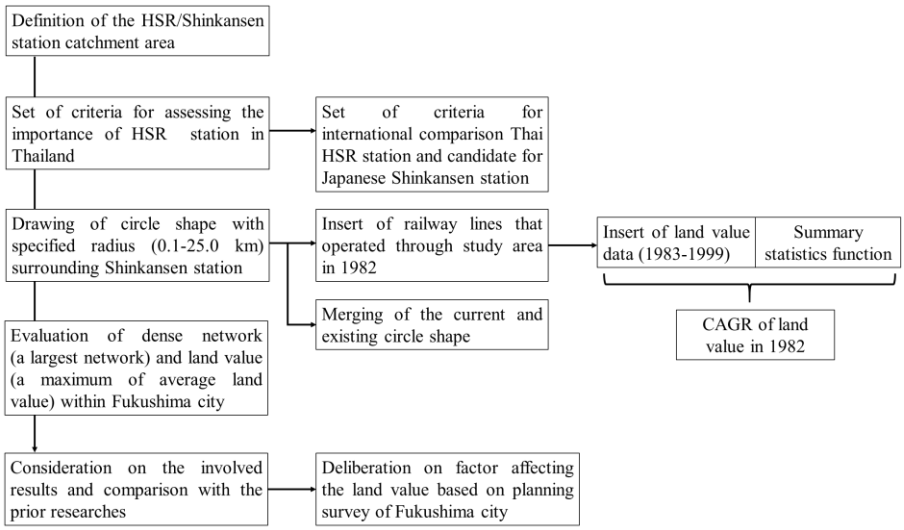

Figure 7.1 Process of analysis

7.2.3 Data sources

As mentioned in the third chapter, Tables 3.1, 3.2, and 3.4 are important to recognize and essential to set the criteria and study an international comparison. The data are received from several sources such as NESDC, SRT, and OTP.

The precise locations of Fukushima Shinkansen station and other railway stations in Fukushima prefecture are obtained from the GIS shapefile provided by e-stat and MLIT

website. GIS shapefiles for these stations are produced by using online satellite imagery techniques (Monkkonen, 2008).

This analysis does not attempt to estimate the land value change in Fukushima prefecture whether public policies may be able to harness and leverage these trends to induce greater land value benefits. For these reasons, we use the actual data extracted from the MLIT website during 1983-2019, but we have limitations of data access, namely public investment in infrastructure, change in land-use regulation, and landowner's investment to test the factor affecting land value. Thus, we consider population and economic growth that received from the basic survey of city planning in Fukushima city, Fukushima city hall.

7.3 Results

7.3.1 Station catchment area

1. The size of the Fukushima Shinkansen station catchment area

Fukushima shinkansen station was imaged and connected Ou main line, Iizaka line, and Abukuma express line in 1982. A dense network was 12.4 km from the city center based on Ou main line because of the largest network and primary feeder services within the boundary of the city. However, the travel distance depended on the feeder systems in different geographies. Therefore, we believed 12.4 km was a more reasonable radius for the Fukushima shinkansen station catchment area as illustrated in Figure. 7.2.

The Fukushima shinkansen station catchment area was simultaneously analyzed by using ArcGIS software with a maximum of average land value perspective during 1983-2019. CAGR method was selected to overcome an absence of historical data in the case of the first year of operation. Table 7.1 shows the relationship between the station catchment area of Fukushima shinkansen station and land value from 1982 to 1991. Fukushima shinkansen station catchment area was constant over time (17.6 km), but a maximum of average land value fluctuated between 162 and 165 Japanese yen/m2. One reason might be the number of buildings declines in 1986.

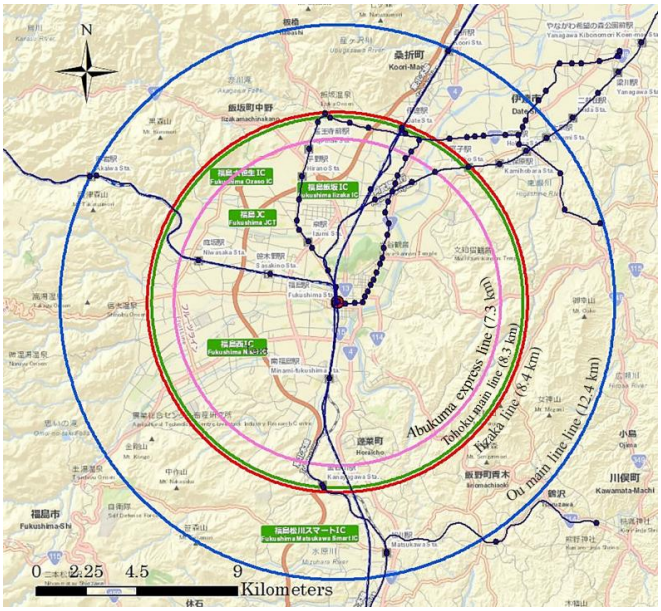

Figure 7.2 Fukushima Shinkansen Station catchment area in different feeder systems in 1982

Table 7.1 Relationship between Fukushima shinkansen station catchment area (km) and a maximum of average land value (JPY/m^2)

Year	Building (unit)	Fukushima shinkansen station catchment area (km)	A maximum of average land value (JPY/m^2)
1982	NA	17.6	165
1983	70	17.6	165
1984	70	17.6	165
1985	70	17.6	165
1986	68	17.6	162
1987	68	17.6	162
1988	68	17.6	162
1989	68	17.6	162
1990	68	17.6	162
1991	68	17.6	162

From the above, the results illustrated that a radius of 12.4 km of the Fukushima shinkansen station catchment area captured a partial area of a radius of 17.6 km of the Fukushima shinkansen station catchment area in 1982 (or 70.45%). These data appeared to suggest that the Fukushima shinkansen station had two layers of the station catchment area. In other words, the first area was the inner catchment area were had a dense network (12.4 km), while the second area was the outer catchment area were had an impact from the inner catchment area (17.6 km) as can be seen in Figure 7.3.

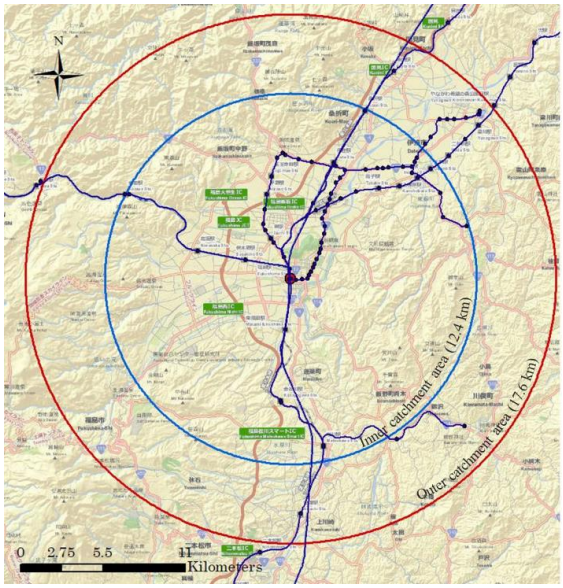

Figure 7.3 Inner and outer catchment area of Fukushima Shinkansen station in 1982

2. Comparison of the prior HSR/Shinkansen station catchment areas

Table 7.2 shows the comparison of inner catchment areas among HSR hubs and HSR/shinkansen lines. The results showed that a radius of 12.4 km of the Fukushima shinkansen station was denser than a radius of 25 km of Californian cities (San Francisco Bay Area and Los Angeles), but less dense than a radius of 10 km of Spanish cities (Barcelona and Madrid) and a radius of 5 km of 17 cities of Tokaido shinkansen line, Northeast Corridor, and California HSR.

Table 7.2 Comparison of inner catchment areas

Station/ HSR line	Catchment area(km)	Population (million persons)	Area (km^2)	Population density (persons/km^2)
Barcelona	10.0	4.96	7,733	641.4
Madrid	10.0	6.45	8,030	803.2
San Francisco Bay Area	25.0	6.17	13,527	456.2
Los Angeles	25.0	17.30	30,783	562.0
Fukushima	12.4	0.29*	768	377.6
Tokaido Shinkansen line	5.0	NA	NA	NA
Northeast Corridor	5.0	NA	NA	NA
California HSR	5.0	NA	NA	NA

Note: *using the growth rate of population during 1975-1980

One of the main reasons was Fukushima city had the limitation of land to development and brought about population density based on the survey of city planning in Fukushima city in 1982. It had less area to develop urbanization (46.56 km2). This area consisted of residential areas (32.72 km2), commercial areas (4.12 km2), and industrial areas (9.72 km2). In contrast, there were 181.44 km2 of an area where could not develop to urbanization, whereas it was covered with forests, mountains, and agricultures (see Figure 7.4).

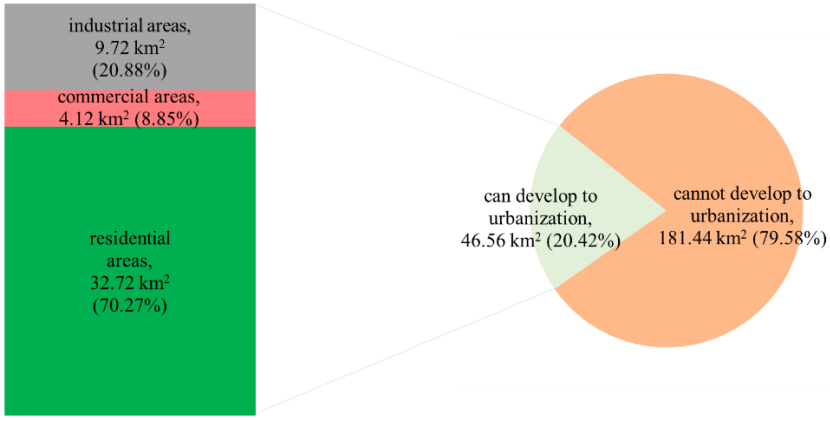

Figure 7.4 Ratio of land use where can and cannot develop to urbanization

3. Effects of land-use and characteristics

The residential areas were the most preferred development as 53.85 % of the ratio of land-use between 1980 and 1985 in Fig. 4. The mixture of residential and commercial areas accounted for 15.90% and was the second-ranking. At the same time, this research took into account the area surrounding Fukushima shinkansen station by a site visit. The result clearly illustrated that a radius of 6-8 km from the Fukushima shinkansen station was consistent with the past. Most of them are residential areas (hotels, apartments, and houses), but the commercial areas (plazas, convenience stores, and supermarkets) are quite a few.

Likewise, this research took into account around Fukushima shinkansen station and other shinkansen stations, e.g., Hakata shinkansen station, Nagoya shinkansen station, and

Yokohama shinkansen station. These results appeared to contradict the above view that mainly established for commercial use, for instance, the local commercial street around station, plazas, and offices. The results perhaps led to alternative urban economic scenarios as well as urban structure formulation in each city.

However, land use surrounding the Fukushima shinkansen station was developed by using phasing investment. This issue possibly led to a limitation of the circle surface method because it could not take the geographical area surrounding the Fukushima shinkansen station into account for reality.

7.3.2 Factor affecting land value and their attribution

1. Population

As Japanese housing and land survey from the Ministry of Internal Affairs and Communications during 1998-2003, the results indicated that the acquisition of land and housing was among people age 15-64 years old. Meanwhile, the largest number of populations in Fukushima city by age group was consistent with the above results (or 67.79% per year) during 1975-1985 as illustrated in Figure 7.5.

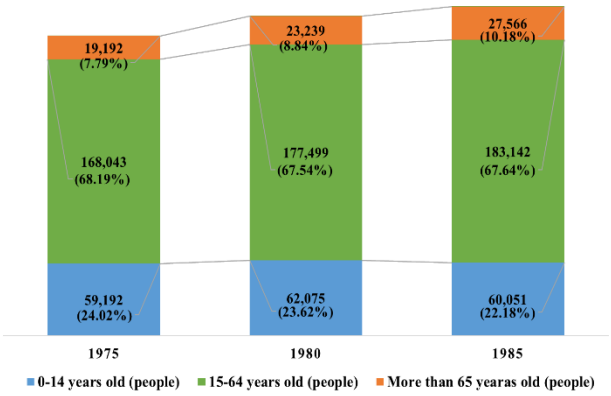

Figure 7.5 Population by age group

Next, the researcher examines the population pyramid from 1975 to 1985 by 5-years age group. The children's generation is gradually declining, but the elderly population is moderately grown. Therefore, it is possible to read the direction of the transition from 1975 by age group. The results presented in Figure 7.7 display that the number of children decreased by 0.76% per year. In the case of the working-age population, it slightly grows thanks to a second baby boom since the 1970s.

Furthermore, we collate the CAGR of the population during 1975-1985 with the land value from 1982 to 1985 (see Table 7.3). The results indicate that the CAGR of population and CAGR of land value is a parallel way (positive value). Hence, we believe that the population factor could affect the land value in the initial phase (1982-1985). Because the population is a demand for land and influences the change in land use. In other words, an increase in demand for land use leads to an increase in rent or buy or sell (Alonso, 1964; Suzuki et al., 2015).

Table 7.3 Population (people) and land value (JPY/m^2)

Year	Population(people)	Land value (JPY/m^2)
1975	246,427	NA
1980	262,812	NA
1982	NA	162.93
1983	NA	165.16
1984	NA	165.16
1985	270,759	165.14
CAGR (%)	0.97	0.45

2. Economics

The population was changed in Fukushima city during 1975-1985 because of a decline in birth rate, an increase of the elderly population, and productivity improvement, including technological innovation as a key for the Japanese economy. However, it was difficult to elucidate the main factors for economic growth.

Regarding the empirical studies, the development of HSR/Shinkansen projects generates a significant impact on urban service industry agglomeration with fast flows of factor resources (Murakami and Cervero, 2012; Zhong et al., 2014). Besides, Japan's industry structure (such as Fukushima city) shifted industrial structure from heavy industry to tertiary industry after World War II owing to a change in social structure issues as illustrated in Table 7.4.

Table 7.4 Number of employees (thousand people)

Year	Primary industry* (thousand people)	Secondary industry** (thousand people)	Tertiary industry*** (thousand people)
1975	285	35,484	65,563
Ratio (%)	0.28	35.02	64.70
1978	522	35,888	73,181
Ratio (%)	0.48	32.75	66.78
1981	557	37,730	86,757
Ratio (%)	0.45	30.17	69.38
1986	479	38,789	92,919
Ratio (%)	0.36	29.34	70.29
Average	460.75	36,972.75	79,605.00
CAGR (%)	9.05	0.88	3.83

Note: *Primary industry: agriculture, forestry, and fishing

**Secondary industry: mining, manufacturing, and construction

***Tertiary industry: wholesale and retail trade, transport and postal services, accommodation and food service activities, information and communications, finance and insurance, real estate, professional, scientific and technical activities, public administration, education, human health, and social work activities, and other service activities

The primary industry was involved in the collection of resources in nature. The secondary industry was related to processing the collected resources. The tertiary sector was concerned with providing services other than the aforementioned activities. Therefore, we conformed to the empirical researches that the impact looked at coming to the trend in the industrial structure.

According to the number of employees, the tertiary industry was the major industry and had 79,605 thousand people (or 68.02 % per market share). The wholesale and retail trade sector ranked first. It employed 32,735 thousand people per year, following by the service sector and manufacturing sector.

In the meantime, Table 7.5 shows the number of offices by major groupings. A tertiary industry was the main industry and had 10,390.50 houses (or 82.71 % of market share). The service sector and electricity, gas, water supply, and heat supply sector in the tertiary industry were the first rank and second rank because of one of the main industries in Fukushima prefecture. These results presumably led to GPP in Fukushima prefecture. It was clear from a macroeconomic point of view that GPP grew a little from 1.47% in 1975 to 1.50% in 1982 (or 0.30% per year).

Table 7.5 Number of offices (houses)

Year	Primary industry (houses)	Secondary industry (houses)	Tertiary industry (houses)
1975	34	1,931	9,319
Ratio (%)	0.30	17.11	82.59
1978	38	2,027	9,788
Ratio (%)	0.32	17.10	82.58
1981	58	2,217	10,896
Ratio (%)	0.44	16.83	82.73
1986	43	2342	11,559
Ratio (%)	0.31	16.80	82.90
Average	43.25	2,129.25	10,390.50
CAGR (%)	5.43	1.97	2.22

Table 7.6 shows the CAGR of the number of offices (houses) and land value during 1975-1986. The results indicated that the CAGR of the number of primary industries, secondary industry, and tertiary industry and CAGR of land value was a parallel way (positive value). Hence, the number of offices factor could affect the land value in the initial phase (1982-1986). Because the development of HSR/shinkansen resulted in a change in accessibility for industries and residential catchment areas as well as a reduced generalized cost. In addition, land value resulted from changes in accessibility that drove the value uplift from transport investment and created the opportunity for enhanced economic activities (Alonso, 1964; Suzuki et al., 2015).

Table 7.6 Number of offices (houses) and land value (JPY/m^2)

Year	Primary industry (houses)	Secondary industry (houses)	Tertiary industry (houses)	Land value (JPY/m^2)
1975	34	1,931	9,319	NA
1978	38	2,027	9,788	NA
1981	58	2,217	10,896	NA
1982	NA	NA	NA	162.93
1983	NA	NA	NA	165.16
1984	NA	NA	NA	165.16
1985	NA	NA	NA	165.14
1986	43	2,342	11,559	165.15
CAGR(%)	5.43	1.97	2.22	0.34

7.4 Conclusion

HSR investment in Thailand is not feasible, but when it utilizes land development surrounding HSR hubs, the economic benefits increase and fit the benchmark. However, the Thai government does not have the practical know-how and experience in how to make it happen. This research determines to study from the lesson learned from Japan, whereas it is the best land development for sustainability.

This research uses the international comparison between a representative HSR station in Thailand and the candidate for Japanese shinkansen stations by using the criteria. Then we highlight how to evaluate the Fukushima shinkansen station catchment area based on dense network and land value approach. Because station catchment area is a vital factor to balance demand and supply of public transportation systems and relates to the land value and floor area ratio.

The present study endeavors to assess the size of the Fukushima shinkansen station catchment area when it was operated in 1982. As a case study, we draw a tentative outlook of the station catchment area surrounding Fukushima shinkansen station in terms of railway routes and land value by using ArcGIS software. In the meantime, drawing of circle surface on the ArcGIS map is a fairly good way for examining the inter-city railway, but it does not take the geography into account when the area developed at a different time as well as we cannot grasp the natural obstacle within the station catchment area.

Regarding the result, the radius of the Fukushima shinkansen station catchment area is 12.4 and 17.6 km based on dense network and land value approach, respectively. On the whole, the Fukushima shinkansen station has two layers of station catchment areas which consisted of the inner catchment area were had a large network (12.4 km) and primary feeder service within the Fukushima city boundary and the outer catchment area were had an impact from the inner catchment area (17.6 km). Since Fukushima city has a limitation of land to develop for urbanization, station catchment area beats only California cities. The specific result from the case study may not provide all factors affecting land value that influenced change in land value because of lack of sufficient data, namely public investment in infrastructure, change in land-use regulation, and landowner's investment. For these reasons, we consider only the population and economic factors. The population, primary industry, secondary industry, and tertiary factor are a significant impact on land value from a macro point of view.

These results bring about some interesting directions for future research. Further study is hence needed to determine the multi-dimensional factors affecting travelers to access the Nakhon Ratchasima HSR hub within the station catchment area. The research outcomes, we expect to grasp the needs and design the fundamental facilities about TOD to increase people's mobility and accessibility.

This study may be useful for developing countries to analyze the station catchment area and developing an appropriate policy relating to the improvement catchment area on HSR/shinkansen stations to make the catchment area more attractive, beneficial, and sustainable as well as consider the feeder systems and level of service for the travelers in the

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CHAPTER 8

DETERMINANTS OF PRIMARY AND SECONDARY ACCESS MODE CHOICES TO HIGH-SPEED RAIL HUB

8.1 Introduction

The connectivity between the origins of the journey and a high-speed railway (HSR) station plays an important role in the access/egress mode choice of transport (Oh et al., 2015; Yin et al., 2015). With the HSR project connecting Thailand's capital Bangkok to Nakhon Ratchasima province currently underway, it thus makes operational and economic sense to adopt and implement the access/egress modes of transport (i.e., the first and last mile of HSR travel) that correspond to the needs of HSR commuters (Tissayakorn et al., 2019a). The northeastern province of Nakhon Ratchasima (NKR) is the land transportation hub and serves the gateway to other northeastern provinces (NESDC, 2017a).

In transit-oriented development (TOD), the goal is to maximize the amount of residential, business, and leisure space within walking distance of public transport. In passenger rail transport, TOD aims to encourage train passengers to switch from private vehicle use to public transport by ways of modernizing the catchment area surrounding railway stations and improving the connectivity between the origins of the journey and the railway stations (Calthorpe 1993; Cervero et al., 2004; Dittmar and Ohland, 2004). According to Oh et al. (2015); Yin et al. (2015), mass-transit feeder services should be adopted as modes of transport to access and egress the HSR station for cities or municipalities with large catchment areas.

Previous research on the first- and last-mile connectivity focused primarily on the mode of transport to access and egress the elevated and underground train stations (Stringham, 1982; Krygsman et al., 2004; Givoni and Rietveld, 2007; Brons et al., 2009). There exists very limited research on the mode of transport to access and egress HSR stations or hubs. A study by Yang et al. (2019) focused exclusively on travel time from the origins of the journey to the HSR hubs in China and found that business travelers would choose subway services over other modes of transport to reduce travel time and the private car use was inversely correlated to the number of subway lines.

Ben-Akiva and Lerman (1985); Krygsman et al. (2004) argued that the travel characteristics of access/egress mode of transport should also account for travel distance and travel cost, in addition to travel time from the origin of the journey. However, since the length of travel time is essentially reflected in the travel cost and travel distance, the interdependency is thus highly likely. To control for interdependency between travel cost, travel distance, and length of travel time, this research replaces the length of travel time with timing (peak and off-time hours). In other words, this current research excludes the travel time (from the origin of the journey to the destination) from the analysis. In this research, the destination is the Nakhon Ratchasima HSR hub.

Specifically, this research investigates the influencing factors of primary and secondary feeder services to access the Nakhon Ratchasima HSR hub and willingness to pay for the feeder services. The influencing factors are categorized into three groups: demographics; the purpose of HSR travel and travel characteristics of primary and secondary feeders and private vehicles; and facilities and infrastructure. The influencing factors of access mode choice to the HSR hub are determined by the multinomial logit model and the willingness to pay by the Tobit model.

The pattern modes of transport to access the HSR hub are first examined and the primary and secondary mass-transit feeders are determined. This research assumes that the HSR passengers use the same mode of transport to access and egress the HSR hub. The study area is the catchment area surrounding the city center of the northeastern province of Nakhon Ratchasima. Besides, this research focuses on the main access mode of transport based on the longest distance from the origin of the journey to the HSR hub.

8.2 Study Area, Sample, and Methodology

8.2.1 Study area

The study area is the catchment area surrounding the city center of NKR (red dot) with a radius of 5.18 km (blue circle). The catchment area includes the NKR municipality (shaded color) and parts of neighboring second-tier municipalities, as shown in Figure 8.1. The catchment area covers 84.33 km^2 with a population of 36,532, using ArcGIS version 10.1. The population in the catchment was calculated based on the registered total population of Nakhon Ratchasima province (National Statistical Office (NSO), 2019a). The NKR municipality is the socioeconomic center of the province, so there are a large number of (unregistered) residents from neighboring second-tier municipalities and provinces working and residing in the NKR municipality.

The radius for the catchment area is the distance between the city center and the farthest station or stop of the primary feeder (Murakami and Cervero, 2012; Zhong et al., 2014). In this research, the primary feeder is the LRT. Furthermore, this study focuses on Nakhon Ratchasima HSR hub (purple dot) due to large gross provincial product, municipality size, travel distance from the origin, ridership (number of HSR passengers), vacant land around the hub, and availability of feeder services (Tissayakorn et al., 2019b).

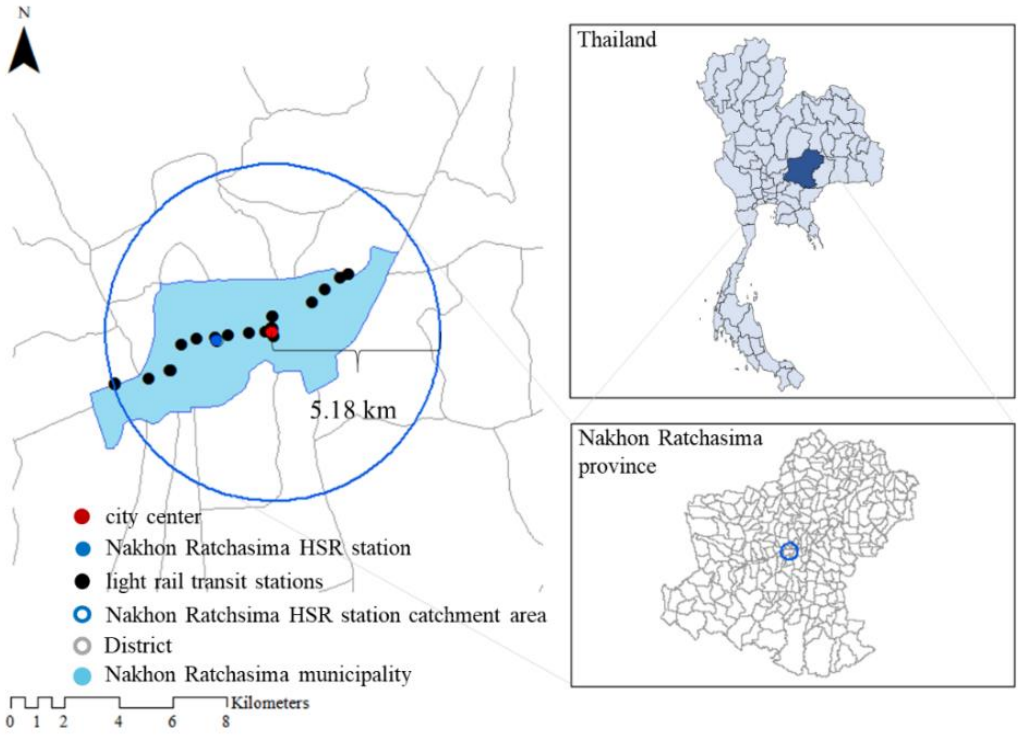

Figure 8.1 The catchment area of Nakhon Ratchasima HSR hub

8.2.2 Sample size

The population in the catchment area of the Nakhon Ratchasima HSR hub was 36,532. The sample size for the survey of access mode choice to the HSR hub was determined by using Krejcie and Morgan formula because of the finite population (Krejcie and Morgan, 1970). The Krejcie and Morgan formula is mathematically expressed in Equation 1.

$$n = \frac{x^2\, NP(1-P)}{e^2\,(N-1)+x^2\,P(1-P)} \tag{18}$$

where n is the sample size, N is the population size, e is the sampling error (0.05), x^2 is the value of chi-square for 1 degree of freedom at the specific confidence level (i.e., 3.841), and P is the population proportion (assumed to be 0.5 for the largest sample size).

The calculated sample size for survey data collection was 377. The locations for data collection included green-line LRT stations with high ridership (OTP, 2016) and civic and economic centers inside the catchment area, e.g., educational institutions, shopping malls, places of worship, hospitals. Figure 8.2 shows the locations (L1 – L20) where the survey data collection was undertaken by in-person interview using a questionnaire (stated preference survey), and 50 – 60 samples were randomly selected from each location. The number of respondents were 1,108 individuals (rather than 377) to avoid missing data. The survey participants had residences inside the catchment area and were of working age or university students because these age groups are prospective customers of the HSR service. The data collection was conducted between the end of February through early March 2020.

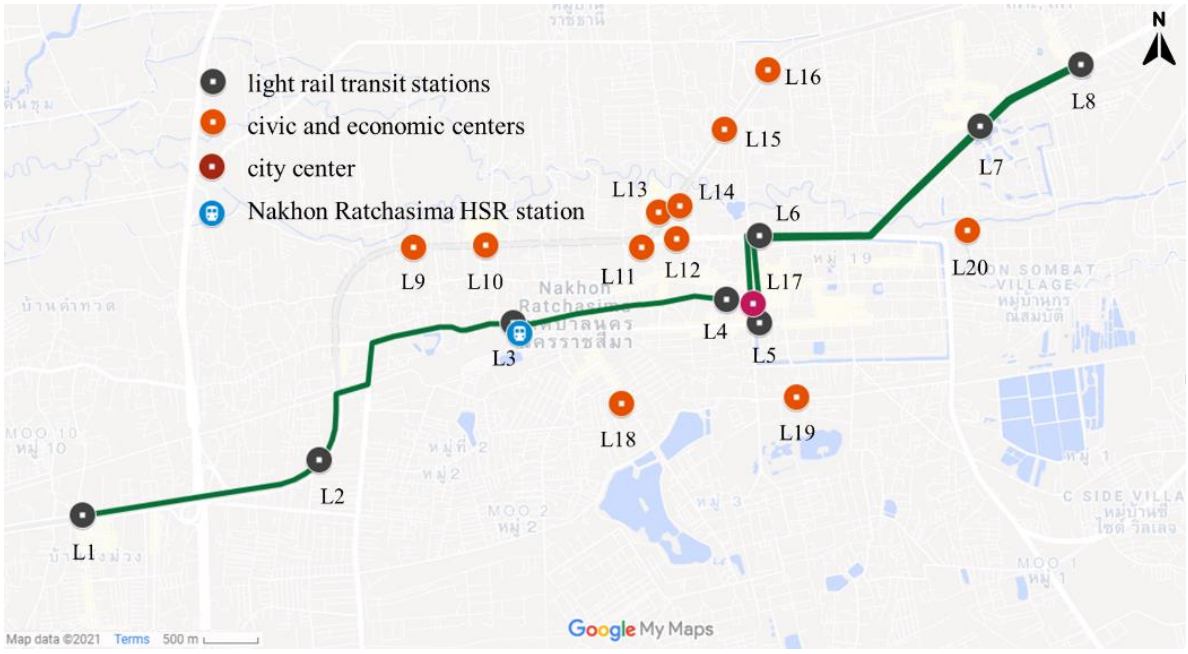

Figure 8.2The locations of survey data collection (L1 - L20)

8.2.3 Questionnaire design

The survey questionnaire consists of three parts: (1) demographics; (2) purpose of HSR travel and travel characteristics of access/egress transport modes; and (3) facilities and infrastructure to access Nakhon Ratchasima HSR hub. The first part of the questionnaire is concerned with the respondents' demographics, including gender, occupation, education,

income, car ownership, and motorcycle ownership. The second part asks the respondents about the mode of transport, fare, travel distance, timing (peak/off-peak) from the origin of the journey to the HSR hub, and the purpose of travel. The responses on travel distance were validated against Google Map.

The third part is comprised of two groupings of questions: (1) the satisfaction levels with the facilities and infrastructure surrounding the HSR hub; and (2) the availability of songthaew shuttle routes and future LRT line near the origin of the journey. In the first grouping, the questions on the levels of satisfaction with facilities and infrastructure surrounding the HSR hub ask about the connectivity and fare integration, walking amenity, and designated parking area (park and ride). The satisfaction-level questions are of 4-point Likert scale, where 1, 2, 3, and 4 denote very dissatisfied, dissatisfied, satisfied, and very satisfied, respectively. In the second grouping, the questions on the songthaew shuttle service and future LRT ask about the availability of songthaew shuttle routes and LRT line within a 500m radius from the origin of the journey (Calthorpe, 1993; Regional Plan Association, 1997; Vuchic, 2005). This research assumes that the HSR passengers use the same mode of transport to access and egress the HSR hub. Prior to data collection, the questionnaire was electronically sent to and validated by a panel of experts in the area of urban and transport planning.

8.3 Conceptual models

8.3.1 Multinomial logit model

Multinomial logit (MNL) is used to determine influencing factors of access mode choice to Nakhon Ratchasima HSR hub via the primary and secondary feeder services. The influencing factors are categorized into three groups: demographics; purpose of HSR travel and travel characteristics of primary and secondary feeders and private vehicles; and facilities and infrastructure. The purposes of travel under study include work and business, leisure, and education, excluding family visit and medical-related travel. As a result, the actual number of respondents used in the MNL model was 793 respondents (out of 1,108 participants), excluding 315 respondents for family visit and medical-related travel. The reason for exclusion is that these two groups of travelers infrequently use the HSR service, in comparison with the three other groups (work and business, leisure, and education).

Private transport (cars and motorcycles) is used as the reference mode of transport in MNL. Private vehicle use is used as the reference because the aim of TOD and this current research is to persuade motorists to switch from private vehicle use to public transport and non-motorized transport (walking and cycling) (Cervero and Sullivan 2010; Bertolini et al., 2012). The MNL model in STATA version 15 is used for analysis. The MNL-based choice modeling is typically used to evaluate consumer preferences in relation to transport alternatives (Feng et al., 2014; Yang et al., 2019).

According to Ben-Akiva and Lerman (1985); Krygsman et al. (2004), the travel characteristics (i.e., travel cost, travel distance, and length of travel time) to access/egress public transport hubs (e.g., railway stations, bus terminals) should be accounted for in the MNL model. Since the length of travel time is essentially reflected in the travel cost and travel distance, the interdependency/multicollinearity is thus highly likely. To control for multicollinearity between travel cost, travel distance, and length of travel time, this research thus replaces the length of travel time with timing (peak and off-time hour). Furthermore, the influencing factors under the three groups of factors (i.e., demographics, travel characteristics, and facilities and infrastructure) were tested for multicollinearity by a variance inflation factor

(VIF). The VIF of the influencing factors are less than 2 %, given that a VIF < 2 % is statistically acceptable (Marquaridt, 1970).

8.3.2 Tobit model

A Tobit model is used to estimate the willingness to pay (WTP) of 793 survey respondents by using the maximum likelihood estimation (MLE) technique (Whitehead, 2003; Whitehead, 2006). In the Tobit analysis, it is assumed that substantial improvements would be made to the facilities and infrastructure surrounding the Nakhon Ratchasima HSR hub. The independent variables in the Tobit model are the demographics in the survey questionnaire. The relationship between WTP and the demographic profile using STATA version 15 can be expressed in Equation 19.

$$WTP = \alpha + \beta_1 \times \text{Gender} + \beta_2 \times \text{Occupation} + \beta_3 \times \text{income} + \beta_4 \times \text{Education} + \beta_5 \times \text{Car ownership} + \beta_6 \times \text{Motorcycle ownership} + \varepsilon_i \quad (19)$$

where *WTP* is the willingness to pay to access Nakhon Ratchasima HSR hub, α is a constant, β_i is the coefficient of the independent variable, and ε_i is an error term.

The expected WTP value can be calculated by Equation 20, where Φ is the standard normal distribution function, $\emptyset$ is the standard normal density function, σ is the standard error of ε_i, Z is the mean of all independent variables, β is the coefficient of the independent variable (Whitehead, 2003).

$$E(WTP) = \phi\left(\frac{z}{\sigma}\beta\right) z\beta + \sigma\emptyset\left(\frac{-z}{\sigma}\beta\right) \quad (20)$$

8.4 Access transport modes to the HSR hub

8.4.1 Choice of access mode in the catchment area

Table 8.1 tabulates the frequency distribution (%) of questionnaire respondents (stated preference survey) by access transport modes to Nakhon Ratchasima HSR hub at 20 survey locations (L1 – L20) in the catchment area. In the table, L1 – L8 are the LRT stations and the rest (L9 – L20) are the civic and economic centers. Once completed in the year 2024, the LRT is the most preferred access mode choice as 32.19 % of the questionnaire respondents on average would select this access transport mode. The main reason given by the respondents is the ability to plan and manage commute time. In addition, certain locations which are the civic and economic centers (L9, L14, L15, and L16) also have large proportions of respondents who prefer the LRT. As a result, this research selects the LRT service as the primary feeder to access the Nakhon Ratchasima HSR hub.

Despite the LRT service, the proportion of private vehicle use on average is still as high as 48.08 %, consisting of 23.64 % and 24.44 % for private cars and private motorcycles, respectively. This could be attributed to the country's accommodative policy on car ownership and subsidized fuel prices. The songthaew shuttle service accounted for 11.76 % (on average) of the survey respondents. The low proportion is attributable to the limited number and frequency of vehicles. The songthaew shuttle service is currently the main public transport in the NKR municipality (without the LRT). Upon the completion of LRT, the songthaew shuttle service would become the secondary feeder of the municipality to access the HSR hub. As a result, the local government has planned to modernize the songthaew shuttle service, including the availability of shuttles, frequency, safety, personnel, and regulations.

Walking as the access mode accounted for 4.43 % (on average) of the survey respondents. The very low percentage is attributable to the country's tropical climate with an average temperature of 35 °C (Thai Meteorological Department, 2020). The other modes of transport consist of tuk-tuk, conventional diesel-run train, bicycle, and taxi service, accounting for 3.54 % (on average).

Table 8.1 Distribution of Questionnaire Respondents
by Modes of Transport to Access Nakhon Ratchasima HSR Hub (%)

Location code*	Location description	Songthaew shuttle	LRT	Walking	Private car	Private motorcycle	Other**
L1	Save One	11.84	67.11	-	11.84	9.21	-
L2	Cherdchai	17.24	41.38	-	10.34	24.14	6.90
L3	Nakhon Ratchasima railway station	-	-	79.55	11.36	9.09	-
L4	Mae Kim Heng	28.95	6.58	3.95	47.37	11.84	1.31
L5	City hall	28.57	17.46	3.17	26.98	23.82	-
L6	Yak papa	5.10	21.43	-	34.69	37.76	1.02
L7	Rajamangala University of Technology	10.71	67.86	-	6.43	13.57	1.43
L8	Ban Nari Sawat	9.38	50.00	-	25.00	15.62	-
L9	Tesco lotus	15.39	61.54	-	7.69	15.38	-
L10	The mall	4.35	47.83	-	17.39	28.26	2.17
L11	Bus terminal 1	7.41	27.78	1.85	18.52	42.59	1.85
L12	IT plaza	-	3.39	-	40.68	55.93	-
L13	Terminal 21	7.69	42.31	-	23.08	26.92	-
L14	Big C	-	52.94	-	11.76	35.3	-
L15	Bus terminal 2	2.99	50.75	-	26.87	16.42	2.97
L16	Makro	10.81	59.46	-	18.92	8.11	2.7
L17	Thao Suranaree monument	56.06	4.55	-	21.21	16.67	1.51
L18	Fort Suranari hospital	10.53	-	-	15.79	73.68	-
L19	Thanon Chira Junction station	1.02	-	-	32.65	17.35	48.98
L20	Sala Loi	7.14	21.43	-	64.29	7.14	-
Average (%)		11.76	32.19	4.43	23.64	24.44	3.54

Note: * The location codes correspond to the survey data locations in Figure 8.2.

** Other includes tuk-tuk, conventional diesel-run train, bicycle, and taxi service.

8.4.2 Choice of access mode in primary and secondary development zones

In this research, the catchment area consists of primary and secondary development zones. The primary development zone covers a radius of 1.90 km from Nakhon Ratchasima HSR hub, which is the maximum acceptable walking distance to the HSR hub (Regional Plan Association 1997; Vuchic 2005). The secondary development zone covers a radius of 5.18 km from the city center, which is the distance between the city center and the farthest station or stop of the primary feeder (Murakami and Cervero, 2012; Zhong et al., 2014). In this research, the primary feeder is the LRT.

Figure 8.3 shows the access mode choices in the primary and second development zones. In the primary development zone, private vehicle use accounts for the largest proportion of the access mode choice to the HSR hub (78.31 %), consisting of 38.96 % and 39.35 % for private cars and motorcycles, respectively. In the secondary development zone, the LRT and songthaew shuttle services make up 76.42 %, consisting of 59.97 % and 16.45 % for LRT and songthaew shuttle services, respectively.

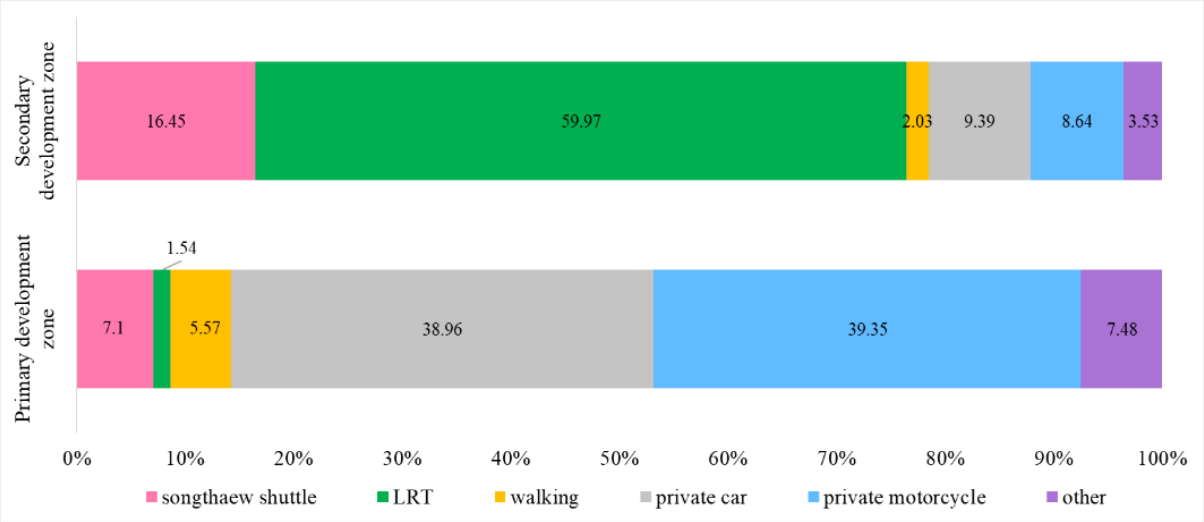

Figure 8.3 Access mode choices in the primary and secondary development zones

Note: other includes tuk-tuk, conventional diesel-run train, bicycle, and taxi service.

8.4.3 Access mode choice relative to travel distance to the HSR hub

Figure 8.4 shows the cumulative survey respondents as a function of access mode of transport and travel distance to the HSR hub. The respondents choose walking as the access mode if the distance between the origin of the journey and the HSR hub is 1.5 km or less. Beyond 1.5 km, the respondents would opt for alternative modes of access, and the number of respondents who would travel on foot decreases rapidly once the distance is beyond 1.6 km. Specifically, less than 6 % of the survey respondents whose origin of the journey is outside the primary development zone choose walking as the mode of access to the HSR hub, consistent with Yang et al. (2019).

The respondents whose origin of the journey is between 1.7 – 2.4 km would choose the songthaew shuttle service to access the HSR hub. Beyond 2.4 km, the respondents would opt for alternative modes of access. The songthaew shuttle fare is flat (0.25 USD) throughout the catchment area. The local government has planned to modernize the songthaew shuttle service.

The respondents start to use the LRT service to access the HSR hub when the travel distance is 2 km or longer. The LRT fares are higher, rendering it less competitive when compared with other access modes of transport. The LRT fares are also higher than the travel costs (i.e., only fuel costs) of private vehicles to access the HSR hub (Figure 8.5). However, once the vehicle maintenance cost and hourly parking charges are taken into account, the use of private vehicles would be significantly costlier than the LRT service. In addition, the LRT service affords the users with the ability to plan and manage travel time as the LRT users face no traffic congestion.

For private vehicle use, the survey respondents would travel by a motorcycle to the HSR hub if the distance between the origin of the journal and the hub is between 1.4 – 2.9 km. Beyond 2.9 km, the respondents would opt for alternative modes of access. Despite the high mobility, this mode of transport poses a high risk to the drivers and pillion riders. In less developed countries including Thailand, motorcyclists ride against the traffic and on the footpath, endangering the safety of pedestrians (Hsu et al., 2003; Pongprasert and Kubota, 2017). Meanwhile, the respondents would choose a private car as the mode of access to the HSR hub if the travel distance is between 1.6 – 3.2 km. Beyond 3.2 km, the respondents would opt for alternative modes of access.

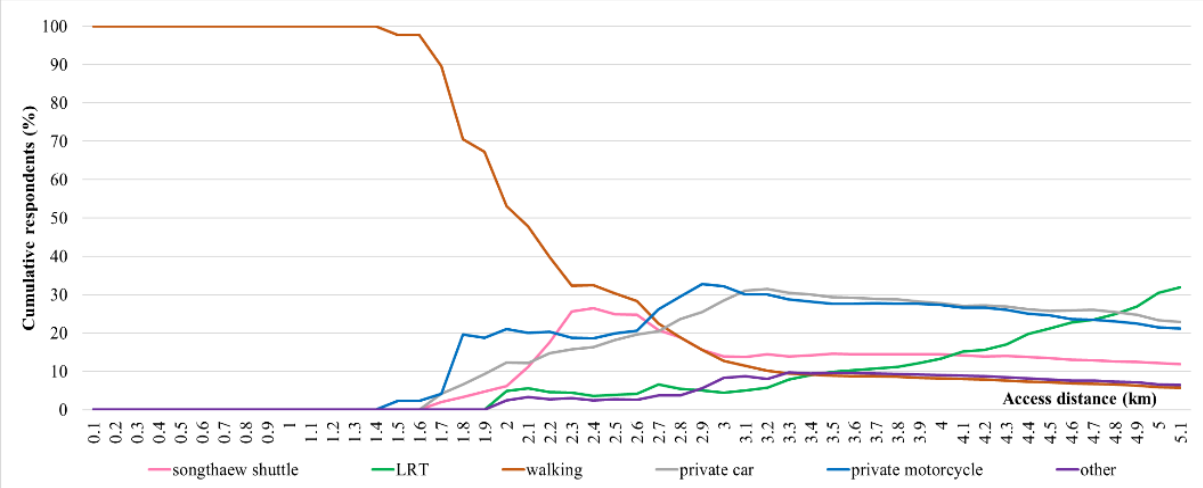

Figure 8.4 Cumulative respondents as a function of access mode of transport and travel distance to the HSR hub

Note: other includes tuk-tuk, conventional diesel-run train, bicycle, and taxi service.

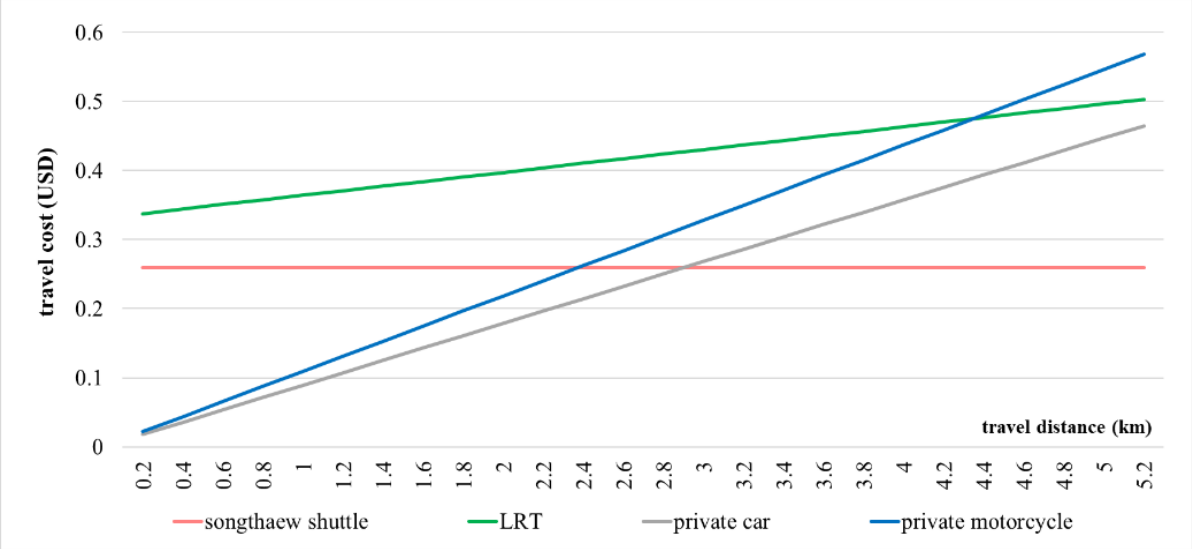

Figure 8.5 The travel cost of different modes of transport relative to travel distance in the catchment area

Source: The Department of Land Transportation for the songthaew shuttle fare, A21 Consultant Co. for the LRT fares, and the Energy Policy and Planning Office for the travel costs (fuel prices) of private vehicles.

8.5 Descriptive analysis

8.5.1 Determinants of access mode choice

In this research, the determinants of access mode choice to Nakhon Ratchasima HSR hub are categorized into three groups: demographics; purpose of HSR travel, and travel characteristics of primary and secondary feeders and private vehicles; and facilities and infrastructure. The purposes of HSR travel include work and business, leisure, and education, excluding family visit and medical-related travel because these two groups of travelers infrequently use the HSR service, vis-à-vis the three other groups.

Table 8.2 tabulates the descriptive analysis of responses of survey respondents. The results show that 40.04 % of the respondents choose the LRT as the access mode of transport to the HSR hub, followed by private car (23.14 %), private motorcycle (21.63 %), and songthaew shuttle (15.19 %). Education is the most cited reason as the purpose of HSR travel (37.59 %), followed by leisure (36.56 %) and work and business (25.85 %). The respondents who are students account for the largest proportion (42.42 %) and private and public employees the second largest (41.97 %).

Around two-thirds of respondents have a bachelor's degree (67.51 %) and would choose public transport over private vehicle use to access the HSR hub. Slightly over half the respondents (53.25 %) are in the low-income bracket, while the respondents in the middle-income bracket account for 41.06 %. In Thailand, the low-, middle-, and high-income brackets are classified as < THB 20,000; 20,000 – 50,000; and > 50,000 per month (NSO, 2019b), given the Thai baht (THB) 30.20/USD exchange rate. The share of respondents with car and motorcycle ownership who use songthaew shuttle to access the HSR hub are 25.83 % and 84.77 %, and those who choose the LRT service are 29.15 % and 87.19 %.

On the travel characteristics, the average travel distance from the origin of the journal to the HSR hub is 3.08 km, with an average travel cost or fare of 0.28 USD. Over two-thirds (68.80 %) of respondents travel to the HSR hub during off-peak hours (68.80 %), while those traveling during peak-hours account for 31.20 %.

On the facilities and infrastructure, the results on four-point Likert scale are reclassified into two classes prior to the MNL analysis to establish the relationship between the dependent variable (access mode choice) and independent variables (three groups of influencing factors). Class I consists of satisfied and very satisfied (3 and 4 on the Likert scale) and Class II of very dissatisfied and dissatisfied (1 and 2 on the Likert scale). The two-class classification of the variables (i.e., connectivity and fare integration, walking amenity, and designated parking area) is derived through trial and error in MNL analysis.

Table 8.2 Descriptive analysis of responses of survey respondents

Variables		Overall	Songthaew shuttle	LRT	Private car	Private motorcycle
Share by mode of transport (%)			15.19	40.04	23.14	21.63
Purpose of travel	Work and business (%)	25.85	17.19	21.78	39.53	43.17
	Leisure (%)	36.56	37.50	32.38	32.56	46.76
	Education (%)	37.59	45.31	45.85	27.91	10.07
Gender	Male (%)	47.65	47.68	42.46	50.87	46.05
	Female (%)	52.35	52.32	57.54	49.13	53.95
Occupation	Student (%)	42.42	54.97	57.04	12.61	42.79

Variables		Overall	Songthaew shuttle	LRT	Private car	Private motorcycle
	Employee-private & public (%)	41.97	35.10	34.67	52.61	42.79
	Self-employed (%)	8.75	7.95	6.53	13.04	8.37
	Business owner (%)	6.86	1.99	1.76	21.74	6.05
Education	Upper secondary (%)	27.26	29.14	24.87	26.96	29.30
	Bachelor's degree (%)	67.51	66.23	69.85	64.35	66.05
	Master's degree (%)	5.23	4.64	5.28	8.70	4.65
Income	Low income (%)	53.25	76.16	61.81	26.09	51.63
	Middle income (%)	41.06	23.18	32.66	60.87	44.65
	High income (%)	5.69	0.66	5.53	13.04	3.72
Car ownership	No (%)	59.93	74.17	70.85	2.61	82.79
	Yes (%)	40.07	25.83	29.15	97.39	17.21
Motorcycle ownership	No (%)	16.61	15.23	12.81	40.00	4.65
	Yes (%)	83.39	84.77	87.19	60.00	95.35
Distance (km)	Average	3.08	3.61	4.58	3.17	2.98
Fare (USD)	Average	0.28	0.38	0.49	0.28	0.33
Timing	Peak hour (%)	31.20	24.22	33.52	32.37	36.72
	Off-peak hour (%)	68.80	75.78	66.48	67.63	63.28
Availability of connectivity & fare integration	Satisfied to very satisfied (%)	15.44	12.50	24.07	7.19	8.47
	Very dissatisfied to dissatisfied (%)	84.56	87.50	75.93	92.81	91.53
Adequacy of walking amenity	Satisfied to very satisfied (%)	24.92	18.75	31.52	19.42	17.51
	Very dissatisfied to dissatisfied (%)	75.08	81.25	68.48	80.58	82.49
Availability/adequacy of designed parking	Satisfied to very satisfied (%)	28.11	20.31	27.51	33.81	31.64
	Very dissatisfied to dissatisfied (%)	71.89	79.69	72.49	66.19	68.36

	Average	Standard deviation
Availability of songthaew routes	2.81	1.40
Availability of LRT line	0.42	0.48

8.5.2 MNL analysis of access mode choices

In this research, the access mode choices in the MNL analysis include LRT (primary feeder) and songthaew shuttle service (second feeder), while private vehicle use (private cars and motorcycles) is the reference. The influencing factors of access mode choice are comprised of demographics; purpose of HSR travel and travel characteristics of primary and secondary feeders and private vehicles; and facilities and infrastructure. The purposes of travel include work and business, leisure, and education, excluding family visit and medical-related travel.

Tables 8.3 – 8.4 present the MNL analysis results of the primary (LRT) and secondary feeders (songthaew shuttle service), respectively, with McFadden's pseudo-R2 of 0.3019 – 0.3959, given 0.2 < the pseudo-R2 < 0.4 is statistically acceptable (Hensher and Stopher, 1979).

In Table 8.3, the significant variables of the primary feeder are travel distance ($p < 0.01$), travel cost ($p < 0.01$), and the availability of LRT line ($p < 0.05$). In Table 8.4, the significant variables of the secondary feeder are middle- and high-income brackets ($p < 0.01$), car

ownership ($p < 0.05$), travel distance ($p < 0.01$), travel cost ($p < 0.01$), the availability of songthaew shuttle routes ($p < 0.05$), and the availability of LRT lines ($p < 0.01$). In the MNL analysis, a negative coefficient indicates the lower likelihood to use the primary and secondary feeder services to access the Nakhon Ratchasima HSR hub. In other words, the respondents opt for private vehicle use over the feeder service to access the HSR hub.

The MNL analysis results also indicate the travel distance, travel cost, and the availability of the LRT line as the common significant variables (with positive coefficients) for both the primary and secondary feeder services. As a result, to successfully convince motorists to switch from private vehicle use to the LRT and songthaew shuttle services, policymakers and concerned government agencies should attach greater emphasis to the travel distance and travel cost of access mode choices as well as the adequacy of the LTR service.

Table 8.3 MNL Analysis Results for the Primary Feeder (LRT Service)

Variables	Work and business	Leisure	Education
	Coefficient (t-value)		
Demographics			
Gender (male = ref.)	-0.5132 (-1.01)	0.4237 (1.03)	-0.0513 (-0.12)
Employee-private & public (student = ref.)	-0.2007 (-0.21)	-0.2572 (-0.42)	-0.4133 (-0.46)
Self-employed (student = ref.)	-0.3872 (-0.38)	-1.1445 (-1.43)	-12.5983 (-0.02)
Business owner (student = ref.)	-0.2564 (-0.26)	-0.9694 (-1.08)	-
Middle income (low income = ref.)	-0.5816 (-0.85)	1.0052 (1.54)	-0.2321 (-0.32)
High income (low income = ref.)	-1.0380 (-1.31)	0.9331 (1.18)	-
Bachelor's degree (upper secondary = ref.)	-0.1559 (-0.25)	0.1697 (0.36)	-0.0027 (0.01)
Master's degree (upper secondary = ref.)	-0.6423 (-0.77)	-0.2090 (-0.23)	0.0443(-0.04)
Car ownership (yes = ref.)	0.3223 (0.50)	-0.5362 (-1.17)	-0.5171 (-0.79)
Motorcycle ownership (yes = ref.)	0.5200 (0.90)	-0.5757 (-1.01)	-0.8689 (-0.91)
Travel characteristics			
Travel distance	-0.5640 (-1.65)	-0.1801 (-0.55)	1.6194** (6.86)
Travel cost	0.9850**(6.18)	0.7061** (5.86)	-0.0021 (-006)
Timing (peak hours = ref.)	0.0571 (-0.23)	-0.3990 (1.27)	0.2694 (0.80)
Facilities and infrastructure			
Availability of connectivity & fare integration (Satisfied to very satisfied = ref.)	-0.3395 (-0.04)	1.0954 (0.48)	0.5011 (1.05)
Adequacy of walking amenity (Satisfied to very satisfied = ref.)	-0.0245 (-0.04)	0.3352 (0.34)	0.5967 (1.04)
Availability/adequacy of designed parking (Satisfied to very satisfied = ref.)	-0.0238 (0.11)	0.1537 (-0.90)	0.4299 (0.60)

Variables	Work and business	Leisure	Education
	Coefficient (t-value)		
Availability of songthaew routes	-0.1854 (-1.00)	-0.1585 (-1.14)	0.1758 (1.33)
Availability of LRT line	0.4301 (0.71)	1.2168* (2.24)	0.2752 (0.56)
Constant	-8.9530* (-5.04)	-7.5699* (-6.29)	-5.5821* (-4.25)
Log-likelihood	-119.5058	-202.9077	-206.3962
LR chi-square	156.62	229.18	178.51
Prob > chi^2	0.0000	0.0000	0.0000
Pseudo R^2	0.3959	0.3609	0.3019

Note: ***, **, and * denote p < 0.001, < 0.01, and < 0.05, respectively.

Table 8.4 MNL Analysis Results for the Secondary Feeder (Songthaew Shuttle Service)

Variables	Work and business	Leisure	Education
	Coefficient (t-value)		
Demographics			
Gender (male = ref.)	-0.2805 (-0.54)	-0.3125 (-0.75)	-0.1805 (-0.40)
Employee-private & public (student = ref.)	0.4264 (0.46)	-0.0484 (-0.08)	0.9734 (1.09)
Self-employed (student = ref.)	0.5976 (0.57)	-0.9540 (1.16)	-13.3176 (-0.01)
Business owner (student = ref.)	0.9694 (1.06)	-0.8890 (-0.97)	-
Middle income (low income = ref.)	-1.022 (-1.56)	0.4787 (0.74)	-1.8048* (-1.96)
High income (low income = ref.)	-2.1669* (-2.45)	1.7072* (2.26)	-
Bachelor's degree (upper secondary = ref.)	0.4686 (0.68)	0.6190 (1.25)	-0.2649 (-0.58)
Master's degree (upper secondary = ref.)	1.0343 (1.18)	0.4243 (0.46)	-0.5074 (-0.32)
Car ownership (yes = ref.)	0.2487 (0.37)	-1.0577* (-2.31)	-0.0817 (-0.13)
Motorcycle ownership (yes = ref.)	0.2348 (0.38)	-0.0346 (-0.06)	-1.2276 (-1.29)
Travel characteristics			
Travel distance	-0.7084 (1.85)	-0.3292 (-1.00)	0.7857** (2.68)
Travel cost	0.4583** (3.38)	0.4641** (3.97)	-0.1163 (-1.34)
Timing (peak hours = ref.)	-0.2926 (0.41)	-0.4771 (1.37)	-0.3499 (-0.69)
Facilities and infrastructure			
Availability of connectivity & fare integration (Satisfied to very satisfied = ref.)	0.6507 (0.33)	1.2666 (-1.55)	-0.4976 (0.74)
Adequacy of walking amenity (Satisfied to very satisfied = ref.)	0.212 (-0.73)	-1.2088 (-0.75)	0.4641 (-1.16)
Availability/adequacy of designed parking (Satisfied to very satisfied = ref.)	-0.4689 (-0.58)	-0.3461 (-1.07)	-0.5421 (0.71)
Availability of songthaew routes	0.1845 (0.38)	-0.3254* (-2.30)	0.0041 (0.03)

Variables	Work and business	Leisure	Education
	Coefficient (t-value)		
Availability of LRT line	0.6756 (1.18)	2.4657** (4.81)	2.0624** (3.97)
Constant	-4.5570* (-2.82)	-4.3048* (-3.84)	-1.0157 (-0.77)
Log-likelihood	-119.5058	-202.9077	-206.3962
LR chi-square	156.62	229.18	178.51
Prob > chi^2	0.0000	0.0000	0.0000
Pseudo R^2	0.3959	0.3609	0.3019

Note: ***, **, and * denote $p < 0.001$, < 0.01, and < 0.05, respectively.

8.6 Tobit analysis of willingness to pay

Table 8.5 presents the willingness to pay for the primary and secondary feeder services to access the Nakhon Ratchasima HSR hub. In this study, the willingness to pay (WTP) is the maximum amount of money a commuter would sacrifice to use the feeder service. Given that substantial improvements are made to the facilities and infrastructure surrounding the Nakhon Ratchasima HSR hub, the Tobit analysis results show that the significant demographic variables are income ($p < 0.001$), car ownership ($p < 0.05$), and motorcycle ownership ($p < 0.05$). The expected WTP for the primary and secondary feeder services to access the HSR hub is 1.094 USD/trip/person.

Table 8.5 Willingness to Pay for the Primary and Secondary Feeder Services to access the HSR Hub

Variable	Maximum Likelihood		
	Coefficient (t-value)	Standard Error	Average
Gender (male = ref.)	0.3873 (0.78)	0.4949	0.5649
Occupation (student = ref.)	0.4019 (0.74)	0. 5424	0.3077
Income (low income = ref.)	5.9157*** (6.44)	0.9191	0.0807
Education (upper secondary = ref.)	0.6602 (1.18)	0.5586	0.2673
Car ownership (yes = ref.)	1.3028* (2.10)	0.6213	0.4161
Motorcycle ownership (yes = ref.)	1.5429* (2.08)	0.7433	0.7907
Constant	17.1621*** (19.51)	0.8795	
σ	6.8668		
Log-likelihood	-2653.0901		
LR chi-square	49.52		
Prob > chi2	0.0000		
Pseudo R^2	0.0092		

Note: ***, **, and * denote $p < 0.001$, < 0.01, and < 0.05, respectively.

8.7 Conclusion

This research had two relevant objectives. First, the methodology developed a strand of research by drawing on the node-pace model. This model was suggested and implemented strategies for the analytical strength of some standard node and place measures. Based on a discussion, an extended butterfly model application was produced visible and knowledge about NKR HSR hub-specific accessibility and spatial development, some of which are not captured in standard node-place analyses.

Second, the empirical and related policies-support objective in that this research included in the model to the NKR HSR hub. This research discussed how to provide the strategic HSR hub put forward in the static vision. Given the LRT project in NKR municipality included in comprehensive analysis and operated with the same year of the HSR project and an extended butterfly model application is calculated using MDCA with experts' involvement and which expresses the TOD planning around the hub. A sensitivity analysis was also carried out to study how the results are affected by changes in weights or indicator values.

This analysis of node-place of NKR HSR hub reveals that had a node index higher than place index. This hub can be classified as an unbalanced node. Inferences were drawn from an extended butterfly model application results to recommend areas for improvement (see Figure 6) based on the low scores of criteria and indicators. Given the standardized score is one for evaluation. All scenarios in sensitivity analysis are not significantly affected. The scores reflect the existing situation from the government strategies and plans which required substantial investment to guide the TOD proposal for NKR HSR hub.

As the node perspective, although the convenient transfer is important for NKR HSR hub, especially neighboring municipalities and cities, feeder services depend on the size of cities. NKR municipalities have one line with two directions for LRT and two routes for songthaew shuttle service, however, most of them operate less frequencies. The limited frequency of LRT and songthaew shuttle service may cover the flow of NKR HSR hub passengers, but it restrains the value of the station as a place because of reduced access to and from the station

The number of songthaew shuttles due largely to the accommodative policy on private vehicle ownership and subsidized fuel prices, resulting in lower levels of service of songthaew shuttle. This performance could integrate fare structure with modes of transportation, while the urban morphology needs to strategically reshape for investment in public transportations. Given the low level of service of songthaew shuttles, concerned agencies need to modernize the songthaew service, improve safety, and provide training to the drivers to successfully convince private vehicle users to switch to this mode of public transport.

The parking capacity (for bikes and private vehicles) is scarce around the hub. The parking management needs to implement by local governments or personal businesses in response to specific parking and traffic problems. The general problems could be addressed (e.g., parking congestion, traffic congestion, and poor pedestrian environments) and the geographic areas are considered how to switch the use of private vehicles to mass transit services or non-motorized transportation.

Ride-sharing services are an alternative to substitute for private vehicle ownership and reduce carbon emissions. The vehicles are located in a residential area, priced by travel time, with convenient pick-up and drop-off procedures. This makes occasional use of an automobile affordable, even for low-income households. The bike-sharing service could be considered as well.

As the place perspective, NKR's population is much more than other cities along the corridor, implying a population threshold is required for viable urban development surrounding hub. However, the remotely located hub suffers from the lack of population threshold and fails the role as an economic hub.

With the intensive land use in the catchment area, a balancing different priorities of path diversity should require to increase with change in community composition in a way that reflects what is valued. The station area development of this hub looks like neighborhood TOD

(local activity node), but it should design to access residents' perceptions about the neighborhood and opinions about potential TOD opportunities.

The walkable area surrounding the hub suffers a remarkable functional and spatial diversity of the functions living, working, and visiting. The clearer definitions should examine for urban design because places vary substantially between definitions leading to substantially different designs. Create, use, and develop put forward frame options for understanding the multiple perspectives.

The HSR hub located less than 5 km from the city center is lacking in densities of metropolitan amenities even though there are some commercial and business facilities around the hub. This area of economic development needs particular development strategies to accumulate information and the explanation for the achievement of economies of agglomeration.

Stimulating TOD through tax incentives would provide the incentive to utilize the station area development more intensively by improving legislation and regulation. TOD needs tax to provide services to generate through retail and commercial properties and to support population moving in viable areas as well as benefit the municipal government. For more discussion, see Chalermpong and Ratanawaraha (2016).

Balancing node and place functions in NKR HSR hub need improvement in many perspectives (e.g., strategic planning, financial supports, actors, and legislation and regulation). TOD planning for in the Thai context is a simplified representation of an even more complex constellation of actors and institutions. However, there is little discussion on the intuitional perspectives and financial support of station area development, especially the planning process and stakeholders. Further is needed to analyze the interaction between socioeconomic needs and quality of places and identify and select planning process approached that can respond to the complexity of the development process.

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CHAPTER 9

An Extended Butterfly Model Application of Analytical Nodes and Places surrounding Nakhon Ratchasima High-speed Rail Hub

9.1 Introduction

Transit-oriented development (TOD) has been described as a spatial planning approach that aimed to integrate transport and land use planning around transit stations. TOD aims to reduce the use of private transport and increase the use of public transit by ways of substantial catchment areas surrounding transit stations and improving transport accessibility. (Calthorpe, 1993; Bertolini, 1996; Bertolini and Spit, 1998; Dittmar and Ohland, 2014; Yin et al. 2015).

According to Dittmar and Ohland (2014), TOD projects need to achieve five main goals of location efficiency, a rich mix of choices, value capture, placemaking, and resolution of the tension between node and place. To achieve these goals and take benefits from them, it is necessary to ensure the urban development interacts with the transit system. In recent years, many studies have been conducted to determine how land use and transportation affect each other and how the development of one may influence the other. However, TOD is easier to be conceptualized than implement. This is to say, integration between land use and transport policies depends on numerous factors related to the practice of land use and transport planning.

The interaction between rail transportation and urban development has been studied using many approaches (e.g., Yin et al. 2015). Land use patterns determine the location of human activities, while the distribution of human actives requires the use of a transportation system (Dittmar and Ohland, 2014). More specifically, land use and transport planning need to be coordinated evaluation based on various factors such as density, diversity, design, and public transportation. A balance between transport functions (node index) and urban functions (place index) could be adopted as a key mechanism for development around transit stations.

Although several studies have explored the importance of TOD around stations, like rail-based public transportation, very few have focused on high-speed rail (HSR) hub, especially its automobile dependency and integration with adjacent areas and streets. With the HSR project connecting Thailand's capital Bangkok to Nakhon Ratchasima province (the HSR project) currently underway, it thus makes operational and economic sense to adopt and implement the general function of the HSR station (i.e. conceptual framework of the node-place model) that matched the needs of HSR hubs (SRT, 2016). The northeastern province of Nakhon Ratchasima (NKR) is the land transportation hub and serves the gateway to other northeastern provinces (NESDC, 2017a).

The objective of this paper is twofold. First, this is a methodological objective in that this research further develops strand of research by paying attention to three major considerations which will be further elaborated in section 4.1: (1) improving the analysis of some existing node and place indicators; (2) incorporating information about the people who use the public transportation to access HSR hub, which reflects the primary and secondary feeder services to HSR hub; (3) incorporating information about the people who pay the transport fare to access HSR hub, which reflects the willingness to pay for the primary and secondary feeder services to access the HSR Hub. Moreover, the methodological elegances to the literature, there is also, second, an empirical and related policies-support objective in that this research applies the model and designates strategic transport and land use for NKR HSR hub.

9.2 Methodology and data

9.2.1 A modified assessment model for NKR HSR Hub

Given the effectiveness of the node-place model for classifying the performance of station areas (e.g., Singh et al. 2017; Case et al. 2018), this research modified the methodology for evaluating the balance of node and place model in terms of strategic support for NKR HSR hub. In this way, the butterfly model developed and operationalized for all railway stations in the Dutch province offered a good starting point. This model was recently modified and applied to the Brussels Regional Express Network by Caset et al. (2018).

The original butterfly model consisted of two wings: a node wing (on the left-hand side), quantifying the accessibility of the station by active travel, public transport, and car; and a place wing (on the left-hand side), quantifying the proximity of the station by design, density and diversity (see Figure 9.1). The model qualified as a location-based accessibility instrument because it quantified accessibility characteristics of a location (Geurs, 2006). The node and place characteristics included in the model furthermore capture two of the accessibility components discerned by Geurs (2006): the transport and land-use components.

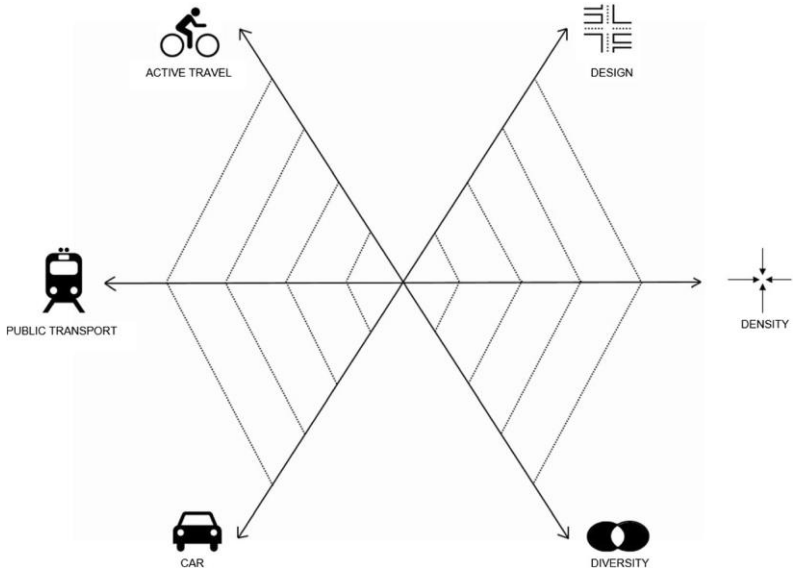

Figure 9.1 The butterfly model applied to the Brussels RER network

Source: Caset et al. (2018)

Accessibility to and from railway stations extended supply-side characteristics because the accessibility of railway stations involved the temporal constraints and individual needs and capabilities of travelers (Giannopoulous and Boulougaris, 1989). As Geurs (2006), temporal constraints involved differences in travel time and cost depending on the time of the day or day, whereas the individual component accounted for stratifications of the demographics. In the case of railway stations, the temporal component mainly involved the transport component. The individual component however required new information to be added to the empirical assessment models discussed above. It required relevant traveler-specific information which might improve particular insights about a station's functioning in the railway network. Hence, five accessibility components (light rail transit, songthaew shuttle, tuk-tuk, taxi service, and motorcycle taxi) might render a more comprehensive and diversified account of a station's level of accessibility, both from the perspective of the node and the place dimension, but also

from the perspective of its travelers. In line with Oh et al. (2015), Yin et al. (2015) and Tissayakorn et al. (2019a), HSR hub should integrate with different feeder services and ranges.

The Thai government put forward an ambitious outlook on the future development of the land use and transport in NKR municipality by 2037 in the National Strategy for NKR spatial policy plan (NESDC, 2018) The policy papers put forward a renewed mid-long term vision extending most of the earlier spatial planning principles, even though rail transport is designed accessibility as the backbone for future spatial developments. This strategic vision was approved by the Thai cabinet and translated into relevant frameworks for the implementation of government agencies (e.g., MOT, 2017).

The objective of the policy paper was to design strategic public transport nodes which had the highest potential for allocation of additional urban development. This potential was determined by (1) the extent to which a location was accessible by public transportations, and (2) the extent to economic development and amenity. Both criteria recently mapped and operated by Oh et al. (2015), Verachtert et al. (2016), and Singht et al. (2017). Drawing on this research, the policy paper put forward a conceptual NKR HSR hub.

The assessment model that resulted from these considerations took the shape of an extended butterfly model application (see Figure 9.2). Below, the structure of the diagram was described, after which the operationalization of the criteria (dimensions) and indicators was detailed. In the process, this research would discuss how to improve the analytical strength of indicators.

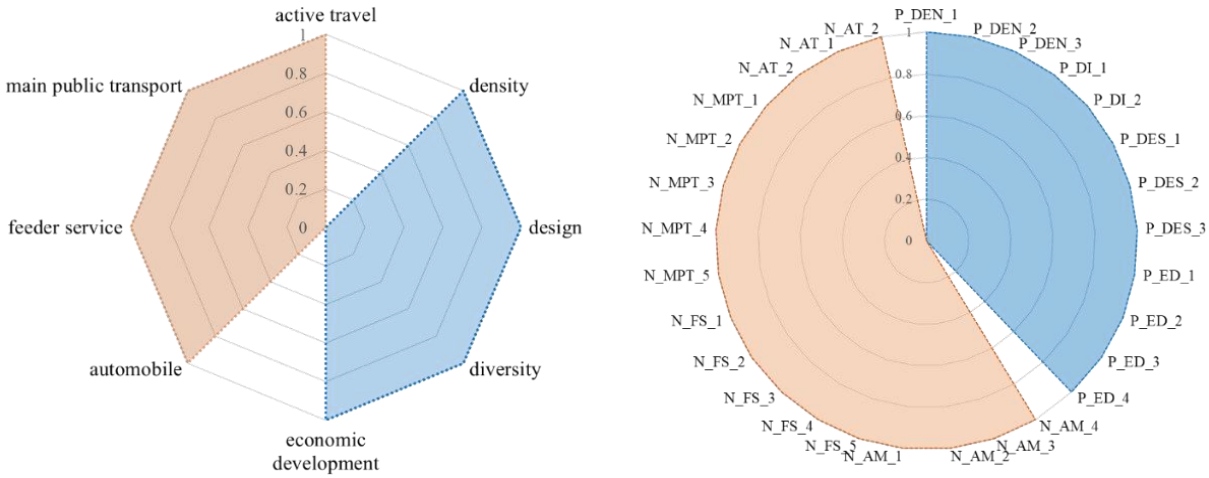

Figure 9.2 An extended butterfly model application (orange color for node-index and blue color for place-index): overall criteria (left) and indicators (right)

9.2.2 Operationalization

1) Node index

- Active travel criteria

This criterion measured the accessibility to and from the HSR hub for active modes of travel (i.e. walking and cycling) that were used by Caset *et al.* 2018. In Table 1, N_AT_1 measured the bike parking capacity within the catchment area. The indicator was measured by digitizing the bike parking using shapefile from DPT (2015), and by consulting Google Earth (GE) and NOSTRA map for the cases in which confusion about a bike parking presence and capacity arose. N_AT_2 was a binary variable indicating the presence of bike

sharing facilities within the catchment area. This indicator was obtained the raw data from Yokohama National University (YNU) (2020) where conducted for "determinants of primary and secondary access mode choices to NKR HSR hub" at the end of February through early March 2020.

- HSR criterion

The first five indicators analyzed characteristics of the HSR service at the station as was rarely done in node-place analyses. In this research, all indicators were adapted from the original indicators that were used by Bertolini (1991). Regarding indicators N_HSR_1 to N_HSR 5, calculations are based on the HSR project data that was obtained from SRT (2017). This government agency was accountable for inter-city railways in Thailand. The timetable of operation in a workday was parallel, while the timetable of operation on holiday was paired. N_HSR_1 indicated the number of directions served at NKR HSR hub based on all available routes listed in the data for the HSR project. N_HSR_2 presented the number of end stations reachable by NKR HSR hub. N_HSR_3 was the total number of trains serving the hub (stop or start at NKR HSR hub) on a workday, while N_HSR_4 was the same indicator but replaced holiday with the workday. Indicator N_HSR_5, counting the number of passengers per day by NKR HSR hub could be predicted in the first year of operation.

- Feeder services criterion

In this research, the feeder services criterion conformed to the HSR criterion and also developed the more specific accessibility indicators which accessed NKR HSR hub from primary and secondary feeder services and willingness to pay (WTP). Below, the sample size, questionnaire survey, conceptual models, access transport modes to the HSR hub, and descriptive analysis were explained, after which the calculation of the indicators was detailed.

First, this research analyzed access transport modes to NKR HSR by using raw data from YNU (2020). The population in the catchment area of NKR HSR hub was 36,532. The sample size for a survey of access mode choice to the HSR hub was determined by using Krejcie and Morgan formula because of the finite population (Krejcie and Morgan, 1970). The calculated sample size for survey data collection was 377. The locations for data collection included green-line LRT stations with high ridership (OTP, 2016) and civic and economic centers inside the catchment area, e.g., educational institutions, shopping malls, places of worship, hospitals. Figure 9.3 shows the locations (L1 - L20) where the survey data collection was undertaken by in-person interview using a questionnaire, and 50 - 60 samples were randomly selected from each location. The number of respondents were 1,108 individuals to avoid missing data. The survey participants had residences inside the catchment area and were of working age or university students because these age groups were prospective customers of the HSR service.

The survey questionnaire consisted of three parts. (1) demographics; (2) purpose of HSR travel and travel characteristics of access/egress transport modes; and (3) facilities and infrastructure to access NKR HSR Hub. The first part was concerned with the respondents' demographics, including gender, occupation, education, income, car ownership, and motorcycle ownership. The second part was involved the mode of transport, fare, travel distance, timing (peak/off-peak) from the origin of journey to the HSR hub, and the purpose of travel. The responses on travel distance were validated against Google Map.

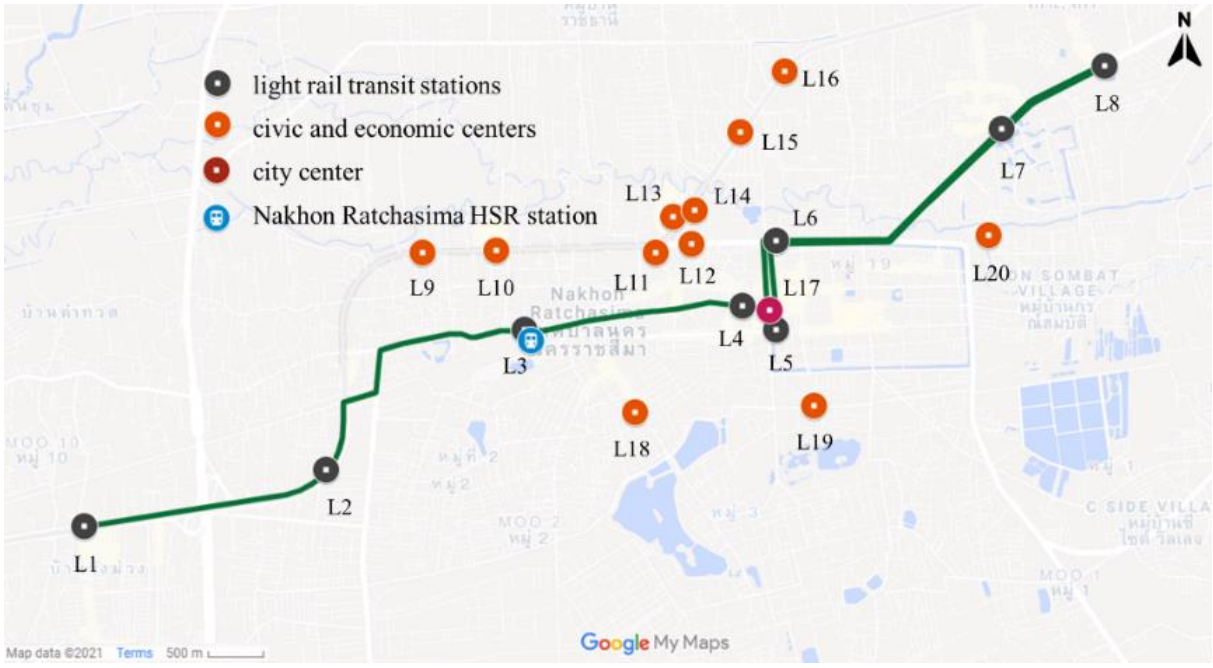

Figure 9.3. The locations of survey data collection (L1 - L20)

The third part is comprised of two groupings of questions: (1) the satisfaction levels with the facilities and infrastructure surrounding the HSR hub; and (2) the availability of songthaew shuttle routes and future LRT line near the origin of journey. In the first grouping, the questions on the levels of satisfaction with facilities and infrastructure surrounding the HSR hub asked about the connectivity and fare integration, walking amenity, and designated parking area. The satisfaction-level questions were of 4-point Likert scale. In the second grouping, the questions on the songthaew shuttle service and future LRT asked about the availability of songthaew shuttle routes and LRT line within a 500 m radius from the origin of journey (Regional Plan Association 1997; Vuchic 2005). This research assumed that the HSR passengers used the same mode of transport to access and egress the HSR hub. Prior to data collection, the questionnaire was electronically sent to and validated by a panel of experts in the area of urban and transport planning.

Second, the conceptual model was consisted of multinomial logit (MNL) model and Tobit model to determinant of primary and secondary access mode choice to NKR HSR hub. The first model (MNL model) was used to determine influencing factors of access mode choice to NKR HSR hub via the primary and secondary feeder services. The influencing factors were categorized into three groups: demographics; purpose of HSR travel and travel characteristics of primary and secondary feeders and private vehicles; and facilities and infrastructure. The purposes of travel under study included work and business, leisure, and education, excluding family visit and medical-related travel. As a result, the actual number of respondents used in the MNL model was 793 respondents, excluding 315 respondents for family visit and medical-related travel. The reason for exclusion was that these two groups of travelers infrequently used the HSR service, in comparison with the three other groups.

Private transport was a reference mode of transport in MNL because of the aim of TOD (Cervero and Sullivan, 2010). The MNL model in STATA version 15 was used for analysis. The MNL- based choice modeling was typically used to evaluate consumer preferences in relation to transport alternatives (Feng *et al.* 2014; Yang *et al.* 2019).

To control for multicollinearity between travel cost, travel distance, and length of travel time, this research thus replaced the length of travel time with timing. Furthermore, the influencing factors under the three groups of factors were tested for multicollinearity by a variance inflation factor (VIF). The VIF of the influencing factors was less than 2 %, given that a VIF < 2 % was statistically acceptable (Marquaridt, 1970).

The second model (Tobit model) was used to estimate the WTP of 793 survey respondents by using the maximum likelihood estimation (MLE) technique (Whitehead, 2003). In the Tobit analysis, it was assumed that substantial improvements would be made to the facilities and infrastructure around the NKR HSR hub. The independent variables in the Tobit model were the demographics in the survey questionnaire (e.g., gender, occupation, and car ownership). The Tobit model in STATA version 15 was used for analysis. The expected WTP value could be calculated by following Whitehead (2003).

Third, as the access transport modes to the HSR hub, the LRT was the most preferred access mode choice as 32.19 % of the questionnaire respondents on average would select this access transport mode. The main reason given by the respondents was the ability to plan and manage commute time. Likewise, certain locations which were the civic and economic centers also had large proportions of respondents who preferred the LRT. As a result, this research selected the LRT service as the primary feeder to access NKR HSR hub.

Despite the LRT service, the proportion of private vehicle used on average was still as high as 48.08 %, consisting of 23.64 % and 24.44 % for private cars and private motorcycles, respectively. This could be attributed to the country's accommodative policy on car ownership and subsidized fuel prices. The songthaew shuttle service accounted for 11.76 % of the survey respondents. The low proportion was attributable to the limited number and frequency of vehicles. The songthaew shuttle service was currently the main public transport in the NKR municipality. Upon the completion of LRT, the songthaew shuttle service would become the secondary feeder of the municipality to access the HSR hub. As a result, the local government had planned to modernize the songthaew shuttle service, including the availability of shuttles, frequency, safety, personnel, and regulations.

Walking as the access mode accounted for 4.43 % of the survey respondents. The very low percentage was attributable to the country's tropical climate with an average temperature of 35 °C. The other modes of transport consisted of tuk-tuk, conventional diesel-run train, bicycle, and taxi service, accounting for 3.54 %.

Fourth, determinants of access mode choice, MNL analysis of access mode choices, and Tobit analysis of willingness to pay were shortly explained in descriptive analysis. Determinants of access mode choice to NKR HSR hub were categorized into three groups: demographics; the purpose of HSR travel and travel characteristics of primary and secondary feeders and private vehicles; and facilities and infrastructure. The purposes of HSR travel included work and business, leisure, and education, excluding family visit and medical-related travel because these two groups of travelers infrequently used the HSR service, vis-à-vis the three other groups.

The results show that 40.04 % of the respondents chose the LRT as the access mode of transport to the HSR hub, followed by private car (23.14 %), private motorcycle (21.63 %), and songthaew shuttle (15.19 %). Education was the most cited reason as the purpose of HSR travel (37.59 %), followed by leisure (36.56 %) and work and business (25.85 %). The respondents who were students accounted for the largest proportion (42.42 %) and private and public employees the second largest (41.97 %).

Around two-thirds of respondents had a bachelor's degree (67.51 %) and would choose public transport over private vehicle use to access the HSR hub. Slightly over half the respondents (53.25 %) were in the low-income bracket, while the respondents in the middle-income bracket accounted for 41.06 %. The share of respondents with car and motorcycle ownership who used songthaew shuttle to access the HSR hub are 25.83 % and 84.77 %, and those who chose the LRT service are 29.15 % and 87.19 %.

On the travel characteristics, the average travel distance from the origin of journal to the HSR hub was 3.08 km, with an average travel cost of 0.28 USD. Over two-thirds (68.80 %) of respondents traveled to the HSR hub during off-peak hours (68.80 %), while those travelling during peak-hours accounted for 31.20 %.

On the facilities and infrastructure, the results on four-point Likert scale were reclassified into two classes prior to the MNL analysis to establish the relationship between the dependent variable (access mode choice) and independent variables (three groups of influencing factors). Class I consisted of satisfied and very satisfied (3 and 4 on the Likert scale) and Class II of very dissatisfied and dissatisfied (1 and 2 on the Likert scale). The two-class classification of the variables (i.e., connectivity and fare integration, walking amenity, and designated parking area) was derived through trial and error in MNL analysis.

The access mode choices in the MNL analysis included LRT and songthaew shuttle service, while private vehicle use was the reference. The influencing factors of access mode choice were comprised of demographics; purpose of HSR travel and travel characteristics of primary and secondary feeders and private vehicles; and facilities and infrastructure. The purposes of travel include work and business, leisure, and education, excluding family visit and medical-related travel.

The significant variables of the primary feeder were travel distance ($p < 0.01$), travel cost ($p < 0.01$), and the availability of LRT line ($p < 0.05$). The significant variables of the secondary feeder were middle- and high-income brackets ($p < 0.01$), car ownership ($p < 0.05$), travel distance ($p < 0.01$), travel cost ($p < 0.01$), the availability of songthaew shuttle routes ($p < 0.05$), and the availability of LRT lines ($p < 0.01$).

The MNL analysis results also indicated the travel distance, travel cost, and the availability of LRT line as the common significant variables for both the primary and secondary feeder services. As a result, to successfully convince motorists to switch from private vehicle use to the LRT and songthaew shuttle services, policymakers and concerned government agencies should attach greater emphasis to the travel distance and travel cost of access mode choices as well as the adequacy of the LTR service.

The WTP was the maximum amount of money a commuter would sacrifice to use the feeder service. Given that substantial improvements were made to the facilities and infrastructure surrounding NKR HSR hub, the Tobit analysis results showed that the significant demographic variables were income ($p < 0.001$), car ownership ($p < 0.05$), and motorcycle ownership ($p < 0.05$). The expected WTP for the primary and secondary feeder services to access the HSR hub was 1.094 USD/trip/person

Indicators N_FS_1 and N_FS_2 represented the total number of feeder services serving the hub on workday and holiday, respectively. In order to calculate the accessibility to and from the HSR hub by songthaew shuttle, tuk-tuk, taxi service, motorcycle taxi, tricycle rickshaw, conventional diesel-run train, and LRT were filtered from publicly available NKRPTO (2020), MRTA (2020), and YNU (2020) data. N_FS_3 indicated the number of directions served by LRT. Indicator N_FS_4, measuring the number of stations that could be

reached within 14:22 min of travel by primary feeder. This research adapted the travel time from 45 min to 14:22 min because of the average travel time of HSR passengers to NKR HSR hub. N_FS_5 was an additional indicator in research because fare was significant variable for the primary and secondary feeder. This indicator was also a part of accessibility indicators for transport planning (Tuan and Son, 2015; Litman, 2016). As a corollary, WTP to access NKR HSR hub could be set 1.094 USD/trip. It was important to note that all five indicators were calculated within the catchment area.

- Automobile criterion

The first automobile criterion focuses on the parking capacity for private cars and private motorcycles. In order to calculate the accessibility to and from the HSR hub by automobile, the stops considered around HSR hub were filtered from publicly available DPT data using ArcGIS 10.1, and consulting GE and NOSTRA map for the cases in which confusion about the automobile parking presence and capacity. N_AM_2 was a binary variable indicating the presence of automobile sharing facilities within the catchment area. The indicator was checked by consulting YNU (2020) data. N_AM_3 and N_AM_4 were measured in ArcGIS 10.1 using OSM data and DPT data, respectively, and indicated the position of the station in the national and regional road network. N_AM_3 indicated the road network distance between the HSR hub and its closest motorway access, while N_AM_4 provided the total length of structural roads within the station catchment area. The structural roads included the following DPT road categories: primary, secondary, and tertiary.

2) Place index

- Density criterion

This criterion referred to the concentration of residents, accommodations, and jobs. Its contribution to the walkability of TOD was detailed in Cervero and Kockelman (1997). P_DEN_1 reflected the density of residents. This data was provided by NSO, on the basis of the geographical coordinates of the official residential address in the national register. P_DEN_2 used a measure of accommodations density. This data was provided by DPT, on the basis of the geographical coordinates of the official accommodative address in the national register. In this research, accommodations were included houses, dormitories, apartments, and condominiums. P_DEN_3 provided the measure of jobs density that were located and disaggregated by the employment sector. This research focused only industrial sector for consideration because of available data. The data was calculated and provided by the Department of Industrial Works (DIW), on the basis of the types of industrial works. The official registered employment and industrial works were subsequently obtained from the DIW. A limitation of the data (residents and jobs) was the people and industrial works who were not registered in DIW.

- Diversity criterion

This diversity (or land-use mix) criterion was a principal ingredient of walkability (Dovey *et al*. 2017). In general, it was often operationalized by the functional mix indicator used by Bertolini (1999). This measure captured functional land-use mix, but it did not capture the spatial configuration of the land-use types (Hess *et al.* 2001). Given this, this research adapted the work of Hess *et al.* 2001 in which the landscape ecology approach to measuring path diversity was applied within the context of land use and transport interaction. Shannon's diversity index was measured by ArcGIS 10.1 which considered the fundamental and spatial diversity of land-use types within each catchment area. P_DI_1 increased as the

number of different land-use types increased and/or the proportional distribution of area among types became more equitable. The data was calculated in ArcGIS 10.1 using DPT data.

An additional indicator P_DI_2, measuring the density of land prices that could be showed the substantial economic activity and attractiveness of land use and transportation. Although the land prices were derived from several factors, the actual land prices could be reached external economic benefits (Suzuki *et al*. 2015; Yin *et al*. 2015). The data was calculated in ArcGIS 10.1 using data from the Treasury Department (TD).

- Design criterion

This criterion aimed to measure the walkable and bikeable access by urban morphology of public space and by the built environment. All indicators were calculated in ArcGIS 10.1 using OSM data. P_DES_1 measured the pedestrian shed ratio of the catchment area. It revealed the actual area that might be covered by walking within a radius of 1.90 km from NKR HSR hub, which was the maximum acceptable walking distance to the HSR hub (Vuchic 2005). The ratio of the total area could be drawn based on the walkable street network from the station, divided by the area of a circle with the same radius. The larger the value, the larger the walkable area around the station. P_DES_2 provided the number of street network intersections with three or more links in the catchment area, as it was an indicator of the connectivity of the street network (Handy *et al*. 2003). The larger the indicator, the more walkable the neighborhood. P_DES_3 measured the total length of an accessible street network for walkability, excluding bikeable lanes. This was the study area uses shared lanes between public transportation, automobile, and bicycle. P_DES_3 slightly differed from P_DES_1 because it was not dependent on the algorithm setting to create the walkable catchment area.

- Economic development criterion

This criterion referred to the private investment per land-use type and the number of service and retail establishments within catchment area (Rene and Wells, 2005). P_ED_1 to P_ED_3 were available (amenities) data at the district level, while P_ED_4 were available (tax earnings) data at the municipality level. All indicators were calculated in ArcGIS 10.1 using data from DPT and NKR municipality data, and consulting open sources for the case in which confusion about the places. In this research, the amenities were emphasized the significant facilities to generate economics and regional specialization (Oh et al. 2015). P_ED_1 measured the important places for daily life (e.g., hospital, pharmacy, restaurant, school, and temple). P_ED_2 measured the larger place to serve in a different area (e.g., shopping mall, department store, and office). P_ED_3 measured the largest place to serve the travelers (e.g., touristic attractions, university, museum, conference center, and exhibition center). P_ED_4 measured the tax earnings of municipalities (house and land tax, local maintenance tax, and signboard tax). This indicator was measured by using a shapefile from NKR municipality with ArcGIS version 10.1.

Table 9.1 Criteria, indicators, and weights for an extended butterfly model application

Criterion	Weights	Code: Indicator description	Weights	Source (year)
Node index				
Active travel	0.03	N_AT_1: bike parking capacity (km^2)	0.57	DPT (2015) GE (2020) NOSTRA Map (2020)
		N_AT_2: presence of bikes-sharing service (yes/no)	0.43	YNU (2020)

Criterion	Weights	Code: Indicator description	Weights	Source (year)
HSR	0.19	N_HSR_1: number of directions served at NKR HSR hub	0.22	SRT (2017)
		N_HSR_2: number of end stations reachable by NKR HSR hub	0.20	
		N_HSR_3: total number of trains serving the hub (arrival and departure/day) on workday	0.21	
		N_HSR_4: total number of trains serving the hub (arrival and departure/day) on holiday	0.14	
		N_HSR_5: number of passengers per day by NKR HSR hub (passengers/day)	0.23	
Feeder services	0.17	N_FS_1: total number of feeder services serving the hub (arrival and departure/day) on workdays	0.22	NKRPTO (2020) MRTA (2020) YNU (2020)
		N_FS_2: total number of feeder services serving the hub (arrival and departure/day) on holiday	0.18	
		N_FS_3: number of directions served by LRT	0.15	MRTA (2020)
		N_FS_4: number of stations that can be reached within 14:22 min of LRT	0.20	
		N_FS_5: WTP (USD/trip)	0.25	YNU (2020)
Automobile	0.06	N_AM_1: automobile parking capacity (free and paid service)	0.25	DPT (2015) GE (2020) NOSTRA Map (2020)
		N_AM_2: presence of automobile sharing facilities (yes/no)	0.18	YNU (2020)
		N_AM_3: road network distance between the HSR hub and its closest motorway access (km)	0.34	DPT (2015) OSM (2020)
		N_AM_4: total length of structural roads (km)	0.23	
Place index				
Density	0.12	P_DEN_1: density of residents (people/km^2)	0.35	NSO (2020)
		P_DEN_2: density of accommodations (units/km^2)	0.30	DPT (2015)
		P_DEN_3: density of jobs (people/km^2)	0.35	DIW (2020)
Diversity	0.12	P_DI_1: Shannon's diversity index	0.43	DPT (2015)
		P_DI_2: density of land prices (USD/km^2)	0.57	TD (2020)
Design	0.09	P_DES_1: pedestrian shed ratio	0.39	OSM (2020)
		P_DES_2: number of street network intersections with three or more links	0.25	
		P_DES_3: total length of an accessible street network for walkability (km)	0.36	
Economic development	0.22	P_ED_1: density of basic amenities	0.16	DPT (2015)
		P_ED_2: density of regional amenities	0.27	
		P_ED_3: density of metropolitan amenities	0.26	
		P_ED_4: tax earnings of municipalities (million USD)	0.31	NKR municipality (2019)

9.3 Results

9.3.1 Node index

NKR HSR hub scores are shown in Figure 9.3. Using the results, FS criterion is the highest score at 0.63 followed by HSR (0.48), AM (0.19), and AT (0.01) criterion, respectively. An average score of 0.40 over a maximum possible score of 1 can be considered as a moderate score for node index. This means that node functionality surrounding hub should focus on substantial improvement, especially AT, AM, and HSR criteria.

In terms of indicators, the high scores are consisted of N_FS_5 (0.94), N_FS_1 (0.91), N_HSR_3 (0.88), N_FS_2 (0.82), and N_HSR_5 (0.71). The moderate score is N_HSR_3 (0.59), while the rest are low scores.

Although NKR HSR hub has only one way to travel at the first stage of the HSR project, the ridership is expected to increase by 7.88 % during 2024-2050 (SRT, 2017). This ridership ranks the second largest among the HSR project as well.

According to SRT (2017), the total length of the HSR project is 252.3 km which was expected to can make a difference in gaining market share to the private vehicle (private cars) and public transportation (bus and conventional diesel-run train). The location of NKR HSR hub also plays competitiveness among HSR hubs because of travel distance (Gleave, 2014).

Although the convenient transfer is important for NKR HSR hub, especially neighboring municipalities and cities, feeder services depend on the size of cities. NKR municipalities has one line with two directions for primary feeder service and two routes for secondary feeder service, however, most of them operate less frequencies. Hence, limited frequency of primary and secondary feeder services may cover the flow of NKR HSR hub passengers, but it restrains the value of the station as a place because of reduced access to and from the station

The number of songthaew shuttles due largely to the accommodative policy on car ownership and subsidized fuel prices, resulting in lower levels of service of songthaew shuttle (DLT, 2020a). This performance can be expanded the service and the challenge to integrate fare structure of public transportations and improve the songthaew shuttle service. The urban morphology needs to strategically reshape for investment in public transportations.

Accessibility to the existing urbanized area is identified a crucial indicator for urban development around NKR HSR hub. This hub is now in progress in constructing dedicated HSR lines, while it is located in NKR municipality and large city. The large city had more negotiation power when the line was designed (Yin et al 2015). Hence, the large hub is located around the city center compared to Seoul HSR hub located in metropolitan cities that increased populations of more than a million (Kim et al 2018).

Most of other indicators (in active travel criterion and automobile criterion) are low scores. The bike parking capacity is remarkably low and automobile parking is also scarce. This is a good illustration of the strategy to reduce congestion, delay, and carbon emissions by providing parking capacity.

The hub provides less bike-sharing and automobile-sharing services. This performance can be expanded the development and challenge to increase the ride-sharing services for reducing private vehicle ownership, traffic congestion, and carbon emissions.

9.3.2 Place index

NKR HSR hub scores are shown in Figure 9.3. Using the results, ED criterion is the highest score at 0.52 followed by DES (0.25), DEN (0.24), and DI (0.23) criterion, respectively. An average score of 0.28 over a maximum possible score of 1 can be considered as a low score for the place index. This means that spatial quality surrounding hub should focus on substantial improvement, especially DES, DEN, and DI criteria.

In terms of indicators, the high scores are consisted of P_ED_2 (0.84) and P_ED_1 (0.61). The moderate scores are P_DES_3 (0.57), P_ED_4 (0.46), and P_DI_2 (0.44), while the rest are low scores.

The role of NKR HSR hub as an economic hub can be evaluated by indirect indicators, e.g., population and business abilities. Relatively high ridership is assumed to be related to the size of cities as a potential demand. NKR HSR hub serves approximately 2.42 million people in 2024 (SRT, 2017). NKR's population is much more than other cities along the corridor, implying a population threshold is required for viable urban development surrounding hub. However, the remotely located hub suffers from the lack of population threshold and fails the role as an economic hub.

In parallel, P_DI_1 and P_DI_2 is a low score and moderate score, respectively. These results mean that a balance of path diversity required improvement. The types of land use are converted from polygon to point because of the size of the station area and identifying points of interest. The residential area is more than half of a proportion (52.07 %), while the accumulation of commercial area and industrial area (17.35 %) and the accumulation of public utility and public assistance are small proportions (20.64 %). These results possible result in neighborhood TOD when compared results with Associates (1992).

The walkable area around this hub fails a remarkable functional and spatial diversity of the functions living, working, and visiting. This result contrasts with NKR province (2018) that aimed to switch the use of the private vehicle to the use of public transportation or non-motorized transportation.

The strong economic activities with basic and regional amenities are consistent with the NKR plan (NESDC, 2017) and Boonlert et al (2019), but the recent economic developments are concentrated in NKR municipality. Conversely, metropolitan amenities are a low score since the functions are spread from NKR municipality to the neighboring municipalities. Tax earnings are moderate score with house and land (5.76 million USD), local maintenance (0.09 million USD), and signboard (0.90 million USD) in 2019. The development around the hub evolves from the initial phase of the HSR project because of the limitation of legislation and regulation to support TOD planning (Chalermpong and Ratanawaraha, 2016; JICA *et al*. 2017). The local government also faces fiscal autonomy and self-reliance from the federal government (Wongpreedee and Mahakanjana, 2011; Metasuttirat and Wangkanond, 2017).

Although this hub is located beside the central business district (CBD), NKR municipality's economic stagnation get down. Up to this point, this result does not support Hall (2009) that the hub would improve attractiveness for CBD. It depends on urban spatial and morphological strategy.

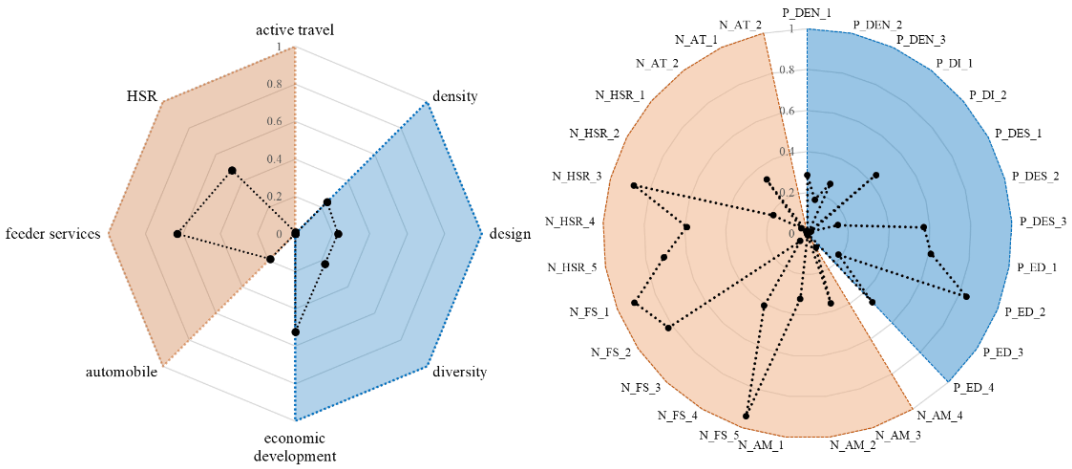

Figure 9.3 NKR HSR hub scores (left: criteria, right: indicators)

Note: low scores are 0-0.39, moderate scores are 0.40-0.60, and high scores are 0.61-1.00

9.3.3 Balancing Node and Place Functions and Sensitivity Analysis

Analyzing the placement of the hub in the node-place diagram, this place can be classified as an unbalanced node. This implies that it was overly crowded with feeder services, economic development, and HSR criteria. At this time, this hub is highly developed with commercial and business facilities. This hub is also an important transfer hub in the northeastern provinces by conventional diesel-run train or local transportation network of NKR.

This analysis is a well-established fact that investment policies and plans were not sufficient to support TOD planning and required to implement by specific actions and tools. Figure 9.3 can hint in identifying those criteria and indicators that scored low and can be improved. Given the standardized score is one for evaluation and the LRT project operates with the same year of the HSR project. Based on the information in an extended butterfly model application, these are identified that can be improved, if need be, and are shown in Figure 9.3. For example, the TOD policy could be to improve active travel, automobile, density, design, and diversity criteria in the catchment area. Any increase in the latter should mean an increase in the number of jobs and improve the accessibility and higher densities in the station area. Parking capacity can be improved to increase parking supply and reduce traffic by distributing trips across different modes of transportation. This research can make a policy decision on the need for improving existing criteria and indicators. The planners need to consider the local components (e.g., local conditions) before the detailed proposal for TOD planning.

Since this research does not expect any uncertainty in the data and weight exercise, sensitivity analysis is adopted to incorporate this uncertainty. The weight for each eight criteria was changed by ± 10 %, one at a time, while others were equally increased or decreased, thereby generating 16 scenarios for this research. The node index ranged from 0.36 to 0.41 and the place index ranged from 0.32 to 0.37 (see Table 9.2). The results are not significantly affected by sensitivity analysis. It should be noted that the results of the sensitivity analysis could notice if the number of criteria and indicators were fewer as it would mean that the total weight of 1 gets spread over fewer criteria and indicators.

Table 9.2 Sensitivity analysis of TOD indicators, node index, and place index

Abbreviation	Base case	(+10% of N_AT)	(-10% of N_AT)	(+10% of N_HSR)	(-10% of N_HSR)	(+10% of N_FS)	(-10% of N_FS)	(+10% of N_AM)	(-10% of N_AM)	(+10% of N_DEN)	(-10% of N_DEN)	(+10% of N_DI)	(-10% of N_DI)	(+10% of N_DES)	(-10% of N_DES)	(+10% of N_ED)	(-10% of N_ED)
N_AT_1	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
N_AT_2	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
N_HSR_1	0.04	0.04	0.04	0.05	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
N_HSR_2	0.19	0.19	0.19	0.23	0.15	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
N_HSR_3	0.88	0.88	0.88	0.03	0.71	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88
N_HSR_4	0.59	0.59	0.59	0.71	0.47	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59
N_HSR_5	0.71	0.71	0.71	0.80	0.62	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71
N_FS_1	0.91	0.91	0.91	0.91	0.91	0.99	0.82	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91
N_FS_2	0.82	0.82	0.82	0.82	0.82	0.91	0.73	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82
N_FS_3	0.05	0.05	0.05	0.05	0.05	0.06	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
N_FS_4	0.41	0.41	0.41	0.41	0.41	0.49	0.33	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41
N_FS_5	0.94	0.94	0.94	0.94	0.94	0.88	0.76	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94
N_AM_1	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.38	0.26	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32
N_AM_2	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
N_AM_3	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.43	0.29	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36
N_AM_4	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.09	0.06	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
P_DEN_1	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.34	0.23	0.28	0.28	0.28	0.28	0.28	0.28
P_DEN_2	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.20	0.14	0.17	0.17	0.17	0.17	0.17	0.17
P_DEN_3	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.32	0.22	0.27	0.27	0.27	0.27	0.27	0.27
P_DI_1	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
P_DI_2	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.52	0.35	0.44	0.44	0.44	0.44
P_DES_1	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.02
P_DES_2	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.19	0.12	0.15	0.15
P_DES_3	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.69	0.46	0.57	0.57
P_ED_1	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.74	0.50
P_ED_2	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.99	0.68
P_ED_3	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.22	0.15
P_ED_4	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.56	0.37
Node index	0.40	0.40	0.40	0.36	0.37	0.41	0.37	0.41	0.39	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Place index	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.35	0.32	0.34	0.33	0.35	0.32	0.37	0.30

9.4 Conclusion

This research had two relevant objectives. First, the methodology developed a strand of research by drawing on the node-pace model. This model was suggested and implemented strategies for the analytical strength of some standard node and place measures. Based on a discussion, an extended butterfly model application was produced visible and knowledge about NKR HSR hub-specific accessibility and spatial development, some of which are not captured in standard node-place analyses.

Second, the empirical and related policies-support objective in that this research included in the model to the NKR HSR hub. This research discussed how to provide the strategic HSR hub put forward in the static vision. Given the LRT project in NKR municipality included in comprehensive analysis and operated with the same year of the HSR project and an extended butterfly model application is calculated using MDCA with experts' involvement and which expresses the TOD planning around the hub. A sensitivity analysis was also carried out to study how the results are affected by changes in weights or indicator values.

This analysis of node-place of NKR HSR hub reveals that had a node index higher than place index. This hub can be classified as an unbalanced node. Inferences were drawn from an extended butterfly model application results to recommend areas for improvement (see Figure 6) based on the low scores of criteria and indicators. Given the standardized score is one for evaluation. All scenarios in sensitivity analysis are not significantly affected. The scores reflect the existing situation from the government strategies and plans which required substantial investment to guide the TOD proposal for NKR HSR hub.

As the node perspective, although the convenient transfer is important for NKR HSR hub, especially neighboring municipalities and cities, feeder services depend on the size of cities. NKR municipalities have one line with two directions for LRT and two routes for songthaew shuttle service, however, most of them operate less frequencies. The limited frequency of LRT and songthaew shuttle service may cover the flow of NKR HSR hub passengers, but it restrains the value of the station as a place because of reduced access to and from the station

The number of songthaew shuttles due largely to the accommodative policy on private vehicle ownership and subsidized fuel prices, resulting in lower levels of service of songthaew shuttle. This performance could integrate fare structure with modes of transportation, while the urban morphology needs to strategically reshape for investment in public transportations. Given the low level of service of songthaew shuttles, concerned agencies need to modernize the songthaew service, improve safety, and provide training to the drivers to successfully convince private vehicle users to switch to this mode of public transport.

The parking capacity (for bikes and private vehicles) is scarce around the hub. The parking management needs to implement by local governments or personal businesses in response to specific parking and traffic problems. The general problems could be addressed (e.g., parking congestion, traffic congestion, and poor pedestrian environments) and the geographic areas are considered how to switch the use of private vehicles to mass transit services or non-motorized transportation.

Ride-sharing services are an alternative to substitute for private vehicle ownership and reduce carbon emissions. The vehicles are located in a residential area, priced by travel time, with convenient pick-up and drop-off procedures. This makes occasional use of an automobile affordable, even for low-income households. The bike-sharing service could be considered as well.

As the place perspective, NKR's population is much more than other cities along the corridor, implying a population threshold is required for viable urban development surrounding hub. However, the remotely located hub suffers from the lack of population threshold and fails the role as an economic hub.

With the intensive land use in the catchment area, a balancing different priorities of path diversity should require to increase with change in community composition in a way that reflects what is valued. The station area development of this hub looks like neighborhood TOD (local activity node), but it should design to access residents' perceptions about the neighborhood and opinions about potential TOD opportunities.

The walkable area surrounding the hub suffers a remarkable functional and spatial diversity of the functions living, working, and visiting. The clearer definitions should examine for urban design because places vary substantially between definitions leading to substantially different designs. Create, use, and develop put forward frame options for understanding the multiple perspectives.

The HSR hub located less than 5 km from the city center is lacking in densities of metropolitan amenities even though there are some commercial and business facilities around the hub. This area of economic development needs particular development strategies to accumulate information and the explanation for the achievement of economies of agglomeration.

Stimulating TOD through tax incentives would provide the incentive to utilize the station area development more intensively by improving legislation and regulation. TOD needs tax to provide services to generate through retail and commercial properties and to support population moving in viable areas as well as benefit the municipal government. For more discussion, see Chalermpong and Ratanawaraha (2016).

Balancing node and place functions in NKR HSR hub need improvement in many perspectives (e.g., strategic planning, financial supports, actors, and legislation and regulation). TOD planning for in the Thai context is a simplified representation of an even more complex constellation of actors and institutions. However, there is little discussion on the intuitional perspectives and financial support of station area development, especially the planning process and stakeholders. Further is needed to analyze the interaction between socioeconomic needs and quality of places and identify and select planning process approached that can respond to the complexity of the development process.

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CHAPTER 10

CONCLUSIONS AND RECOMMENDATIONS

This dissertation mainly aims to develop a comprehensive study to provide and improve transit-oriented development strategies surrounding HSR hub toward the sustainable development in Thai context. This chapter concludes the findings derived from decision making mechanism and regional, urban, and station-area level. Then the future prospects for further research are discussed.

10.1 Summary of key findings

10.1.1 Policy and regulation

The HSR project in Thailand was a strategic investment which expected to drive economic activities and economic growth along the pathway. The HSR project is not only infeasible but also faced four main barriers to development for the Thai government (operation service, TOD, the new organization and personnel, and fare structure). Based on the mechanism of the barriers of the Thai government for the HSR project, TOD plays an important key to drive the HSR project to sustainable development around the transit stations by improving transit stations with accessibility and land use with transport demands. TOD is integration between transportation systems and urban development.

The transportation system is divided into main public transportation (HSR hub) and feeder services (songthaew shuttle, LRT, and tuk-tuk) which connected the HSR hub to access and egress the railway passengers in various ranges. In the case of transport perspective, there are critical points in terms of operation (operation service), management (the new organization and personnel), and service (fare structure). The technical operation service is a political issue with investors about signaling and telecommuting and tract works from Bang Sue to Ban Phachi section. If the Thai government determines to use shard tracks in this section, the safety and reliability should perceive for railway passengers in advance.

The new organization and panel to drive the HSR project should act for railway operation and urban development since the HSR is an advanced technology and needs to hire experts to the joint venture (for land development) and hire private sector (for O&M section) However, Ministry of Finance and SRT are the managers to reduce the financial risk based on agreement. The fare structure for the HSR project can complete with private transportation and train's first-class and second-class, while other modes of transportation cannot naturally challenge. The developer should provide the marketing measures to support demand.

Meanwhile, urban development involves many factors to implementation (e.g., TOD index, legislation and regulation, and urban and transport planning), but the Thai government does not have the practical know-how to make it happened. An international transferable TOD concept from international viewpoints can be learned the decision-making from the best practices of other governments to promote and support the Thai context (i.e., specific areas for special development, land and community management, positive measure for town planning, organization, investment, and legislation and regulation).

Legislation and regulation are the key factors to drive other factors to successful TOD based on international experience. Thailand has similar development with Japan in terms of legislation and regulation. Yet, Thailand lacks many legislation and regulations such as urban

renewal, land collection, and integration between transit stations and urban development when compared with Japan. Besides City Planning Act is related to many acts in different government agencies. It affects the management and decision-making because of viewpoints. On the Thai side, the hard regulation is land expropriation around transit stations and needs revision because the development cannot take benefit to developing commercial areas. Besides, the Thai government does not have financial tool to support the developers and investors of the TOD project.

Specific areas for special development require setting the potential area for development through the master plan by using the node-place model. This model defines the general function of the station area to redevelopment in terms of balancing node-index (transportation systems) and place-index (urban development). The score in each dimension can assist the planners and governments to improve and classifies the TOD typologies to development.

Land and community management is an alternative to collect lands from different stakeholders for land readjustment and local people with low values and benefits for land banking. However, the private developer and government will have a condition to exchange such as public investment and taxation. Positive measures for town planning require the urban planners to encourage and attract the developers to invest by exchanging the benefits such as FAR bonus, and FAR transfer.

The organization includes policy agencies, local governments, and private developers to work together. Local government is a key driver for TOD in several countries to learn know-how from developers, but the practical approach between the Thai federal government management and local government is different. This is the management of federal government is centralized and local government obtains the low monetary for developing infrastructures.

10.1.2 Operation

Fukushima Shinkansen station is a representative Japanese Shinkansen and matches Nakhon Ratchasima HSR hub based on the gross provincial product, municipality size, travel distance from the origin, ridership, vacant land around the hub, and availability of feeder service.

At the regional level, the Fukushima Shinkansen station can stimulate the macroeconomic for the long run after the operation. The performance after the operation of the Fukushima Shinkansen station outperforms the performance before the operation of Fukushima Shinkansen station on a small scale, even though the station is a big size and locates on the mainline. Meanwhile, in the case of the short-term, the economy has weak productivity performance in some duration because it receives the risk to endure external factors such as oil crisis, economic bubble, and inflation rate. Hence, policy implementations to regulate transportation demand are a considerable tool for economic activity and social welfare.

The compound annual growth rate method proves that the operational Fukushima Shinkansen station is a negative impact on the Fukushima prefecture due to a decline in population and production value. This negative impact refers to shrinking the Fukushima prefecture. The local government should provide strategies and plans to test pre- and post-evaluation with negative factors.

In terms of economic development, the development of the Fukushima Shinkansen station is not only generative economic growth but also originates economic development in Fukushima prefecture. Because after the opening of the Fukushima Shinkansen station during

1990-2000, there has been an upward trend in the human development index of 0.33 percent per year due to support factors (longevity factor and standard of living factor), even though the number of outpatients has significantly undergone a rapid change.

At the urban and station-area level, the Fukushima Shinkansen station is evaluated the station catchment area by drawing the circular shape around the station via ArcGIS. This approach does not take geography into account when the area developed at a different time and the researcher cannot grasp the natural obstacle within the station catchment area.

A radius of the station catchment area is 12.4 and 17.6 km based on dense network and land value perspective, respectively. The station catchment area (12.4 km) beats only California cities since Fukushima city has a limitation of land to develop for urbanization. The specific results from the case study may not provide all factors affecting land value that influenced change in land value because of lack of sufficient data, namely public investment in infrastructure, change in land-use regulation, and landowner's investment. For these reasons, this research focuses on only the population and economic factors. The population, primary industry, secondary industry, and tertiary factor are a significant impact on land value from a macro perspective.

Meanwhile, in the case of the Nakhon Ratchasima HSR hub, the catchment area surrounding the city center of NKR is a radius of 5.18. Given that LRT is selected as the primary feeder service to access the Nakhon Ratchasima HSR hub. The Nakhon Ratchasima municipality is the socio-economic center of Thailand's northeastern province of Nakhon Ratchasima. The catchment area consists of primary and secondary development zones, covering a radius of 1.90 km from the Nakhon Ratchasima HSR hub and 5.18 km from the city center, respectively.

The survey results on access mode choice indicate the LRT (32.19 %) and songthaew shuttle services (11.76 %) as the primary and secondary feeders. The share of private vehicle use to access the HSR hub is as high as 48.08 %. As a result, it is necessary to convince motorists to switch from private vehicle use to public transport as modes of transport to access the HSR hub. Specifically, in the primary development zone, private vehicle use accounts for the largest proportion of the access mode choice to the HSR hub (78.31 %). In the secondary development zone, the LRT and songthaew shuttle services make up 76.42 %, consisting of 59.97 % and 16.45 % for LRT and songthaew shuttle services, respectively.

The MNL analysis results indicate that the significant variables of the primary feeder are travel distance, travel cost, and the availability of LRT line, while those of the secondary feeder are middle- and high-income brackets, car ownership, travel distance, travel cost, the availability of songthaew shuttle routes, and the availability of LRT lines. The MNL analysis also indicates the travel distance, travel cost, and the availability of the LRT line as the common significant variables for the primary and secondary feeder services.

The Tobit analysis results show that the significant demographic variables are income, car ownership, and motorcycle ownership, given tangible improvements are made to the facilities and infrastructure surrounding the Nakhon Ratchasima HSR hub. The expected WTP of the survey respondents for the primary and secondary feeder services to access the HSR hub is 1.094 USD/trip/person, vis-à-vis the travel costs of songthaew shuttle and LTR service (from the farthest LTR station to the HSR hub) of 0.25 USD and 0.50 USD, respectively. The finding demonstrates that the commuters are willing to pay if significant improvements are made to the facilities and feeder service quality, especially to the songthaew shuttle service.

Given the low level of service of songthaew shuttles (e.g., low number and frequency of vehicles), concerned agencies need to modernize the songthaew service, improve the safety, and provide training to the drivers to successfully convince private vehicle users to switch to this mode of public transport. To effectively discourage private vehicle use, the NKR municipality could adopt and implement high congestion charge penalty and land-use development (e.g., the parking lot some distance away from the HSR entrance), in addition to the mass-transit primary and secondary feeder systems.

To redevelopment around Nakhon Ratchasima HSR hub, an extended butterfly model is modified assessment for node and place model. Nakhon Ratchasima HSR hub is located in Nakhon Ratchasima municipality and beside the CBD, but it is classified as an unbalanced node with a moderate node-index score on average (0.40) and a low place-index score on average (0.33), given that the maximum score of node-index and place-index is 1. The classification implies that transportation supply is significantly higher than urban activities of station areas.

With the weighting method for subjective evaluation, a sensitivity analysis is adopted to validate the results and check for the potential uncertainties in weights and data. Sensitivity analysis is calculated with 16 scenarios by changing ± 10 % of weight values of each criterion and indicator at a time. The newest node-index score on average ranges from 0.36 to 0.41, while the newest place-index score on average ranges from 0.32 to 0.37. The results from all scenarios are not significantly affected by sensitivity analysis.

The criteria scores and indicators scores reflect the existing situation from the government strategies and plans which are sufficient to TOD and will require substantial investment in the station area. The local government may decide to improve TOD around the Nakhon Ratchasima HSR hub by improving its low-scoring criteria and indicators. The results for node-index and place-index hint to identify the problem of the station. The specific TOD policy for the Nakhon Ratchasima HSR hub could be improved Active travel, automobile, diversity, and design based on criteria with the most potential for improvement of the extended butterfly model application. At the urban development and spatial development, the scores are useful to guide the TOD proposal for the Nakhon Ratchasima HSR hub.

10.1.3 TOD strategies in the HSR project in Thailand

1) Policy and operation

- Transport policy

- Set one signaling and telecommunication for one alignment (dedicated tracks) to prevent the safety and reliability (Chapter 4).

- Establish the new organization and panel by the State Railway of Thailand and Ministry of Finance. The operation and maintenance should hire outsources, while TOD should cooperate with private land developers (Chapter 4).

- Provide the financial risk management and indirect income to overcome the fare structure (Chapter 4).

- Implement the policy and strategy division and driver division to the national viewpoint and operator division and developer division to the local viewpoint (Chapter 5).

- Provide the financial measures and tools to support developer (Chapter 5).

- Implement the policies by providing regulator in terms of land use, human settle, and externalities such as quality of life (Chapter 6).

- Provide the pre-evaluation and post-evaluation for the criteria and indicators that influenced the HSR hub (Chapter 6).

- Set the primary and secondary feeder services to access to and from HSR hub for designing transport network and station catchment area (Chapter 7-8).

- Improve the access mode choice to and from HSR hub by improving travel distance, travel cost, and the availability of the LRT line for the primary and secondary feeder services (Chapter 8).

- Set the expected WTP for the primary and secondary feeder services to access the HSR hub is 1.094 USD/ trip/ person, vis-à-vis the travel costs of songthaew shuttle and LTR service of 0.25 USD and 0.50 USD, respectively (Chapter 8).

- Provide the feeder services to neighboring municipalities and cities (Chapter 9).

- Improve the image of LRT service by improving the quality of service to meet the majority HSR passenger (Chapter 9).

- Improve the parking capacity to people to switch the private transport to public transport (Chapter 9).

- Improve ride-sharing at the station area to substitute for private vehicle ownership and reduce carbon emissions (Chapter 9).

- Land-use policy

- Provide spatial development and planning at the national, regional, sub-regional, provincial, town, and specific area levels to set policy statements on spatial development (Chapter 5).

- Build the necessary population and industries to promote sustainable economic development (Chapter 7).

- Balance the different priorities of path diversity to increase with change in community composition (Chapter 9).

- Provide and maintain a better pedestrian environments and facilities for HSR passengers (Chapter 9)

- Improve economic growth and attract HSR passengers (Chapter 9) Improve and provide tax intensive to utilize the station area development more incentive (Chapter 9).

- Improve and provide tax incentive to utilize the station area development (Chapter 9)

2) Regulation

Rectify the expropriation or propose a proposal TOD which involved the spatial planning in each level and identified the organizations to lead in each of issues (Chapter 4-5).

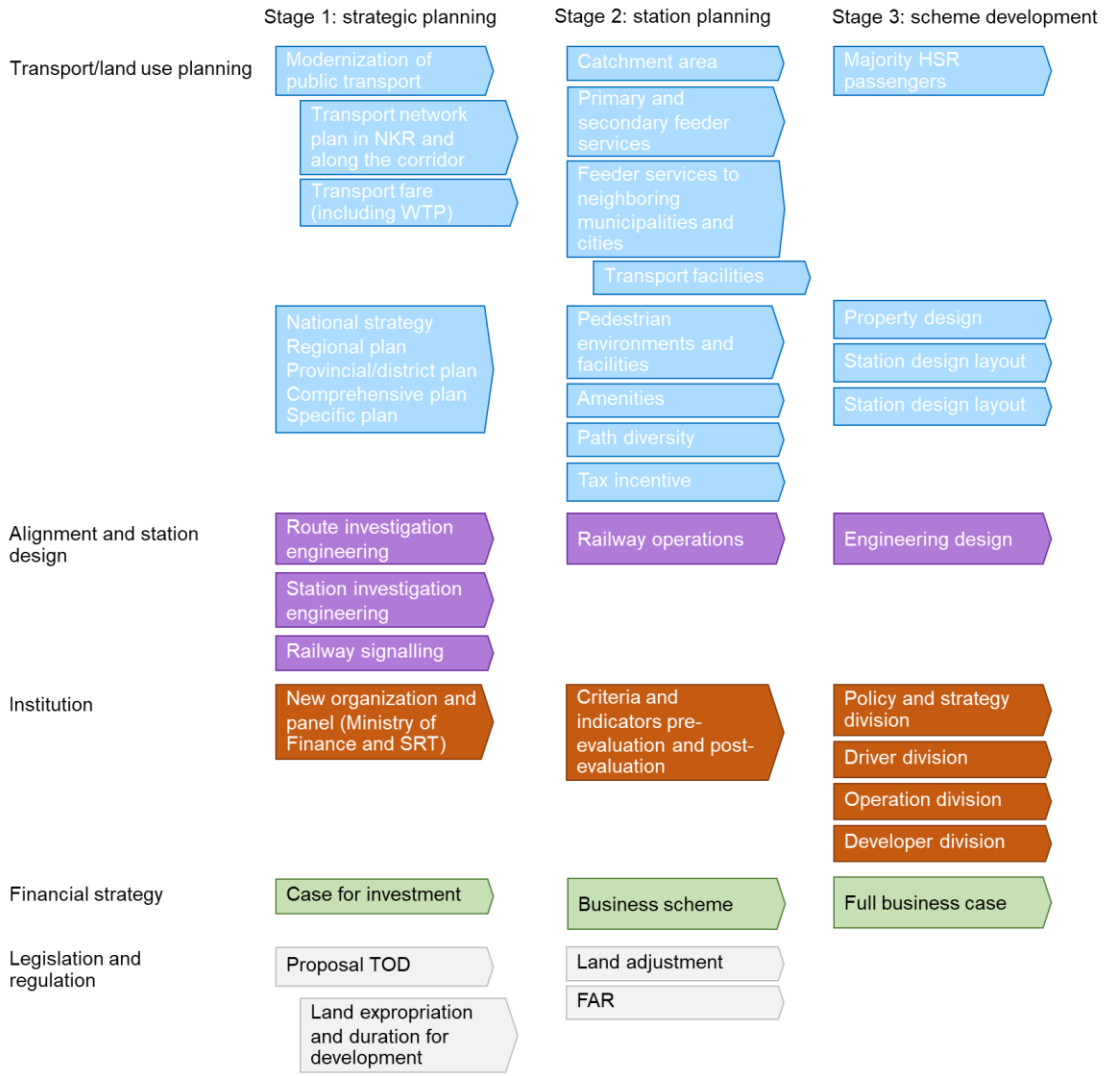

Figure 10.1 TOD strategies in the HSR project in Thailand

10.2 Future prospects

This study attempts to introduce the preliminary research on TOD strategies surrounding Nakhon Ratchasima HSR hub. Further researches are required to identify and adopt planning approaches that can respond to the complexity of the development process, focus on building and urban design for integrating with developments in the local context, overcome automobile in the primary development zone, and respond to uncertainty in development urban process.

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SCHOLARLY PUBLICATIONS

Published journal articles:

Tissayakorn, K., Nakamura, F., Tanaka, S., Miura, S. (2019a) A Study on the Barriers of the Thai Government for Development of High Speed Rail Project, Journal of the Eastern Asia Society for Transportation Studies, vol. 13, pp. 555-573.

Conference proceedings:

Tissayakorn, K., Nakamura, F., Tanaka, S., Miura, S. (2019b) Measuring the impact of economic development on Fukushima Shinkansen station investment. Proceedings of 2019 International Conference Asia-Pacific Planning Societies.

Forthcoming journal articles/Forthcoming conference proceedings/Under revision:

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Tissayakorn, K., Nakamura, F., Tanaka, S. A meta-analysis of critical factors from international transit-oriented development perspective. (The full paper is under screening)

Award:

Best Paper Presentation Award at 2019 International Conference Asia-Pacific Planning Societies, August 2019

APPENDIX A

(QUESTIONNAIRE SHEET AND SURVEY PERMISSION)

1) QUESTIONNAIRE INFORMATION
2) THE LIGH RAIL TRANSIT PROJECT
3) SURANAREE UNIVERSITY OF TECHNOLOGY
4) THE MALL
5) BUS TERMINAL 2
6) NAKHON RATCHASIMA RAILWAY STATION

Transportation and urban engineering laboratory
Graduation School of Urban Innovation
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Questionnaire on High-Speed Rail Station Accessibility and Built Environment

The Questionnaire is a part of a study on transit-oriented development strategies surrounding high-speed rail hub, a case study of Nakhon Ratchasima HSR hub. The research is a doctoral student who studies at a transportation and urban research group, Graduate School of Urban Innovation, Institute of Urban Innovation, Yokohama National University, Japan.

The main objective is to (1) investigate the patterns of access trip to Nakhon Ratchasima high-speed rail station, and (2) what are the factor affecting users to a propensity to use public transportation to Nakhon Ratchasima high-speed rail station. This questionnaire consists of three parts including socioeconomic information, accessibility, built environment.

The above data will be a useful and significant impact on transit-oriented development surrounding Nakhon Ratchasima high-speed rail hub to expedite the advancement of transportation and urban development in the city. Our research team would like to thank you for all support and the data will be used only for research purpose.

Thank you very much

Professor Fumuhiko Nakamura

Associate Professor Shinji Tanaka

Mr Kittipong Tissayakorn

Ph.D. student

Survey team

For staff only	
Name (……..…..)	Sample No. (……..)
Place (……)	Date (……)
	Time (……) AM / PM

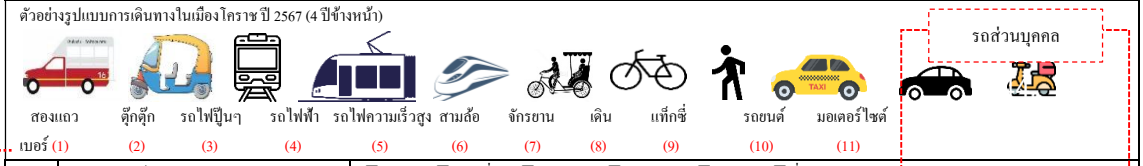
Target groups: the people who live in a radius of 5.18 km from the city center

สำหรับเจ้าหน้าที่	ลำดับของแบบสอบถาม (……..)
ชื่อ (คุณ……..)	วันที่ (……กุมภาพันธ์ 2563)
สถานที่ (เดอะมอลล์, เทอมินอล 21, บขส, มทส, รถไฟ……)	เวลา (……) เช้า/บ่าย

ส่วนที่ 1: พฤติกรรมการเดินทางเพื่อเข้าถึงสถานีรถไฟความเร็วสูงนครราชสีมา

ตอนที่ 1: การเข้าถึงสถานีรถไฟความเร็วสูงนครราชสีมาของผู้เดินทาง

ตัวอย่างรูปแบบการเดินทางในเมืองโคราช ปี 2567 (4 ปีข้างหน้า)



สองแถว (1) | ตุ๊กตุ๊ก (2) | รถไฟปฐุนๆ (3) | รถไฟฟ้า (4) | รถไฟความเร็วสูง (5) | สามล้อ (6) | จักรยาน (7) | เดิน (8) | แท็กซี่ (9) | รถยนต์ (10) | มอเตอร์ไซค์ (11)

1	วัตถุประสงค์ในการเดินทาง	☐ ทำงาน ☐ ท่องเที่ยว ☐ การศึกษา ☐ ครอบครัว ☐ สุขภาพ ☐ อื่นๆ.....					
2	ถ้าท่านจะต้องเดินทางมาสถานีรถไฟความเร็วสูงนครราชสีมา ท่านจะเลือกรูปแบบการเดินทางอย่างไร	บ้าน/หอ	จุดเปลี่ยนรูปแบบการเดินทางที่...				สถานีรถไฟความเร็วสูงนครราชสีมา
			1	2	3	4	
		สถานที่					
		การเดินทาง					
3	ความถี่ในการใช้บริการ (ครั้ง/เดือน)	☐ 1	☐ 2	☐ 3	☐ 3	☐ อื่นๆ.....	
4	ความเต็มใจที่จะจ่าย (บาท/ทิศทาง)	☐ 10	☐ 15	☐ 20	☐ 25	☐ อื่นๆ.....	
5	ระยะทางที่ยอมรับได้ (กิโลเมตร)	☐ 0.5	☐ 1	☐ 1.5	☐ 2.5	☐ อื่นๆ.....	
6	ระยะเวลาที่ยอมรับได้ (นาที)	☐ 5	☐ 10	☐ 15	☐ 20	☐ อื่นๆ.....	

ตอนที่ 2: ปัจจัยที่มีผลกระทบต่อพฤติกรรมการเดินทางเข้าถึงย่านสถานีรถไฟความเร็วสูงนครราชสีมา

1	การเชื่อมต่อของระบบขนส่ง	☐ น้อยมาก	☐ น้อย	☐ ดี	☐ ดีมาก
2	ความน่าดึงดูดของระบบขนส่ง	☐ น้อยมาก	☐ น้อย	☐ ดี	☐ ดีมาก
3	ความน่าดึงดูดในการเดิน	☐ น้อยมาก	☐ น้อย	☐ ดี	☐ ดีมาก
4	การพัฒนาพื้นที่รอบสถานี	☐ น้อยมาก	☐ น้อย	☐ ดี	☐ ดีมาก
5	โครงข่ายถนนครอบคลุมการเดินทาง	☐ น้อยมาก	☐ น้อย	☐ ดี	☐ ดีมาก
6	สวนสาธารณะ	☐ น้อยมาก	☐ น้อย	☐ ดี	☐ ดีมาก
7	ที่จอดรถ	☐ น้อยมาก	☐ น้อย	☐ ดี	☐ ดีมาก
8	ราคาค่าโดยสาร	☐ แพงมาก	☐ แพง	☐ ถูก	☐ ถูกมาก
9	คุณภาพการให้บริการระบบขนส่ง	☐ ไม่พอใจมาก	☐ ไม่พอใจ	☐ พอใจ	☐ พอใจมาก
10	ช่วงเวลาที่ใช้บริการ	☐ เร่งด่วน (6:30-8:30 เช้า หรือ 4:30-17:30 เย็น)		☐ นอกเวลาเร่งด่วน	
11	ความสามารถในการเดิน (นาที)	☐ 5	☐ 10	☐ 15	☐ อื่นๆ.....

ส่วนที่ 2: การเปลี่ยนรูปแบบการเดินทางจากรถส่วนบุคคล (รถยนต์/มอเตอร์ไซค์) เป็นระบบขนส่งสาธารณะในย่านสถานีรถไฟความเร็วสูงนครราชสีมา

1	ระยะทางจากบ้าน/หอถึงหน้าปากซอย (เมตร)	☐ < 50 ☐ 51-100 ☐ 101-150 ☐ 151-200 ☐ อื่นๆ.....	
2	ความถี่ในการใช้รถยนต์/มอเตอร์ไซค์ (วัน/สัปดาห์)	**รถยนต์**	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
		มอเตอร์ไซค์	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
3	เดินทางพร้อมกับ ญาติ/ครอบครัว/เพื่อน	☐ ใช่ ☐ ไม่ใช่	
4	รับ-ส่ง ญาติ/ครอบครัว/เพื่อน	☐ ใช่ ☐ ไม่ใช่	
5	มีที่จอดรถฟรีที่ที่ทำงาน	☐ ใช่ ☐ ไม่ใช่	
6	มีที่จอดรถฟรีที่บ้าน	☐ ใช่ ☐ ไม่ใช่	
7	เหตุผลที่จะเปลี่ยนมาใช้ระบบขนส่งสาธารณะ (3 อันดับ) //เขียนตัวเลข 1,2,3	☐ ความปลอดภัย ☐ สะอาดและสะดวกสบาย ☐ ครอบคลุมพื้นที่ที่จะเดินทาง ☐ ค่าโดยสารถูก ☐ ลดระยะเวลาในการเดินทาง ☐ ไม่ได้ใช้รถยนต์/รถมอไซค์	
8	ระยะทางจากที่ทำงานถึงระบบขนส่งสาธารณะ(รถไฟฟ้า/รถสองแถว) (เมตร)	☐ < 50 ☐ 51-100 ☐ 101-150 ☐ 151-200 ☐ อื่นๆ.....	

ส่วนที่ 3: ข้อมูลส่วนบุคคล

1	เพศ	☐ ชาย ☐ หญิง
2	อายุ (ปี)	☐ ≤ 22 ☐ 23-40 ☐ 41-64 ☐ ≥ 65
3	อาชีพ	☐ นักเรียน/นักศึกษา ☐ พนักงานออฟฟิส ☐ ว่างงาน ☐ ฟรีแลนซ์ ☐ อื่นๆ.....
4	คุณอาศัยอยู่ที่ไหน	จุดอ้างอิง..... ถนน..... ซอย.....
5	รายได้ (บาท/เดือน)	☐ ≤ 20,000 ☐ 20,001-50,000 ☐ ≥ 50,001
6	การศึกษา	☐ มัธยมศึกษา ☐ ปริญญาตรี ☐ ปริญญาโท ☐ อื่นๆ.....
7	คุณมีรถยนต์หรือมอเตอร์ไว้ครอบครองหรือไม่	รถยนต์ ☐ ไม่ ☐ มี (☐ 1 ☐ 2 ☐ อื่นๆ.....) มอเตอร์ไซค์ ☐ ไม่ ☐ มี (☐ 1 ☐ 2 ☐ อื่นๆ.....)
8	คุณมีใบขับขี่หรือไม่	☐ มี ☐ ไม่มี

สาระสำคัญของโครงการ

- ค่าโดยสาร 10+1*ระยะทาง
- ความถี่ในการให้บริการ
  - 10 นาที/ขบวน
  - 5 นาที/ขบวน (7:00-8:30, 16:00-17:30 น.)

นครราชสีมา (G13)	ระยะทาง (กม.)	ระยะเวลา (นาที)	ค่าโดยสาร (บาท)
ปากช่อง	78.89	19:33	222
อยุธยา	142.78	34:27	337
สระบุรี	188.89	45:33	420
กรุงเทพ	253	77:00	535

ที่ TUEL 2563

มหาลัยแห่งชาติโยโกฮะมะ
คณะวิศวรกรรมสาสตร์
สาขาวิศวกรรมเมืองนวัตกรรม
75-5 โทคิวะได โฮโดกายะ
เมืองโยโกฮะมะ จังหวัดคานะกะวะ
240-8501 ประเทศญี่ปุ่น

6 กุมภาพันธ์ 2563

เรื่อง ขอความอนุเคราะห์พื้นที่และอนุญาตทำการเก็บข้อมูลเพื่อการวิจัย
เรียน คณบดีคณะวิศวกรรมศาสตร์ มหาวิทยาลัยเทคโนโลยีสุรนารี

เนื่องด้วยกระผมนายกิตติพงษ์ ทิสยากร เป็นนักศึกษาปริญญาเอก คณะวิศวกรรมศาสตร์ สาขาวิศวกรรมระบบขนส่งและการพัฒนาเมือง มหาลัยแห่งชาติโยโกฮะมะ ประเทศญี่ปุ่น และโฟกัสความสำคัญกับการทำวิจัยเรื่อง ยุทธศาสตร์การพัฒนาพื้นที่รอบสถานีรถไฟความเร็วสูง กรณีศึกษาสถานีรถไฟความเร็วสูงนครราชสีมา โดยกระผมอยู่ระหว่างการวิเคราะห์วัตถุประสงค์ที่ 4 และ 5 ของงานวิจัยประกอบด้วย เรื่องพฤติกรรมการเดินทางเข้าถึงสถานีรถไฟความเร็วสูงฯ และเรื่องการพัฒนาพื้นที่ของเมืองให้สอดรับกับทัศนคติของนักเดินทางภายในระยะการเข้าถึงของสถานีรถไฟความเร็วสูงฯ นั้น

ในการนี้ เพื่อให้การดำเนินงานวิจัยเป็นไปอย่างมีประสิทธิภาพ กระผมจึงใคร่ขอความอนุเคราะห์ท่านและผู้เชี่ยวชาญด้านวิศวกรรมขนส่งและการพัฒนาเมือง เพื่อโปรดพิจารณาอนุญาตให้กระผมเข้าพบและสัมภาษณ์เกี่ยวกับแบบสอบถามข้างต้น ตามวันและเวลาที่ท่านนัดหมาย ระหว่างวันที่ 20 กุมภาพันธ์ 2563 ถึง 3 มีนาคม 2563 ช่วงเวลา 11:00 ถึง16:30 น. เพื่อเป็นข้อมูลในการทำงานดุษฎีนิพนธ์ดังกล่าวต่อไปอย่างมีประสิทธิภาพ ทั้งนี้ งานวิจัยดังกล่าวมอบหมายให้นายกิตติพงษ์ ทิสยากร เป็นผู้ประสานงาน
e-mail: ktissayakorn@gmail.com หรือ tissayakorn-kittipong-pt@ynu.jp

จึงเรียนมาเพื่อโปรดพิจารณาและหวังเป็นอย่างยิ่งว่าจะได้รับความอนุเคราะห์จากท่าน และขอขอบคุณมา ณ โอกาสนี้

ขอแสดงความนับถือ

กิตติพงษ์ ทิสยากร

(นายกิตติพงษ์ ทิสยากร)
ผู้ทำการวิจัย

ห้องวิจัยวิศวกรรมขนส่งและการพัฒนาเมือง
โทร/โทรสาร (+81)-45-339-4039

ที่ TUEL 2563

มหาวิทยาลัยแห่งชาติโยโกฮะมะ
คณะวิศวรกรรมสาสตร์
สาขาวิศวกรรมเมืองนวัตกรรม
75-5 โทคิวะได โฮโดกายะ
เมืองโยโกฮะมะ จังหวัดคานะกะวะ
240-8501 ประเทศญี่ปุ่น

7 กุมภาพันธ์ 2563

เรื่อง ขอความอนุเคราะห์พื้นที่และอนุญาตทำการเก็บข้อมูลเพื่อการวิจัย
เรียน คุณชินาภัฒน์ พิมพ์ศรีแก้ว (ผู้จัดการทั่วไปปฏิบัติการ)
สิ่งที่ส่งมาด้วย สำเนาแบบสอบถาม

เนื่องด้วยกระผมนายกิตติพงษ์ ทิสยากร เป็นนักศึกษาปริญญาเอก คณะวิศวกรรมศาสตร์ สาขาวิศวกรรมระบบขนส่งและการพัฒนาเมือง มหาวิทยาลัยแห่งชาติโยโกฮะมะ ประเทศญี่ปุ่น และโฟกัสความสำคัญกับการทำวิจัยเรื่อง ยุทธศาสตร์การพัฒนาพื้นที่รอบสถานีรถไฟความเร็วสูง กรณีศึกษาสถานีรถไฟความเร็วสูงนครราชสีมา โดยกระผมอยู่ระหว่างการวิเคราะห์วัตถุประสงค์ที่ 4 และ 5 ของงานวิจัยประกอบด้วย เรื่อง พฤติกรรมการเดินทางเข้าถึงสถานีรถไฟความเร็วสูงฯ และเรื่องการพัฒนาพื้นที่ของเมืองให้สอดรับกับทัศนคติของนักเดินทางภายในระยะการเข้าถึงของสถานีรถไฟความเร็วสูงฯ นั้น

ในการนี้ เพื่อให้การดำเนินงานวิจัยเป็นไปอย่างมีประสิทธิภาพ กระผมและคณะทำงานจำนวน 3 ท่าน มีความจำเป็นต้องลงพื้นที่เพื่อเก็บข้อมูลจากแบบสอบถามของประชาชนผู้อาศัยในเมืองนครราชสีมา และคัดเลือกเฉพาะพื้นที่ที่มีศักยภาพในการให้บริการประชากรในการทำกิจกรรมต่างๆ ซึ่งรวมพื้นที่ของหน่วยงานท่านด้วย ระหว่างวันที่ 20 กุมภาพันธ์ 2563 ถึง 3 มีนาคม 2563 ช่วงเวลา 10:00 ถึง 20:30 น. รวมทั้ง มีความประสงค์ที่จะขอสัมภาษณ์ ลูกค้าและหรือสถานีขนส่งผู้โดยสาร จังหวัดนครราชสีมา ประมาณ 100-150 คน ทั้งนี้ งานวิจัยดังกล่าวมอบหมายให้นายกิตติพงษ์ ทิสยากร เป็นผู้ประสานงาน e-mail: ktissayakorn@gmail.com หรือ tissayakorn-kittipong-pt@ynu.jp

จึงเรียนมาเพื่อโปรดพิจารณาและหวังเป็นอย่างยิ่งว่าจะได้รับความอนุเคราะห์จากท่าน และขอขอบคุณมา ณ โอกาสนี้

ขอแสดงความนับถือ

กิตติพงษ์ ทิสยากร

(นายกิตติพงษ์ ทิสยากร)
ผู้ทำการวิจัย

ห้องวิจัยวิศวกรรมขนส่งและการพัฒนาเมือง
โทร/โทรสาร (+81)-45-339-4039

ที่ TUEL 2563

มหาวิทยาลัยแห่งชาติโยโกฮะมะ
คณะวิศวรกรรมสาสตร์
สาขาวิศวกรรมเมืองนวัตกรรม
75-5 โทคิวะได โฮโดกายะ
เมืองโยโกฮะมะ จังหวัดคานะกะวะ
240-8501 ประเทศญี่ปุ่น

7 กุมภาพันธ์ 2563

เรื่อง ขอความอนุเคราะห์พื้นที่และอนุญาตทำการเก็บข้อมูลเพื่อการวิจัย
เรียน ผู้บริหารสถานีขนส่งผู้โดยสาร จังหวัดนครราชสีมา (คุณศรรบ หล่อประเสริฐ)
สิ่งที่ส่งมาด้วย สำเนาแบบสอบถาม

เนื่องด้วยกระผมนายกิตติพงษ์ ทิสยากร เป็นนักศึกษาปริญญาเอก คณะวิศวกรรมศาสตร์ สาขาวิศวกรรมระบบขนส่งและการพัฒนาเมือง มหาวิทยาลัยแห่งชาติโยโกฮะมะ ประเทศญี่ปุ่น และโฟกัสความสำคัญกับการทำวิจัยเรื่อง ยุทธศาสตร์การพัฒนาพื้นที่รอบสถานีรถไฟความเร็วสูง กรณีศึกษาสถานีรถไฟความเร็วสูงนครราชสีมา โดยกระผมอยู่ระหว่างการวิเคราะห์วัตถุประสงค์ที่ 4 และ 5 ของงานวิจัยประกอบด้วย เรื่องพฤติกรรมการเดินทางเข้าถึงสถานีรถไฟความเร็วสูงฯ และเรื่องการพัฒนาพื้นที่ของเมืองให้สอดรับกับทัศนคติของนักเดินทางภายในระยะการเข้าถึงของสถานีรถไฟความเร็วสูงฯ นั้น

ในการนี้ เพื่อให้การดำเนินงานวิจัยเป็นไปอย่างมีประสิทธิภาพ กระผมและคณะทำงานจำนวน 3 ท่าน มีความจำเป็นต้องลงพื้นที่เพื่อเก็บข้อมูลจากแบบสอบถามของประชาชนผู้อาศัยในเมืองนครราชสีมา และคัดเลือกเฉพาะพื้นที่ที่มีศักยภาพในการให้บริการประชากรในการทำกิจกรรมต่างๆ ซึ่งรวมพื้นที่ของหน่วยงานท่านด้วย ระหว่างวันที่ 20 กุมภาพันธ์ 2563 ถึง 3 มีนาคม 2563 ช่วงเวลา 8:00 ถึง 20:30 น. รวมทั้ง มีความประสงค์ที่จะขอสัมภาษณ์ ลูกค้าและหรือสถานีขนส่งผู้โดยสาร จังหวัดนครราชสีมา ประมาณ 100-150 คน ทั้งนี้ งานวิจัยดังกล่าวมอบหมายให้นายกิตติพงษ์ ทิสยากร เป็นผู้ประสานงาน e-mail: ktissayakorn@gmail.com หรือ tissayakorn-kittipong-pt@ynu.jp

จึงเรียนมาเพื่อโปรดพิจารณาและหวังเป็นอย่างยิ่งว่าจะได้รับความอนุเคราะห์จากท่าน และขอขอบคุณมา ณ โอกาสนี้

ขอแสดงความนับถือ

กิตติพงษ์ ทิสยากร

(นายกิตติพงษ์ ทิสยากร)
ผู้ทำการวิจัย

ห้องวิจัยวิศวกรรมขนส่งและการพัฒนาเมือง
โทร/โทรสาร (+81)-45-339-4039

ที่ TUEL 2563

มหาวิทยาลัยแห่งชาติโยโกฮะมะ
คณะวิศวกรรมศาสตร์
สาขาวิศวกรรมการพัฒนาเมืองด้วย
นวัตกรรม 75-5 โทคิวะได โฮโดกายะ
เมืองโยโกฮะมะ จังหวัดคะนะกะวะ
240-8501 ประเทศญี่ปุ่น

6 กุมภาพันธ์ 2563

เรื่อง ขอความอนุเคราะห์พื้นที่และอนุญาตทำการเก็บข้อมูลเพื่อการวิจัย
เรียน ผู้ว่าการรถไฟแห่งประเทศไทย

เนื่องด้วยกระผมนายกิตติพงษ์ ทิสยากร เป็นนักศึกษาปริญญาเอก คณะวิศวกรรมศาสตร์ สาขาวิศวกรรมระบบขนส่งและการพัฒนาเมือง มหาวิทยาลัยแห่งชาติโยโกฮะมะ ประเทศญี่ปุ่น และโฟกัสความสำคัญกับการทำวิจัยเรื่อง ยุทธศาสตร์การพัฒนาพื้นที่รอบสถานีรถไฟความเร็วสูง กรณีศึกษาสถานีรถไฟความเร็วสูงนครราชสีมา โดยกระผมอยู่ระหว่างการวิเคราะห์วัตถุประสงค์ที่ 4 และ 5 ของงานวิจัยประกอบด้วย เรื่อง พฤติกรรมการเดินทางเข้าถึงสถานีรถไฟความเร็วสูงฯ และเรื่องการพัฒนาพื้นที่ของเมืองให้สอดรับกับทัศนคติของนักเดินทางภายในระยะการเข้าถึงของสถานีรถไฟความเร็วสูงฯ นั้น

ในการนี้ เพื่อให้การดำเนินงานวิจัยเป็นไปอย่างมีประสิทธิภาพ กระผมและคณะทำงานจำนวน 8 ท่าน มีความจำเป็นต้องลงพื้นที่เพื่อเก็บข้อมูลจากแบบสอบถามของประชาชนผู้อาศัยในเมืองนครราชสีมา และคัดเลือกเฉพาะพื้นที่ที่มีศักยภาพในการให้บริการประชากรในการทำกิจกรรมต่างๆ ซึ่งรวมพื้นที่ของหน่วยงานท่านด้วย ระหว่างวันที่ 19 กุมภาพันธ์ 2563 ถึง 4 มีนาคม 2563 ช่วงเวลา 07:00 ถึง 20:30 น. ทั้งนี้ งานวิจัยดังกล่าวมอบหมายให้นายกิตติพงษ์ ทิสยากร เป็นผู้ประสานงาน e-mail: ktissayakorn@gmail.com หรือ tissayakorn-kittipong-pt@ynu.jp

จึงเรียนมาเพื่อโปรดพิจารณาและหวังเป็นอย่างยิ่งว่าจะได้รับความอนุเคราะห์จากท่าน และขอขอบคุณมา ณ โอกาสนี้

ขอแสดงความนับถือ

กิตติพงษ์ ทิสยากร

(นายกิตติพงษ์ ทิสยากร)
ผู้ทำการวิจัย

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โทร/โทรสาร (+81)-45-339-4039

APPENDIX B

DATA ACCESS REQUEST

1) THE DEPARTMENT OF PULIC WORKS AND TOWN & COUNTRY PLANNING
2) THE TREASURY DEPARTMENT)

ที่ TUEL 2563

มหาวิทยาลัยแห่งชาติโยโกสะมะ
คณะวิศวกรรมสาสตร์
สาขาวิศวกรรมการพัฒนาเมืองด้วยนวัตกรรม
75-5 โทคิวะได โฮโดกายะ เมืองโยโกสะมะ
จังหวัดคะนะกะวะ 240-8501 ประเทศญี่ปุ่น

10 กุมภาพันธ์ 2563

เรื่อง ขอความอนุเคราะห์ข้อมูลประกอบการทำยุทธศาสตร์การพัฒนาพื้นที่โดยรอบสถานีรถไฟความเร็วสูง
เรียน โยธาธิการและผังเมืองจังหวัดนครราชสีมา

ตามที่นายกิตติพงษ์ ทิสยากร นักวิเคราะห์นโยบายและแผน ระดับชำนาญการ กองยุทธศาสตร์การพัฒนาโครงสร้างพื้นฐาน สำนักงานสภาพัฒนาการเศรษฐกิจและสังคมแห่งชาติได้รับทุนรัฐบาลญี่ปุ่นเพื่อลาศึกษาต่อในระดับปริญญาเอก ด้านการพัฒนาเมืองด้วยนวัตกรรม มหาลัยแห่งชาติโยโกสะมะ ประเทศญี่ปุ่น ระหว่างวันที่ 1 ตุลาคม 2561 – 1 ตุลาคม 2564 ภายใต้หัวข้อวิจัย "ยุทธศาสตร์การพัฒนาพื้นที่โดยรอบสถานีรถไฟความเร็วสูง กรณีศึกษาสถานีรถไฟความเร็วสูงนครราชสีมา" โดยมีศาสตร์จารย์ ดร. ฟุมิฮิโกะ นากามุระ เป็นประธานกรรมการควบคุมดุษฎีนิพนธ์ ซึ่งขณะนี้อยู่ในระหว่างขั้นตอนการเก็บข้อมูลเพื่อใช้ประกอบการวิเคราะห์ความเหมาะสมเชิงพื้นที่และประเมินความสัมพันธ์ระหว่างผู้ใช้บริการและดัชนีการพัฒนาพื้นที่โดยรอบสถานีรถไฟความเร็วสูงนครราชสีมานั้น

ในการนี้ มหาวิทยาลัยแห่งชาติโยโกสะมะขอความอนุเคราะห์ข้อมูลมาตรฐานสีสัญลักษณ์การใช้ประโยชน์อาคาร มาตรฐานสัญลักษณ์การใช้ประโยชน์ที่ดิน และข้อมูลที่สำคัญตามมาตรฐานกรมโยธาธิการและผังเมือง (Database Design) ภายในพื้นที่รัศมี 6.2 กิโลเมตรจากอนุสาวรีย์ท้าวสุรนารี จังหวัดนครราชสีมา ระหว่างปี 2547 – 2563 จากโยธาธิการและผังเมืองจังหวัดนครราชสีมาในรูปแบบ shapefile หรือชั้นข้อมูลที่สามารถเปิดเผยได้ในระดับสารสนเทศเพื่อใช้เป็นข้อมูลสนับสนุนการวิเคราะห์ข้อมูล ซึ่งข้อมูลดังกล่าวจะไม่ส่งผลกระทบต่อองค์กรของท่านและใช้เพื่อการวิจัยเท่านั้น โดยมอบหมายให้นายกิตติพงษ์ ทิสยากร โทรศัพท์ (+81) 94-048-4359 จดหมายอิเล็กทรอนิกส์ ktissayakom@gmail.com เป็นผู้ประสานงาน

จึงเรียนมาเพื่อโปรดพิจารณาและให้ความอนุเคราะห์ด้วย จักขอบคุณยิ่ง

ขอแสดงความนับถือ

(ศาสตร์จารย์ ดร. ฟุมิฮิโกะ นากามุระ)
รองอธิการบดีมหาวิทยาลัยแห่งชาติโยโกสะมะ

ห้องวิจัยวิศวกรรมขนส่งและการพัฒนาเมือง
โทรศัพท์ (+81) 45-339-4039

ที่ TUEL 2563

มหาวิทยาลัยแห่งชาติโยโกฮะมะ
คณะวิศวกรรมศาสตร์
สาขาวิศวกรรมการพัฒนาเมืองด้วยนวัตกรรม
75-5 โทคิวะได โฮโดกายะ เมืองโยโกฮะมะ
จังหวัดคะนะกะวะ 240-8501 ประเทศญี่ปุ่น

10 กุมภาพันธ์ 2563

เรื่อง ขอความอนุเคราะห์ข้อมูลประกอบการทำยุทธศาสตร์การพัฒนาพื้นที่โดยรอบสถานีรถไฟความเร็วสูง
เรียน ธนารักษ์พื้นที่นครราชสีมา

ตามที่นายกิตติพงษ์ ทิสยากร นักวิเคราะห์นโยบายและแผน ระดับชำนาญการ กองยุทธศาสตร์การพัฒนาโครงสร้างพื้นฐาน สำนักงานสภาพัฒนาการเศรษฐกิจและสังคมแห่งชาติได้รับทุนรัฐบาลญี่ปุ่นเพื่อศึกษาต่อในระดับปริญญาเอก ด้านการพัฒนาเมืองด้วยนวัตกรรม มหาลัยแห่งชาติโยโกฮะมะ ประเทศญี่ปุ่น ระหว่างวันที่ 1 ตุลาคม 2561 – 1 ตุลาคม 2564 ภายใต้หัวข้อวิจัย “ยุทธศาสตร์การพัฒนาพื้นที่โดยรอบสถานีรถไฟความเร็วสูง กรณีศึกษาสถานีรถไฟความเร็วสูงนครราชสีมา” โดยมีศาสตร์จารย์ ดร. ฟุมิฮิโกะ นากามุระ เป็นประธานกรรมการควบคุมดุษฎีนิพนธ์ ซึ่งขณะนี้อยู่ในระหว่างขั้นตอนการเก็บข้อมูลเพื่อใช้ประกอบการวิเคราะห์ความเหมาะสมเชิงพื้นที่และประเมินความสัมพันธ์ระหว่างผู้ใช้บริการและดัชนีการพัฒนาพื้นที่โดยรอบสถานีรถไฟความเร็วสูงนครราชสีมานั้น

ในการนี้ มหาวิทยาลัยแห่งชาติโยโกฮะมะขอความอนุเคราะห์ข้อมูลราคาประเมินที่ดินรายแปลง ราคาค่าธรรมเนียมที่ดินรายแปลง และราคากลางคิดค่าธรรมเนียมรายแปลง ภายในพื้นที่รัศมี 6.2 กิโลเมตรจากอนุสาวรีย์ท้าวสุรนารี จังหวัดนครราชสีมา ระหว่างปี 2555 – 2567 จากสำนักงานธนารักษ์พื้นที่นครราชสีมาในรูปแบบ shapefile หรือชั้นข้อมูลที่สามารถเปิดเผยได้ในระดับสารสนเทศ เพื่อใช้เป็นข้อมูลสนับสนุนการวิเคราะห์ข้อมูล ซึ่งข้อมูลดังกล่าวจะไม่ส่งผลกระทบต่อองค์กรของท่านและใช้เพื่อการวิจัยเท่านั้น โดยมอบหมายให้นายกิตติพงษ์ ทิสยากร โทรศัพท์ (+81) 94-048-4359 จดหมายอิเล็กทรอนิกส์ ktissayakorn@gmail.com เป็นผู้ประสานงาน

จึงเรียนมาเพื่อโปรดพิจารณาและให้ความอนุเคราะห์ด้วย จักขอบคุณยิ่ง

ขอแสดงความนับถือ

(ศาสตร์จารย์ ดร. ฟุมิฮิโกะ นากามุระ)
รองอธิการบดีมหาวิทยาลัยแห่งชาติโยโกฮะมะ

ห้องวิจัยวิศวกรรมขนส่งและการพัฒนาเมือง
โทรศัพท์ (+81) 45-339-4039