Catchment Area on Fukushima Shinkansen Station using Geographic Information System Approach and Land Value Perspective

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High-Speed Rail (HSR) development for regional connectivity between Bangkok-Nong Khai (phase 1: Bangkok-Nakhon Ratchasima) is facing how to drive it to sustainable development whereas the economic benefit and financial benefit are lower than the benchmark. Meanwhile, transit-oriented development (TOD) is one of the tools to promote sustainable development in several countries, especially Japan is the best practice methodology. Furthermore, Nakhon Ratchasima HSR station wishes to improve more sustainable development in the future by using the Fukushima Shinkansen station model.

The research problem in the TOD which is still not identified, many transport and urban planners do not determine the optimal catchment area around the HSR stations when HSR operated. Hence, this study is intended to analyze and evaluate the size of the catchment area of Fukushima Shinkansen station can be considered as a best practice. Our research uses geographic information system software and land value data. As a result, the catchment area drives land value changes and provides the opportunity to improve economic activities.

Key Words : *catchment area, GIS, land value, Fukushima Shinkansen station, Fukushima city*

1. INTRODUCTION

Nowadays, High-Speed Rail (HSR) development for regional connectivity between Bangkok-Nong Khai (phase 1: Bangkok-Nakhon Ratchasima) is one of the international mega-projects under the "Memorandum of Understanding between the Government of the Kingdom of Thailand and the Government of the People's Republic of China on Cooperation on Thailand's Railway Infrastructure Development on the Strategic Framework for Development of Thailand's Transportation Infrastructure 2015-2022 (B.E. 2558-2565)". This HSR project is approved by Prayut cabinet since July 2017 and expected to operate in 2022. It brings about economic activities, reduced traffic conjection, boosts productivity, expands travel choices and improved mobility.

Nevertheless, the feasibility study of the HSR project is not feasible whereas the economic return (8.56%) and financial return (NA) are lower than the benchmark in economics (12%) and in finance (5%) based on office of the National Economic and Social Development Council criteria. In other words, Thailand's government is facing how to drive the HSR project for sustainability in the long-term. The feasibility study also recommends that if the gov-

ernment utilizes the land development around the stations (or transit-oriented development (TOD)), economic benefit will increase from 8.56% to 11.68%. Thus, TOD is one of the alternative tools to increase economic benefit, but the Thailand's government does not have the practical know-how, and experience in how to make it happen around the transport hubs. Thailand also has limitation of land development around the transport station based on Constitution of the Kingdom of Thailand, BE 2560 (2017), Expropriation and Acquisition with Immovable Property Act, BE 2562 (2019), and Town Planning Act, BE 2518 (1975).

Moreover, this HSR project has yet four obstacles to find the solution based on an interview with Thailand government officers during December 2018-January 2019. For instance, (1) a limit of track work for operating two systems (Japanese and Chinese system) between Bang Sue station and Ban Phachi station section, (2) applicable TOD around the HSR stations, (3) the new organization and personnel for driving HSR project and (4) HSR fare can complete with private cars, the first-class train and the second-class train even though an advantage over the value of time.

Then, we have made the mechanism for their obstacles based on how to drive the HSR project to sustainable development (see figure 1). As a result, TOD is the most influential factor in the mechanism because it has the highest linkage; therefore, TOD may be required to originate the benefits for the HSR project. However, TOD composes of various parameters, for example, policy linkage, stakeholder, land use, transport systems and regulation. Indeed, the catchment area of transit services (this is defined in the next section) is one of the key elements for TOD and prescribes the floor area ratio within the station area[30].

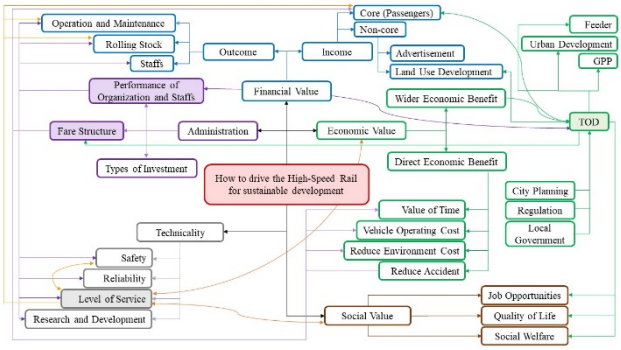

Fig.1 The mechanism of the barriers of the Thailand government for the HSR project

Studies regarding the TOD in Thailand, they are mainly concerned with issues such as what kind of a policy framework and regulation for a TOD, what are the characteristics of a TOD and what is the role of weather, built-environment, and accessibility geographical characteristics in influencing users. Moreover, the previous studies have clearly shown the potential TOD and the station catchment area for transit service affects transit ridership, land use and socioeconomic impact.

Meawhile, the previous studies lack the HSR station catchment area should be when the HSR station opened. Hence, this study first attempt to focus on the characteristics of a TOD for HSR stations in Japan so as to identifying the radius of the catchment area and recommendation relating to improve TOD on Nakhon Ratchasima HSR station based on the lessons we learned the Fukushima Shinkansen station (this is explained in section 3 why we choose Fukushima Shinkansen station as a case study).

The main goal of this paper is to analyze and evaluate the catchment area when the Fukushima Shinkansen station operated based on land value. As well as the hypothesis is which factors in land value affects when opening the Fukushima Shinkansen station. Furthermore, the methodology of this paper is mix analysis (quantitative and qualitative analysis) by using a geographic information system (GIS) method with land value data.

The paper is structured as follows: in section 2, we review the existing studies, focusing on theoretical and empirical studies that relate to the catchment area for transit hubs. Next, why we select the Fukushima Shinkansen station as a case study is described in section 3. Section 4 explains the methodology and data collection for analysis. Then, section 5 presents the results of the catchment area of Fukushima Shinkansen station, while the concluding remarks and further research are provided in section 6.

2. LITERATURE REVIEW

Area development around the transport station (or TOD) will generate direct and indirect benefits to the area in economic benefit, social benefit, and environmental benefit. Furthermore, it also brings about alternative routes for travel, capable accessibility, and economic return to local government, operator, property developer including labor in the commercial/industrial sector. Thus, TOD is one of the strategies in urban development that will benefit the mobile society in the short-term and sustainable society in the long-term.

(1) TOD concept

TOD has been a new urbanism (building blocks) concept at a regional scale and forms a network of

high-density and mixed-use nodes of development linked by transit cooridors[2, 5, 13]. New urbanists have advocated in the USA to endeavor to go back to an older form of streetcar suburbs.

TOD in the USA has been built around light rail transit and bus transit service. It is contained a mix of housing, retail and office space and open space within a quarter-mile (or approximately 400 m) of a transit station or along a transit corridor. Furthermore, it is the heart of a successful regional development strategy in some countries that stress compact growth, open space, and sustainability[4].

Based on the high-quality rail transit service as a catalyst for TOD, the cities strategies are the vision of development nodes linked by the transit services. Meanwhile, TOD is well known and popular until there are many countries apply it around the transit stations[17, 19, 25, 26].

(2) TOD plan and TOD typologies

TOD plan ideally comprises of the studies of existing land use, public infrastructure (including street and car parking), community facilities, and proposal for the plan[7]. The challenge in the transit station plan is how to combine all of them to a sustainable feature that is necessary to achieve a working balance between equity, economy, ecology, and livability.

In the meantime, TOD typologies around the transit station have different types; thereore, it must be analyzed and classified TOD with city context together to achieve a suitable development in each area[22, 29].

(3) Indicators for development success

Evaluating TOD is analyzed by two dimensions which consist of an area of major benefits and area-based factors. (1) area of major benefits is defined as the stakeholders receives from TOD such as mobility choices, public safety, and economic development. (2) area-based factors is defined as the results that receives from successful station area and region such as the public sector and private sector[9, 14].

The key of success TOD includes strategies (macro level) and design (micro level) factor such as an easy accessibility for pedestrian, a direct connections between transport modes and transit facilities, an environmentally friendly technology, and a safetand secure design. In addition, the number of passengers, land-use change, and property value factors were TOD indicators to measure the successful TOD[8, 23].

(4) Catchment area

The catchment area of the transit station can be defined as the zone (the service area or core area) that is willingness to travel to and from the station with the transport modes available[1, 15]. However, willingness to travel also varies by person, trip purpose, gender, age, climate, land use, and income.

The size of the geographical catchment area is a circle shape with the station at the center and affects the travel demand to determine the number of passengers that uses the stations in different radius[3, 11, 20]. Therefore, we can discuss the catchment area in terms of its radius.

Japan railway system is operated by various private companies; hence, the ridership is a crucial factor for financial return. Railway companies (operators) have to realize the catchment area concept to transport and urban planning as much capacitance as possible, whereas the users are sometimes the people who work or reside in the catchment area of the station. Thus, attractive people to work or reside in the catchment area is one of the strategies in railway companies.

The existing literature on station catchment area focuses on urban transit systems for commuters. The distance in the catchment area is proved by a few studies on urban transit. The station catchment area is often defined 400-800 m radius from the station for a transit station[12, 20]. However, the station catchment area for HSR system should differ from that and has lager accessibility as shown below:

a) HSR stations in Southern california

The land use concept for HSR stations was suggested by Catz and Cristian. It should encompass a larger radius with 1.61-4.83 km around the station area depending on the feeder systems of the HSR stations[18].

b) 17 existing Shinkansen station on Japanese Tokaido line, 30 developed Amtrak stations on the Northeast corridor and 25 proposed HSR stations in California

This study used GIS software with the lastest data on job market profiles during 2001-2010 for Japan and 2002-2008 for the U.S. in 5 km. The result showed that it had highly economic development impacts on the regions to shift forward knowledge and service-intensive business[21].

c) Marid, Barcelona, Los Angeles and San Francisco HSR station

Their locations were tested 10 and 25 km as the radius for catchment areas for all stations by using GIS software with an aggregate score of population, population density, employment and income based on U.S data in 2010 and Spanish data in 2009. The outcome suggested that low-density cities (U.S cities) were less than attractive higher density cities

(Spanish cities). Policymakers and transport planners had to carefully consider the urban structure and its effect on HSR competitiveness[24].

d) Zaragoza, Valladolid, Segovia, Toledo, Ciudad Real and Puertollano HSR station

Spanish HSR stations were focused on the spatial analysis of ridership surveys and employ distance during April 2008 and December 2009; depending on the stations. The empirical analysis examined that station catchment areas were among 33-111 min of maximum travel time. The structure and shape of the catchment area might be significantly affected by other elements. Moreover, transport networks around the station might generate demand for stations[28].

(5) Land value

This paper defines land value as the fair market value of land and excluding buildings. There are several articles study the transit systems in developed countries and developing countries. The common result of their studies shows that land value will increase due to population growth, economic development, public investment in infrastructure, change in land use regulation, and landowner's investment[25]. However, the net benefit from the station varies on station characteristics, an income of the people, and station catchment area[6].

(6) Summary of literature review

The mixed results of the previous studies that examine the station catchment area for HSR based on diverse measurements, data ranges, and locations. As well as none of them analyze the HSR station catchment area should be when it operated. Hence, the importance of carrying out this research is to analyze and evaluate the optimal catchment area at Fukushima Shinkansen station when operated in 1982 as well as an influential factor in land value after opening Fukushima Shinkansen station as a hypothesis.

3. INTERNATIONAL COMPARISON-WHY SELECT FUKUSHIMA SHINKANSEN STATION

As the HSR project, there are six HSR stations, namely, Bang Sue, Don Muang, Ayutthaya, Saraburi, Pak Chong, and Nakhon Ratchasima. Moreover, Bang Sue and Don Muang HSR station located in the capital of Thailand and other places in rural areas.

In this regard, Nakhon Ratchasima is a representative rural HSR station and wish for a change in the future whereas (1) Nakhon Ratchasima province perspective: it is a gateway of Northeastern region in Thailand, is a regional capital and big-sized city of HSR station, is its low population density and has several infrastructure projects investment plans in the future. Furthermore, it is also promoted as the center of investment, health service, education, industrial and tourism, refer to the following The Twelfth National Economic and Social Development Plan and (2) Nakhon Ratchasima HSR station perspective: the distance of the HSR station can compete with aircraft[10], it is a big-sized HSR station and around the station has the vacant land of SRT around 0.0352 km^2 to develop land use (see figure 2).

Meanwhile, Fukushima Shinkansen station on Tohoku Shinkansen line is the best rural HSR station in Japan than other stations because it is similar in terms of HSR station type, station size, distance and travel time with Nakhon Ratchasima HSR station. Although the surrounding area of the stations is the difference, we will be considered how to increase the potency before-after the opening of the HSR project in the future (see table 1).

4. RESEARCH APPROACH AND DATA SET

(1) Lesson learnt from the previous studies

The most valuable lesson learned in the existing research is how to analyze and evaluate the size of the station catchment area. It is the main point for urban planners or operators to optimize land use.

However, they did not consider the exact station catchment area when the opening HSR station could be because it may lose an opportunity to make the full advantage of transit ridership, land use and regulation, for instance, TOD financial plans and restrictive zoning.

It is quite difficult to collect the time-series data in

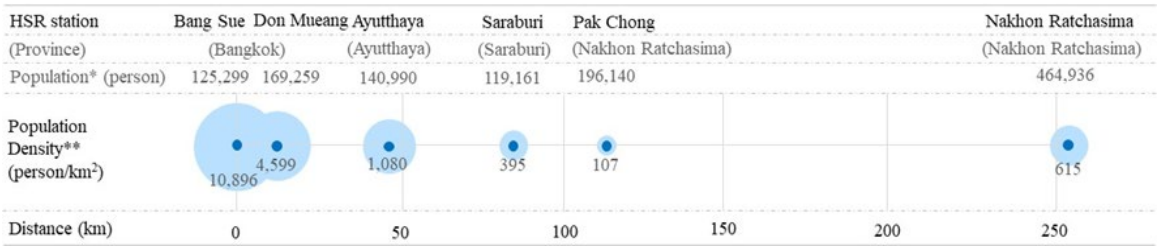

Fig.2 HSR stations along the corridor

Table 1 Comparison between Nakhon Ratchasrima HSR Station and Candidate Shinkansen Stations

Station (Operating year)	Shinkansen line (Operator)	City (Province)/ City (Prefecture)	Station type*	Station size	Distance from capital city to Shinkansen station (km)	Travel time (Shinkansen train) (h)
Case study in Thailand						
Nakhon Ratchasima (2022)	Northeast (NA)	Nakhon Ratchasima (Nakhon Ratchasima)	Type 1	Big	253	1:01 (Fuxing)
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	0:98 (Hakutaka)
Nagaoka (1997)	Joetsu Shinkansen (JR East)	Nagaoka (Nagano)	Type 1	Big	245.1	1:02 (Taki)
Hamamatsu (1964)	Tokaido Shinkansen (JR East)	Hamamatsu (Shizuoka)	Type 1	Big	238.9	0:79 (Hikari) 0:84 (Kadama)
Tsubamesanjo (1982)	Joetsu Shinkansen (JR East)	Sanjo (Niigata)	Type 1	Small	268.7	1:12 (Taki)

*There are three types of Shinkansen stations which are the 1st type of Shinkansen stations: development of a new Shinkansen station in the area with existing/conventional railway, the 2nd type of Shinkansen stations: an expansion of the existing station in the area with a conventional railway and the 3rd type of Shinkansen stations: developing a new Shinkansen station with a new urban development.

the past in each parameter. Hence, we endeavor to concentrate on the land value factor to identify attributable the changes to the HSR station catchment area.

(2) Research methodology

We compare the international HSR station between Japan and Thailand by using our criteria; station type, station size, distance and travel time, whereas Japan is a famous and popular TOD for its excellent mobility and sustainability. An international comparison is important for HSR in Thailand, where is the first developing country to develop, and need to push sustainable development in the future.

Based on the previous studies, the station catchment areas for HSR stations have large range (1.61-25 km) and different methodologies, for example, economic development and aggregate score

(population, population density, employment, and income). The analytical approach is based on panel data on Fukushima's land value from National Land Numerical Numerical Information Bureau, Ministry of Land, Infrastructure, Transport, and Tourism (MLIT), Japan. Nevertheless, due to data coverage incompleteness, data source, and data access limitation about analyzing and estimating, the only viable choice is to use public values in this study.

The panel data are geographically matched up to 0.1 km circular buffers around the Fukushima Shinkansen station on the Tohoku Shinkansen line by using GIS shapefile.

(3) Data collection

The precise location of Fukushima Shinkansen station, Fukushima prefecture on Tohoku Shinkansen line is obtained from the e-stat, Japan. Meanwhile, land value data from 1983 to 2019 (L01-83_07-GML – L01-19_07-GML) are extracted from the Bureau of National Land Numerical Numerical Information, MLIT, Japan. GIS shapefile provided by GIS point shapefiles for this station is produced using online satellite imagery techniques[9].

5. RESULTS

(1) Catchment area

Since our study focuses on rural HSR station (Fukushima Shinkansen station), we consider a reasonable HSR catchment area what it should be when it operated. The Fukushima Shinkansen station links to four railway feeder lines which are Tohoku main line, Ou main line, Izaka line, and Abukuma express line. In Fukushima city, Ou main line is a large (dense) network within 8.13 km of the central business district since 1982. This distance depends on the type of feeder system. A high potential/quality transport system like regional trains will have a larger catchment area than a lower potential/quality transport system. We believe 8.13 km is a more reasonable radius for Fukushima Shinkansen station as well as 5-25 km HSR catchment area are proposed by the previous studies as the references[21, 24].

We also analyze the catchment area at Fukushima Shinkansen station from 1983 to 2019 by using GIS software and land value perspective. The result of the catchment area is shown in figure 3 as land value perspective maps. The 8.13 km of catchment area captures a partial area of the catchment area (17.6 km) at Fukushima Shinkansen station in 1983. In general, our analysis shows the Fukushima Shinkansen station has better accessibility than Spanish cities, but lower accessibility than Tokyo based on the dense network.

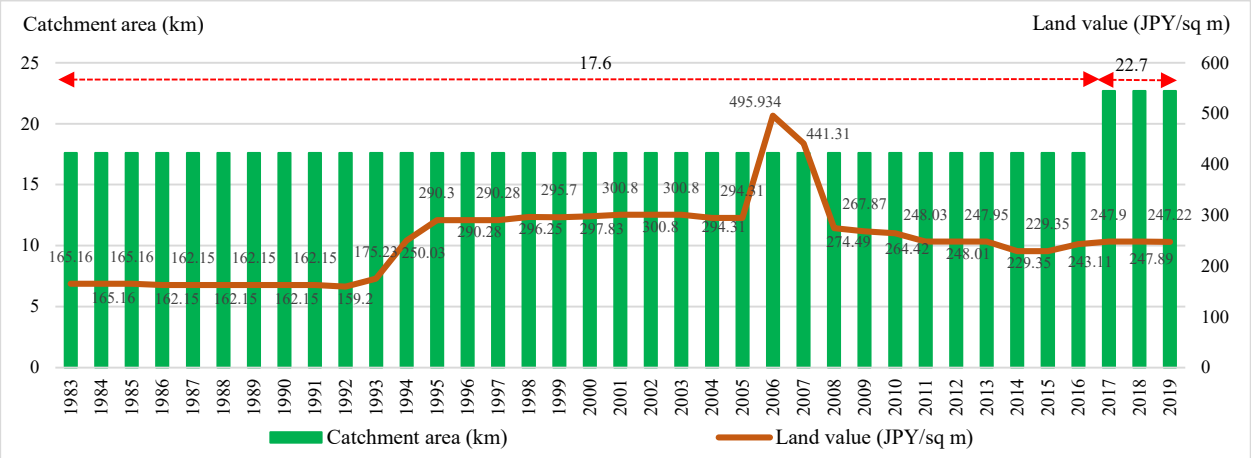

Fig.3 Relationship between Catchment Area (km) and Land Value (JPY/sq m) on Fukushima Shinkansen Station

6. CONCLUSION

Transport planners and urban planners have to consider transit catchment areas not only to forecast the transit ridership but also to prescribe for land development, impacts and regulations on a parallel path. This study approaches to investigate the Fukushima Shinkansen station catchment area to identify the radius of the catchment area and recommendation relating to improve TOD on Nakhon Ratchasima HSR station based on the lessons we learned the Fukushima Shinkansen station.

Based on the result, it shows that the density network influences the catchment area in direct variation and larger than the capital city (Tokyo and Marid)[21, 24]. The critical importance of density network based on the potential/quality transport system that connects to the Shinkansen station. Beyond the results, future work should explore the land value and their attribution to Fukushima city to test the

effective factors in the land value impact.

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