Southeast Asian Journal of Economics 6(2), July-December 2018: 115-143

Received: 18 May 2018
Accepted: 5 October 2018

Spatial Evaluation of Road Expansion and Economic Performance in Thailand

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Abstract

This paper aims to find the correlation between the expansion of road networks and the economic performance in Thailand; growth and inequality. The expansion of road networks is segregated into two cases, namely, growth of national highways and of rural roads. The research aims to specify which type of road generates higher economic growth and lower inequality. Road network data are used in the study to investigate the development of the road network during the 10-year period and to subsequently specify economic activities around the affected area. The proxy of economic activity is determined by night-time light data, which can be observed from outer space. Results found that national highways have a strong relationship with provincial growth enhancement and inequality reduction, and higher than the relationship of rural roads. However, if the roads are built in the area with high road congestion, they will increase higher growth but higher inequality relative to the area with low road congestion. The implication is that the government should balance the trade-off between growth and inequality when they expand road networks.

Keywords: Road, Nightlights, Geography, GIS, Spatial Economics

1. Introduction

Road network is particularly an important sector of economic activity, especially in developing countries, including Thailand. Road network improvement has been shown to induce economic growth and development because it indicates the global flows of money, goods and people. Road networks also provide access to nearly every necessity of life, such as access to health, education, agricultural inputs and extension services.

The World Bank indicates that roads have been the core transportation in Thailand. The land transport is dominated by road networks. Currently, a total of 462,133 km of roads exist in the country, with 98.5% of the roads, including paved village roads, which have a very high ratio relative to other most middle-income countries and less than 4,000 km of railroad tracks. These figures indicate that the majority of transportation modes in Thailand consist of road networks. In addition, road transport has become the most significant sector of the Thai economy given that 87.5% of Thailand's freights are transported via roads.

The road network in Thailand has been exclusively developed since WWII and has increasingly gained importance as it can provide better accessibility to the communities both in urban and rural areas. Furthermore, the Thai government continues to invest heavily on a road network systems as evidenced by several road infrastructure projects that are currently in progress—Bt 61 billion for fiscal year 2015. This indicates an increase from the Bt 52 billion of the fiscal year allotment for the transport logistic system improvement.

The Highway Act B.E. 2535 (1992), which was subsequently modified in B.E. 2549 (2006), stipulated that Thailand's highways are divided into five administrative categories, with each one having its own unique purpose. Firstly, special highways or motorways are high-capacity highways built with controlled-access operation by the Department of Highways (DOH) designed for high-speed traffic. Secondly, national highways or the primary highways connect most major settlements, such as regions, provinces, districts and other important destinations. National highways contain one- to four-digit route numbers (depending on their importance), which begin with 1 to 4 (depending

on the region). Similar to motorways, the highways are maintained by the DOH. Thirdly, rural highways or rural roads usually link the areas in the intra-provinces, which are under the control of the Department of Rural Roads (DOR), including construction, expansion and repair projects. Fourthly, highways that serve as the usage for local traffic are the local highways, which are maintained by a local administrative organisation or a local government. Lastly, concession highways are the highways granted by the legal government with the DOH. Hence, each type of highway serves different purposes, and provides unique beneficial contribution to the country.

This paper emphasises the two types of highways to be part of the study, namely, national and rural highways. These two highways have their unique functions. National highways enhance the countrywide connectivity among regions and focus on the linkage. By contrast, rural highways or rural roads improve the accessibility in the local areas or intra-provinces–the access among villages, markets, schools and medical centres. As mentioned above, these two highways have different purposes, namely, connectivity and accessibility. This paper carefully examines the effect of the development of national and rural highways on the economic activities. The study aims to investigate which road network generates higher economic activities and more equal diffusion to the area through an analysis that uses a geographic information system (GIS) software application. The results of this study can serve as a guideline for policymakers as they design road infrastructure projects that can expand road networks in the country.

The measurement of economic activities in the study is usage of a proxy on the amount of light observed from outer space. More particularly, Henderson et al. (2012) has stated that measuring the economic or gross domestic product (GDP) growth allows for another alternative proxy, the changes in 'night lights'. Many previous studies have demonstrated that night lights reflect human manifest and economic activity (e.g. Elvidge et al., 1997; Sutton and Costanza, 2002; Ebener et al., 2005). Furthermore, Handerson et al. (2012) also proved that lights data are advantageous over other measurements that could serve a similar purpose (e.g. electricity consumption) because night lights are adequate for the countries or regions that lack information. Night lights data are available in nearly all the areas on earth (both habitat and

inhabited) and are also high-time frequency data. The brief introduction and details of night lights data will be described further in later section of the paper.

The remainder of this paper is structured as follows. Section 2 presents the research objective. Section 3 reviews empirical studies exploring the different findings of previous studies on the effect of road network and the measurement of economic activities. Section 4 describes the data of economic activity measurement and growth of road network. Section 5 establishes the study methodology. Section 6 presents the results, and Section 7 proposes the conclusion.

2. Research Objectives

This paper mainly aims to study the effect of the growth of road networks segregated into two cases (i.e. growth of national highways and of rural roads) on the economic performance in Thailand. More specifically, this paper identifies and compares the development between the two types of road concerning which one generates higher economic growth or equally diversified economic activities. Furthermore, the improvement of road network data is then used to estimate a correlation with the growth of both the Gross Provincial Product (GPP) and the GINI index.

This paper also estimates the correlation between road network effects and the growth of the GPP and the GINI index under the area of different road congestion around itself. If the roads are constructed closer to the area with more road concentrations, the growth creation may differ from the area with less concentration.

3. Literature Review

This paper aims to evaluate the relationship and effect of road network on economic activities, more specifically on how the improvement of two types of road networks in Thailand affects the economy of the country. Queiroz and Gautam (1992) pointed out that transportation is an essential ingredient of nearly everything man does to supply himself with the necessities of life. In Thailand, road network is declared as the most important mode of transportation. Hence, development of road network is hypothesised to have an effect on economic activities.

This section reviews empirical studies that focus on the relationship of road network and economic activities, which could be relevant to the current research. The related literature is separated into two parts, namely, road network and measurement of economic activity.

3.1 Road Network

Windle and Cramb (1997) described road network development as a promoter of economic growth by providing a means of transportation for goods, such as agricultural products, to regional or international markets with low time cost. In addition, road network is a frequently used mode of transportation, which also plays an important role in an economic activity. Yeser (1990) stated that transportation has been considered for a long time as an essential factor driving regional, economic and social development. Hence, not only economic development has been influenced by road network but also social development, which directly benefits the people. For example, road networks provide people access to services, schools, markets and medical and healthcare centres.

Blum (1982) demonstrated that the nature of relationship between road network improvement and economic development has been the subject of debates amongst politicians and researchers for many years. Nevertheless, numerous studies stated that a strong relationship exists between economic development and transport infrastructure. For example, Jiwattanakulpaisarn et al. (2008) and Aldagheiri (2009) stated that transport infrastructure improvement induces economic growth and development as it allows the flow of goods and workers, which can then lead to high-quality production technology to generate further output. In other words, it enhances the efficiency of goods and labour movement for production. The growth of road network can also have an effect on the growth of economic activity. In addition, both one-single type road and a few of the hierarchy and surface types exist, in which each one has its own functional purpose, such as the difference between a highway and a local road. Forman et al. (2003) characterised a highway as generally having long distances and connecting high population and major urban areas or a local road connecting farmland or residential houses. Moreover, Layton (1996) stated that there is less accessibility to land

on a highway compared with a local road because the latter is normally surrounded by agricultural landscapes. Thus, the current study aims to probe into the functionality of these two types of road networks and their effects on the economic activities or economic growth, using a case study in Thailand.

The Global Competitiveness Report published by the World Economic Forum (WEF) has ranked Thailand as the 28th best road network worldwide with a score of five out of possible seven, which is higher than the world average of 3.7. Road transport is currently the most significant sector of the economy in Thailand because land transport is dominated by road networks, and nearly 100% of freights are transported via roads. Pomlaktong et al. (2011) stated that the government implements the policy that encourages road network infrastructure because it may lead to land uses and later stimulate the economic growth for many regions. Thailand is centrally located within the Greater Mekong Subregion (GMS), which is surrounded by Myanmar, Laos and Cambodia. Hence, trade and investment are promoted via road networks and transport improvements to generate the country's growth by easing the trade transportation.

3.2 Measurement of economic activity

To identify whether the highway or local road has a greater effect on economic growth, the economic activities occurring because of these road network improvements must be measured. Numerous studies have evidenced that night-time light that can be observed from outer space and collected by satellites can be employed as a proxy for economic activity. For example, Elvidge et al. (1997) first studied the correlation of the night light area and economic activity at the country level and concluded that a strong relationship exists; thus, night-time light provides a very useful proxy in measuring economic activity. Forbes (2013) also reported that night-time light data are correlated with GDP. In addition, the study of Henderson et al. (2012) utilised the changes in night lights to measure economic growth; they indicated that light growth is a proxy for GDP growth over the long term and further tracks short-term fluctuation in growth. The night light data measured the economic activities both in the country and global levels. Doll et al. (2000) extended the study further by investigating the relationship between night light and GDP for several countries.

4. Data

The data used in the study consist of road networks in Thailand, both as shapefile and night-time light raster data collected by the US air force satellites, which will be thoroughly reviewed as follows:

4.1 Road Network Data

Road network data used in the study are derived from GIS (Geographic Information System) application by distinguishing only the development of the road networks or the new roads constructed during the period of time for both national and rural highways. The road network data are similar to a road map image but in the form of shapefile data. Road network is one of the data sets in the Transport Fundamental Geographic Data Set (FGDS) derived and collected by the Ministry of Transport of Thailand.

This paper investigates the new road networks constructed within the ten-year period between 2006 and 2016. For a clearer understanding, the new road networks are derived from two different road map data collected in different time periods. Firstly, the 2016 road map data were collected. These illustrate all types of road networks in the country during that time period in which the national highway, rural road and other roads are included together as one map aspect. Secondly, 2016 road map data were collected but with further specificity. These two road map data illustrate one-type hierarchy road for each road map data set: one is a national highway whilst another is a rural road as represented in Figure 1. Using all road network data and one-type hierarchy road network data to identify later the differences among them and subsequently investigate the new or growth of road network during a specific time period. The data are separately studied between national and rural highways to analyse clearly on the growth of each highway on the economic activities.

Figure 1. National Highway (Left) and Rural Road (Right), 2016

4.2 Night Light Data

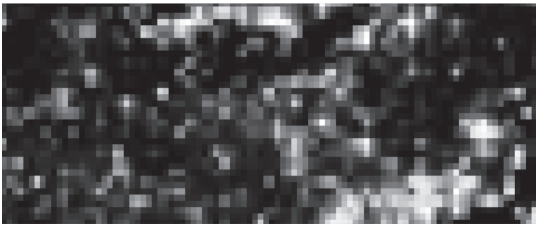
Night-time light data from outer space serve as the measurement to proxy economic activities used in the study. Over the last several years, numerous studies have reported that night-time light data correlate well with the GDP. For example, Forbes (2013) proved that night light data can be identified as a representative for economic activity at all examine scales. Moreover, the extreme relationship between night-time lights and GDP at the country level has been investigated in (Elvidge et al., 1997). To measure human activity using other alternatives for the entire country is not that easy owing to unavailable resources of information and biases from unequal information accessibility. For such purposes, Kulkarni et al. (2011) suggested that the night light data are a useful measurement as it directs human activity.

The satellite imagery was obtained from the night-time light data gathered by the US department of Defence Meteorological Satellite Program (DMSP) from the US air force. The DMSP satellites have been circling around the earth 14 miles per day, recording the intensity city of earth-based light collected at the same instant time for each location on the planet every night, around 8:30 to 10:00 p.m. local time. Their Operational Line Scanner System (OLS) sensors are designed to collect low-light imaging data to detect the moonlight reflected by clouds. (See Figure 2) Therefore, the light recorded only permanent and stable lights from cities, towns and other sites, which are then filtered to remove lights created by forest fires, fishing boats or flickering lights and also other northern and southern lights, such as aurora activity. Thus, the night lights are mostly man-made lights, which restricted intense sources of natural light. Each DMSP-OLS satellite generates pixels that are 30 arc-second grids, which are the grid square by the size of 1 km × 1 km (approximately 0.86 square km). The light intensity or range between 0 to 63, where 0 refers to the darkest spot or no light and 63 for the brightest or maximum light (See example in Figure 3).

Figure 2. Night lights data 2016

Source: Image and data processing by NOAA's National Geographical Data Center. DMSP data collected by US Air Force Weather Agency

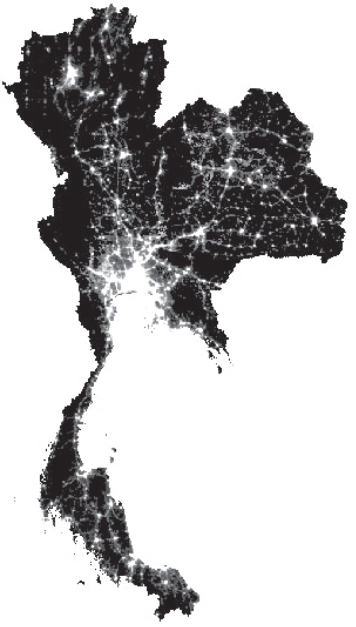
Figure 3. Light Level as White-Shade Grid



The night-time light raster data can be downloaded freely on the Internet (http://ngdc.noaa.gov/eog/dmsp/downloadV4composites.html). This paper utilises the raster data containing the night-time light data collected in year 2006 and most recently collected data in 2016.

However, the image of night lights from the original source is the entire figure of the earth. The calculation of the mean of night light value can be performed by overlaying the provincial polygon shapefiles, and then averaging the value of each grid within the polygon area. The overlaid shapefile of Thai nightlight is shown in Figure 4.

Figure 4. Night Lights Image of Thailand, 2016



5. Methodology

The methodology section is explained in the following two parts: Road network and economic activity analysis and estimation method.

5.1 Road network and economic activity analysis

In an attempt to extract new road networks that have been constructed since 2006 or developed between these past ten years, a geographical analysis is required to consider the study. The GIS application suitable for working and analysing with maps and geographic information is used in the study.

This study distinguishes the development of a road network infrastructure or growth of the new road network in the past ten years between two types of roads in Thailand. The cases were initially divided into national highways, focusing on the linkages between large urban areas and major cities, and then into rural roads/highways that focus on the intra-province accessibility. The process of investigating the new road network involved erasing the same road networks overlaid between two data sets, namely, all-type road networks collected in 2006 and one-type hierarchy road networks collected in 2016, and leaving out only a new one. In other words, after overlaying these two road map images, a feature class was created by overlaying the input features with the polygon of the erase features. Thus, only those portions of the input features that fell outside the erase features outside the boundaries were copied and created to a new image. The methods detailed as follows were applied to both data sets (national highway, 2016 and rural road, 2016) one at a time. Firstly, the one-type hierarchy road networks collected in 2016 were used as a base layer or input features. By contrast, all types of road networks, which consisted of shapefile data of all roads and highways in Thailand collected in 2006 were used as an erase feature. All the road networks from one-hierarchy data that overlay on all types of data will be deleted as the former declares as the same roads that were not newly constructed or improved. However, the road networks from one-hierarchy-type data that fell outside all types of data were left out and generated as a new image. The new road networks were not yet constructed in the past because they were newly improved. Therefore, the resulting images consisted of two shapefile data or the national highways and rural roads that were developed and constructed in these past ten years. These are referred as the expansion of road networks (See Figure 5).

Figure 5. New national highway network (Left) and new rural road network (Right) that constructed between 2006-2016

The next step after studying the new road network was to sequentially create buffer polygons around each of every route to a specific radius distance for both national highway and rural road. This was done to determine the economic activities that occurred due to the growth of road networks. The term 'buffer' is technically used in the literature to analyse the area around the input features, such as presenting an ecological zone around waterways and distances from condominiums that a certain mass transport station is located and such. In this study, the buffer was employed to identify the economic activities around the input features, which in the study consisted of the new road network construction within specific distances. The surroundings were segregated into four radius widths: 1, 3, 5 and 10-km radius from the road, to investigate the extent to which the road networks can affect the economic activities. Moreover, exploring that problem at the most further distance from the road, 10-kmr radius, we wish to know whether the economic activities in those areas literally obtain the effect from the road network merely from other factors. The new road networks with lengths less than 10 km were excluded in this study to attain a clearer result of the new road network improvement, considering that 10 km should be sufficiently far to cause no effect of new road building.

After extracting the newly constructed or improved road networks within these past ten years, the following process was to buffer around the route, in which the buffers were generated on both sides of the line, road network, in the form of a round shape with radius of 1, 3, 5 and 10 km, respectively, to analyse the surroundings from the road network (See Figures 6 and 7).

Figure 6. The buffer polygon of new road network

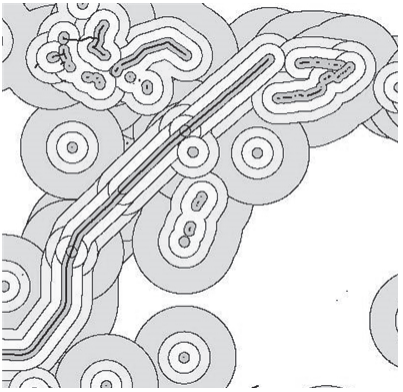
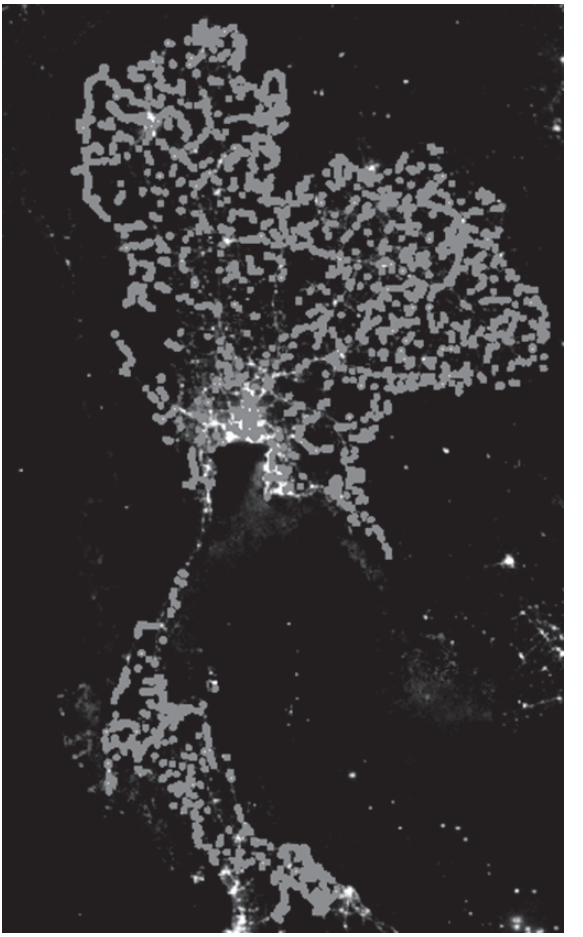


Figure 7. The buffer polygon of new road network (zoom in)

The road networks, both national highway and rural road, distinctly identify their locations within a specific province in the country to facilitate management and investigation. Finally, for economic activity identification, the measurement of night-light data was the next step. The methods detailed as follows were applied to both datasets (national highway and rural road). The economic activities were analysed separately for each buffer radius to identify the difference in the effect of the road network. Hence, four datasets exist for national highway and rural road each. More particularly, the mean of night lights was identified in each of the areas surrounding these new road networks within the specific radius. Night-time light raster data were used to overlay behind the road networks that were buffered earlier (Figure 8) to

summarise the values of night light raster data within the zones of another dataset, i.e. the road network. A report on the average night lights that occurred around the road network to a statistic table follows. The process was performed with every radius: 1, 3, 5 and 10 km. Moreover, the procedure was performed twice with night-time light raster data collected in 2006, the year at which the new road was still not constructed. Another dataset used was the raster data that should be collected in 2016, the year at which the new road network was already constructed and improved.

Figure 8. The buffer polygon of new road network with night lights raster data



Hence, for each type of road network, the following two sets of data exist: mean of night light around the road network in 2006 and mean of night light around the road network in 2016. One dataset consisted of four different radii of buffer polygon datasets: 1, 3, 5 and 10 km. After the result of these two datasets from different years, the difference of night-time light was later calculated for each specific distance area from the road. The results indicated changes in night light or economic activity that occurred from the improvement of the road networks. The results are described later in Section 6.

5.2 Estimation Method

This paper also estimated the correlation between the change in economic activities owing to the development of road networks and growth of GPP. Moreover, the growth of the GINI index was determined using ordinary least square (OLS) regression. Thus, a two-model specification exists: one runs the regression of changes in economic activities from national highway and rural road on the growth of GPP, whilst another runs the regression of changes in economic activities on the growth of the GINI index to analyse whether the improvement of road network technically affects the economy or generates any growth to the country.

In an attempt to estimate the model, we used the same economic activity calculation method mentioned earlier, except the current one. The mean of night light dataset was separated into 76 provinces rather than calculated as a whole country level as before to identify how night light changes or how the growth of economic activities would occur if a new road was built. This was also done so that we can run a regression on the GPP for each province. The models are presented below.

5.2.1 Growth of GPP equation

$$growth_{GPP} = \beta_1 \Delta HW + \beta_2 \Delta RR + \varepsilon$$

In the equation, growth GPP is the growth of GPP, HW is a mean of night light resulting from the growth of the national highway, and RR is a mean of night light due to the growth of rural road.

5.2.2 Growth of GINI index equation

$$growth_{GINI} = \alpha_1 \Delta HW + \alpha_2 \Delta RR + \varepsilon$$

In the equation, growth_GINI is the growth of the GINI index.

No constant exists for both the GPP and GINI index equations because the current study aims to estimate the real change in GPP and GINI index affected only by the new road network; hence, the unobservable constant changes that can occur due to other factors will be included in the error term. This finding is quite similar to the fixed effect model and is suitable for the model when a small observation occurs similar to these two models in this paper.

In addition, the control variable for the 10-year economic growth by other factors is observed and eliminated from the model by a change in the mean of nightlight at a 10-km distance from the road during 2016 and 2006.

This paper constructed two interaction variables, namely, the interaction between the mean of night light due to the growth of national highway and the length of other highways within a 10-km buffer. This was done to indicate the road congestion around the road of interests (HW × LHW). We also determined the interaction between the mean of night light due to the growth of rural road and the length of other highways within a 10-km buffer to indicate the road congestion around the road of interests (RR × LHW). If the roads were constructed closer to the area with more road concentration, the growth creation may differ from the road with less concentration.

6. Results

The result is separated into two cases to be clearly distinguished between the effect of national highway and rural road on economic activity in the surrounding area. Then, a comparison between these two types of roads is provided. The process begins with the example of statistical result from the mean of night light in the area with a 1-km radius distance from the national highway and the calculation of difference in the mean of night light for each route. For example, in Buri Ram Province, the Krasang-Raka road has a mean night light of 1.85 in year 2006 and 15.65 in year 2016, with the length of the

road at 30.8 km. The calculation of difference in night light requires the use of the weight average method as the length of each road is not the same; otherwise, the weight average method is used. Hence, the resulting value is at a different base. After calculating for difference in the mean of night light for each and every road network in the country, these values are summed up as a total value to analyse the value in the country level, divided by the sum of the length of the road network to obtain the weight average of difference in the mean of night light. The calculation is separately performed for specific distance radii with two datasets: national highway and rural road. According to the table, the mean of night light increases because of the improvement or construction of a new road network; thus, road network has an effect in terms of generating economic activities. For clear identification, the results are constructed both in table and graphical data for each type of road network. (See example on Table 1)

Table 1. Mean of night light of area within 1-km distance radius from national highway (Partial Result)

2006					2016				*Difference in Night light*
NAME	*Province*	*Mean*	*Length*	*Mean* Length*	*NAME*	*Mean*	*Length*	*Mean* Length*	
Bangna-Suvarnabhumi airport entrance	Bangkok	62.95	14.9	938.06	Bangna-Suvarnabhumi airport entrance	63	14.9	938.70	0.63
Bangpli-Kingkaew	Bangkok	62.83	13.9	874.41	Bangpli-Kingkaew	63	13.9	876.77	2.36
Krasang-Raka	Buri Ram	1.85	30.8	56.93	Krasang-Raka	15.65	30.8	482.47	425.54
Kumuang	Buri Ram	0.14	16.4	2.24	Kumuang	2.34	16.4	38.35	36.11

6.1 National highway

According to Table 1, the second and third columns represent the mean of night light occurring from the national highway in each distance radius for the years 2006 and 2016, respectively. The graph is plotted as two approximately linear lines from the value of Table 2 (See Figure 9), which are the mean of night light in both years, representing the average of night light in the improved or recently constructed areas around the new national highway.

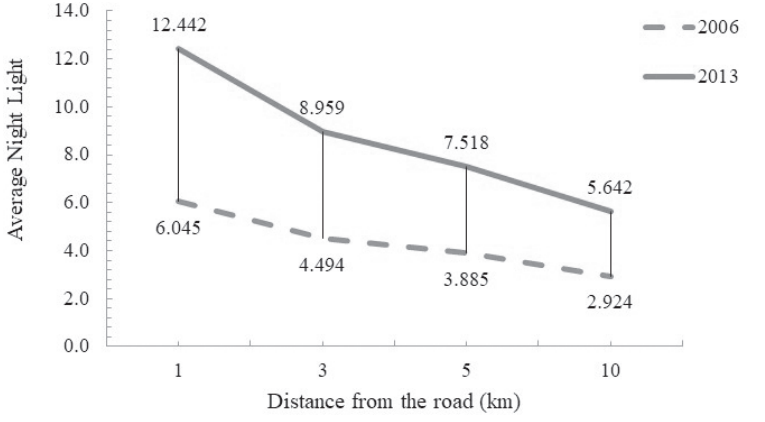
This finding identifies the extent of brightness of the night for each distance from the road between the years 2006 and 2016.

Moreover, the gap between the two lines is the difference in the mean of night light or the economic activities due to the national highway, which is calculated in the last column from Table 1. The trend of the curve is relatively the same for both years before and after the new road construction. For example, at a 1-km radius area from the road, the mean of night light in 2016 is 12.4, and gradually declines thereafter. However, in 2016, the mean of night light is nearly doubly higher relative to the mean of night light in 2006. The finding suggests that the construction of a new road network increases the brightness of night light, indicating that the new road network generates high economic activities.

Table 2. Mean of night light in the area around national highway

Distance (km)	Mean of NL in 2006	Mean of NL in 2016	Difference in mean
1	6.045	12.442	6.397
3	4.494	8.959	4.465
5	3.885	7.518	3.633
10	2.924	5.642	2.718

Figure 9. Changes of night light due to national highway



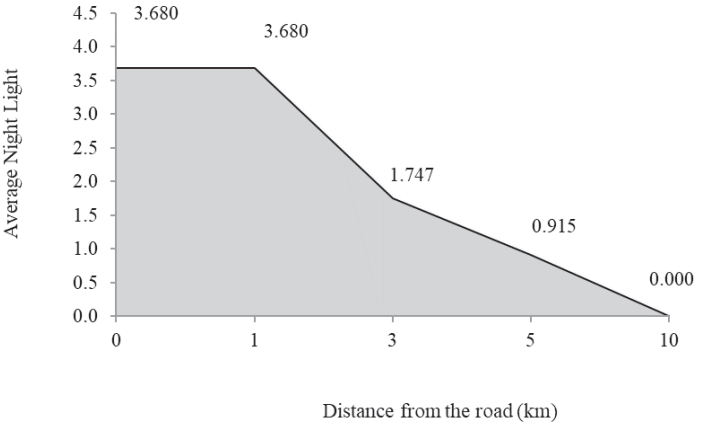
In an attempt to calculate the pure effect of road network on the economic activities or mean of night light, other factors that may affect the change in night light must be excluded. This paper assumes that the distance of 10 km is too far to technically have an effect from the new road network construction. Hence, changes in night light occurring after improving new road networks might be due to other factors and not from the road network, thereby deeming it a control variable. Table 2 illustrates that in the value of difference in the mean of night light at 10 km distance, 2.718 is a control variable, that is, other factors generating the growth of night light. Considering that the study aims to identify the effect of road network only, this value must be subtracted from each difference in the mean of night light values from other distances to determine the real growth of night light. Table 3 presents the results.

Table 3. Changes in night light due to national highway improvement

Distance (km)	Mean of NL in 2006	Mean of NL in 2016	Difference in Mean of NL	Real difference
0				3.680
1	6.045	12.442	6.397	3.680
3	4.494	8.959	4.465	1.747
5	3.885	7.518	3.633	0.915
10	2.924	5.642	2.718	0.000

As can be seen in Figure 10, the line represents the changes in night light occurring from the new national highway network constructed in the past 10 years. Moreover, the area under the graph identifies the total value of economic activities from the national highway improvement, which is calculated to be 14.05. (See Figure 10)

Figure 10. Economic activities due to national highway improvement



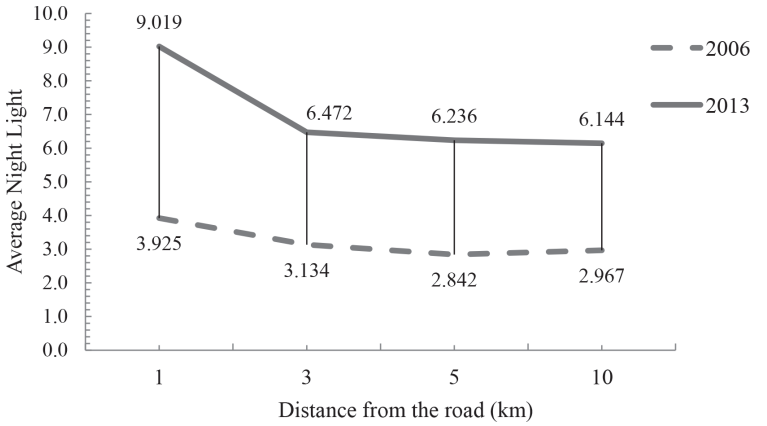
6.2 Rural road

From Table 4 and Figure 11, the method is the same as the national highway result. The second and third columns represent the average night light of the specific distance area from the rural road, which include 1, 3, 5 and 19-km radius for the years 2006 and 2016, respectively. The result is relatively the same. In 2016, the mean of night light is thrice higher in every distance relative to 2006, except that the trend of the line differs from the national highway. The graph of the mean of night light around the area of rural road is at the peak in 1-km distance and sharply declines in the 3-km distance; then, it becomes entirely stable within the 10-km distance in 2016.

Table 4. Mean of Night light in the area around rural road

Distance (km)	Mean of NL in 2006	Mean of NL in 2016	Difference in mean
1	3.925	9.019	5.095
3	3.134	6.472	3.339
5	2.842	6.236	3.394
10	2.967	6.144	3.177

Figure 11. Changes of night light due to rural road

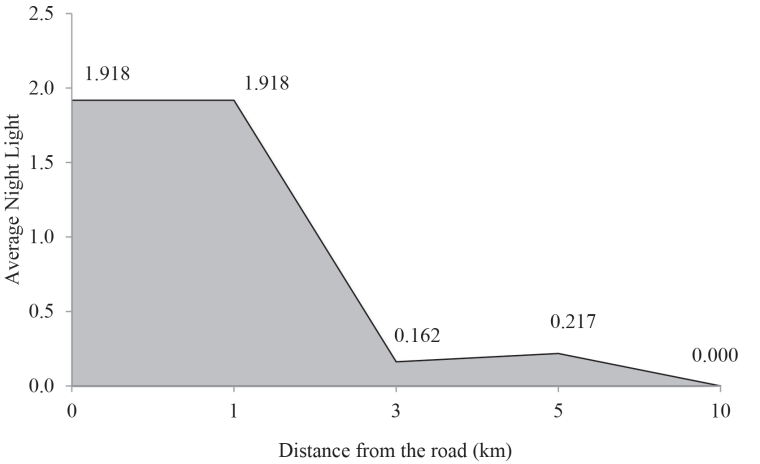


As presented in Table 5, the last column illustrates the difference in the mean of night light between years 2006 and 2016, which occurred because of the new rural road network construction and other factors. Therefore, the calculation followed the same method described earlier: treating the value of 10-km distance as a control variable, that is, other factors affecting the changes in night light. To study the real growth of night light resulting from the rural road network only, the value of 10-km distance, 3.177, is subtracted from the three values of difference in the mean of other distances (Figure 12 and Table 5).

Table 5. Changes in Night light due to rural road improvement

Distance (km)	*Mean of NL in 2006*	*Mean of NL in 2016*	*Difference in Mean of NL*	*Real difference*
0				*1.918*
1	*3.925*	*9.019*	*5.095*	*1.918*
3	*3.134*	*6.472*	*3.339*	*0.162*
5	*2.842*	*6.236*	*3.394*	*0.217*
10	*2.967*	*6.144*	*3.177*	*0.000*

Figure 12. Economic activities due to rural road improvement



In an attempt to study the diffusion of economic activities between these two types of roads, namely, national highway and rural road (see Figures 10 and 12, respectively), the trends of the line are different. Rural road obviously has an effect on the mean of night light only at the radius distance less than 3-km away from the road network because the graph begins to stabilise at the 3-km distance. By contrast, from Figure 11, national highway is indicated to have an effect on the mean of night light to the area with more than 10-km radius distance as the graph remains unstable and gradually declines. The national highway seems to diversify the growth of economic activities equally and better relative to the rural road.

6.3 Estimation Results

In the result of estimation model in Column 1 of Table 6, the coefficients of the national highway demonstrated a strong effect in both model specifications, namely, growths of GPP and the GINI index. The growth of GPP equation indicates that both national highway and rural road are positively significant to the growth of GPP. However, the national highway has high statistical significance at 1% and also high coefficient at 2.602194. (See Table 6). In other words, the new national highway generates higher growth to the country as a whole, relative to the rural road.

Table 6. Regression results

	Growth of GPP		*Growth of GINI index*	
	1	*2*	*3*	*4*
Variables	*Coefficient*			
NH	*2.60****	*1.58****	*-0.26****	*-0.29****
	0.002	*0.003*	*0.007*	*0.004*
RR	*0.10**	*0.06**	*-0.07****	*-0.14**
	0.099	*0.082*	*0.000*	*0.052*
NH x LNH		*1.64****		*0.16****
		0.000		*0.000*
RRxLNH		*0.13****		*0.09****
		0.000		*0.000*
Number of observations	*76*	*76*	*76*	*76*
F (2,74)	*13.26*	*18.69*	*43.29*	*36.15*
R-squared	*0.3757*	*0.4413*	*0.1955*	*0.2088*

Remarks: *, **, *** indicates 90%, 95% and 99% confidence interval, respectively

Whereas the interaction variables to indicate road congestion are added in Column 2, they suggest that building both highway and rural road are beneficial to economic growth. However, building highways at areas with more road concentrations is more conducive to growth than building rural roads.

The result of Column 3 in Table 6 confirms the growth of the GINI index, which indicates the income inequality of the country. The results indicate that the national highway has a greater effect on the GINI index relative to rural road. However, in this specification, national highway and rural road are highly statistically significant at the 1% level with a negative sign, indicating

that these new road networks hamper the growth of the GINI index, which in turn, reduces income inequality.

The additional interaction variables in Column 4 of Table 6 indicate that building both highways and rural roads close to the area with high road concentrations can increase inequality but also increase economic growth.

7. Conclusion

As roads are constructed, growth is generated because the economic activities measured from the changes in night-time light have increased through time. However, the growth of economic activity occurs because a new national highway network is widely scattered and diversified. Conversely, for rural road networks, the growth of economic activities, which are concentrated within the 3-km radius distance area, can be attributed to the fact that most residents or manufacturing industries are located close to the road network. Moreover, the total growth value of economic activity specifically due to the road network is high in the national highway. This finding proves that national highway can better generate growth compared with rural road.

From the result of the estimation model, the coefficients of national highway determination are stronger in both the growths of GPP and the GINI index equation compared with the rural road coefficients. This result is expected, given that the improvement of national highway leads to greater changes in the mean of night light in the surrounding areas. The analysis suggests that a national highway has an essential role in generating growth and reducing income inequality. Nevertheless, as the primary road of the country, national highway has an effect on the national level. By contrast, as a secondary road for intra-province connections, rural road does not substantially affect the nation as a whole. However, the improvement of rural road might still generate income for the local area as it continues to decrease the growth of the GINI index.

Economic activities must be equally diversified. Therefore, the national highway should be given attention in terms of improvement and effective construction, in order to create connectivity and linkage among large urban areas and major cities. The linkage function of a national highway can

enhance more flow of money or goods. Improving the national highway creates connectivity of other highways in the entire network. Therefore, economic effect can be distributed over the country. Moreover, such an effect may also alter the comparative advantage across locations, which leads to spatial redistribution of economic activities from the provinces. For example, certain provinces or regions might have specific inputs that others do not have; with the linkage, each region can focus on what their area of specialisation and later trade goods with others. Instead of concentrating on things each region does best and exchange with others for other things that they do best, every region can be better off. For the national highway, the main road can generate GPP, which refers to income at the provincial level via trade of goods. Tourism can also be promoted as national highway enables province-to-province connection, which is easy and convenient for transportation and journey. Thus, the growth of both the GPP and the GINI index equation indicate that connectivity is influenced by the growth and inequality in the country.

Considering the structure of Thailand, growth is mostly generated in large cities and not equally diversified since the past. Hence, connectivity can link big cities together and better diversify the economic activities of each region. Focusing on growth is important. Most countries or governments have been attempting to find ways to generate growth. However, diversifying the benefit and opportunity equally to society notably requires substantial effort. Thus, the effect may not be too apparent at a sudden point in time but with patience, the effect would be positively worthwhile in the long run.

This paper may not obviously conclude methods of building roads to increase economic performance effectively. Nonetheless, there must be a trade-off between growth and inequality. If roads are built in areas with other congested roads, such process will promote further growth but may also increase inequality at the provincial level. Thus, the government must strike a balance these two aspects when building national roads and highways.

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