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Original Article

Cross-border shipment route selection utilizing analytic hierarchy process (AHP) method

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Abstract

Becoming a member of ASEAN Economic Community (AEC), Thailand expects a growth of cross-border trade with neighboring countries, especially the agricultural products shipment. To facilitate this, a number of strategies are set, such as the utilization of single check point, the Asian Highway (AH) route development, and the truck lane initiation. However, majority of agricultural products traded through the borders are transported using the rural roads, from growing area to the factory, before continuing to the borders using different highways. It is, therefore, necessary for the Department of Rural Roads (DRR) to plan for rural road improvement to accommodate the growth of the cross-border trades in the near future. This research, thus, aims to select potential rural roads to support cross-border shipment utilizing the analytic hierarchy process (AHP) method. Seven key factors affecting rural roads selection, with references from transport and other related literatures, are extracted. They include:1) cross-border trade value, 2) distance from border to rural road, 3) agriculture and processed agriculture goods transported across the border, 4) compatibility with national strategies, 5) area characteristics around the rural road, 6) truck volume, and 7) number of rural roads in the radius of 50 kilometers from the border. Interviews are conducted with the experts based on seven key factors to collect data for the AHP analysis. The results identify the weight of each factor with an acceptable consistency ratio. It shows that the cross-border trade value is the most important factor as it achieves the highest weight. The distance from border to rural road and the compatibility with national strategies are also found crucial when making rural road selection decision. The Department of Rural Roads could use the results to select suitable roads, and plan for road improvement to support the cross-border shipment when the AEC is fully implemented.

Keywords: analytic hierarchy process, cross-border shipment, cross-border trade, route selection, rural roads

1. Introduction

In the past two years, the cross-border trade value between Thailand and neighboring countries had been increasing about 80% and the average growth rate is 20%. After attending the ASEAN Economic Community (AEC) in 2015, the trade value tends to increase accordingly, which is not only a benefit to the local residents but also have an influence on the relationships between Thailand and neighboring countries.

There are 89 borders between Thailand and neighboring countries which consist of 33 permanent borders and 56 temporary checkpoints. Moreover, there are a number of trade doors which will be more significant after the attention to AEC in 2015, such as Singkorn border (Thailand-Myanmar) in Prachuap Khirikan province, Chong Sa-ngum border (Thailand-Cambodia) in Srisaket province, Chong Mek border (Thailand-Laos) in Ubon Ratchathani, etc. These borders connect with the production source of the country, such as natural rubber and processed rubber, steel, sugar,

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consumer goods, engine, animal feed, construction materials, etc. A number of product sources and factories are located around the rural roads connecting them to essential trading partners, like Myanmar, Laos, and Cambodia. Thus, the cross-border trade value will increase after completely entering the AEC in 2015 that will lead to the increase of transportation of raw materials, processed goods, and other goods over the rural roads. As a result, it is necessary to study the truck transportation network over the rural roads to extend the service life of the rural roads that link the product sources, factories, and trade routes together. In addition, this study considered potential factors influencing rural road network selection and development for cross-border shipment. This research utilized the AHP method and summarized the seven significant factors to be used in the route selection and maintenance planning process.

2. Contributing Factors for the Route Selection

There are a number of literatures in the area of route selection. The National Economic and Social Development Board (2013), for example, suggested two key factors in route development, including agriculture and processed agriculture goods transported across the border, and the compatibility with national strategies. Ammarapala *et al.* (2013), on the other hand, recommended six factors affecting rural road selection necessary for weigh station establishment: 1) heavy truck traffic volume, 2) annual average daily traffic (AADT), 3) proximity to the Department of Highways (DOH) weight stations, 4) industrial hubs, 5) agriculture hubs, and 6) industrial zone. The National Economic and Social Development Board (2014) recommended five key factors necessary for rural road selection serving cross-border shipment. They include 1) cross-border trade value, 2) distance from border to rural road, 3) area characteristics around the rural road, 4) truck volume on the rural roads, and 5) number of rural roads in the radius of 50 kilometers from the border. Based on the above literatures, this study categorized significant factors for the route selection process into seven factors, including:

2.1 Cross-border trade value

Special economic border research (National Economic and Social Development Board, 2014) applied the characteristic and cross-border trade value in the selection of suitable area for establishing the special economic zone phase I and phase II. Besides, this study considered the cross-border trade value as a main factor for the route selection in the rural road network development.

2.2 Distance from border to rural road

Special economic border research (National Economic and Social Development Board, 2014) concluded that the main problem of cross-border development is the transportation network between Thailand and neighboring countries has not been improved. Moreover, model scheme manoeuver of the rural road network development for supporting the borderline province (DRR, 2014) stated that the connection and accessibility are part of the route selection process for the development of rural road network.

2.3 Agriculture and processed agriculture goods transported across the border

A strategy of the Ministry of Commerce (Office of Permanent Secretary Ministry of Commerce, 2011) emphasized on the development of the international trade and the advantage of the AEC. Moreover, this strategy discovered the pilot industrial scheme showing in Table 1. In addition, The 2nd National Logistics Development plan (2013-2017) (National Economic and Social Development Board, 2013) also supports the agriculturist and entrepreneur in the supply chain of agriculture goods and food '*from farms to forks*'. This plan focuses on the urban area in the radius of 30-50 kilometers from the border to support the expansion of border trade by developing the potential permanent border, temporary border, and temporary checkpoint to become a standardized customer information quality (CIQ) border.

Table 1. Summary of eight pilot industries (Ministry of Industry, 2011).

Industry Group	Pilot Industries
Highest Profit to Country	• Food and beverage • Rubber • Textile
Skilled Labor	• Automobile and auto parts • Jewelry
Social Development	• Clothing
Technology	• Electric appliance
Infrastructure	• Machinery and mold
Environment	• Renewable energy

2.4 Compatibility with national strategies

National economic and strategic plans have effects on national logistics development, such as the 2nd National Logistics Development Plan (2013-2017) (National Economic and Social Development Board, 2013), the National Industrial Development Master Plan (2012-2031) (Ministry of Industry, 2011), and the Special Economic Border.

2.5 Area characteristics around the rural road

Special economic border research (National Economic and Social Development Board, 2014) stated that the suitable area for establishing the special economic zone phase I have to be on proper geography in favor of the transportation, border crossing, and safety. Moreover, this research also defined the environment as a main factor for rural roads development.

2.6 Truck volume on the rural roads in the radius of 50 kilometers from the border

Model scheme manoeuver of the rural road network development for supporting the borderline province (Department of Rural Roads, 2014) determined the traffic volume as a main factor for the route selection for the development of rural roads network. Furthermore, the study of transport network and the construction of weigh station in Eastern Thailand (Department of Rural Roads, 2014) also

determined the truck volume as a significant factor for transport network development.

2.7 Number of rural roads in the radius of 50 kilometers from the border

The 2nd National Logistics Development Plan (2013-2017) (National Economic and Social Development Board, 2013) and the National Industrial Development Master Plan (2012 – 2031) (Ministry of Industry, 2011) considered the way to develop the national economic and social development plan, government policy, and the connection of AEC in 2015 by constructing a lot of strategies, such as supply chain enhancement focusing on the area within 50 kilometers from the border, and the utilization of multi-modal transportation.

3. Materials and Methods

The analytic hierarchy process (AHP) is a pair wise comparison method of measurement theory (Saaty, 2008). It was used to determine the best rural road for development of road network for cross-border shipment in each region of Thailand since this method is an effective and popular approach to simplify complex problems, both concrete and abstract. It divides problem into factors then arranges them into hierarchy chart. After that, each factor is valued to compare and contrast in order to determine the most significant factor and choice. Rattanavarin (2007) concluded the advantages of AHP as following, (a) easy to use as data is in form of hierarchy chart, (b)precise, (c) easy to prioritize as results are in form of digits, (d) capable of handling both subjective and objective factors, and (e) eliminating any bias in decision.

The AHP has been used in various areas of decision making. For example, road network selection, resource allocation, production improvement, evaluation of environmental impact, designed road network, highway alignment, and rail maintenance planning (Banai, 2006; Berrittella *et al.*, 2007; Wei *et al.*, 2005;). Cheng and Li (2001) constructed a method of AHP with eight steps as followings;

1.Cleary define the decision problem.

2.Defining the criteria relating to the decision problem: This is achieved through a number of literature reviews in the studied areas.

3.Setting up the decision hierarchy in which the first level of hierarchy represents goal in making decision: The second level displays main criteria. The third level are secondary criteria (optional as if the main criteria is not clear) and the last level are choices.

4.Data collection from experts: Greenbaum (1993) and Melon *et al.* (2008) stated that 5 – 7 experts are considered reliable, since too much data complicate data management, and require higher costs.

5.Construct matrix to employ pair-wise comparison. To compare factors, intensity of importance of each factor is required since factors are not equally important. Saaty (1980) set up fundamental scale with 9 levels of intensity as shown in Table 2. Pairwise comparisons of all factors are done in matrix. Level 1 ($a_{ij} = 1$) means a_i and a_j are equally important. Level 5 ($a_{ij} = 5$) means a_i is much more important than a_j and level 9 ($a_{ij} = 9$) means a_i is extremely more significant than a_j.

Table 2. Fundamental scale of AHP (Saaty, 1980).

Intensity of importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Moderate importance of one over another	Experience and judgment strongly favor one activity over another
5	Essential of strong importance	Experience and judgment strongly favor one activity over another
7	Very strong importance	An activity is strongly favored and its dominance demonstrated in practice
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation
2, 4, 6, 8	Intermediate values between the two adjacent judgment	When compromise is needed

The intensity of importance of each factor can be compared only for a pair over diagonal line. For example, if a_{12} is equal to 7 then a_{21} will be equal to 1/7.

6.Estimating relative weight of elements on each level in the hierarchy from model analysis.

7.Calculating the consistency ratio (CR (to completely measure the consistency in the pair-wise comparison .For example, if the result is factor A is 2 times more important than factor B and factor B is 2 times more important than factor C, so this comparison is inconsistent . This problem can be solved by adjusting the study and re-calculating the result .Moreover, Saaty)1980 (showed the average of the random index)RI (value for matrices of order 1 to 10 using a sample size of 500 .As in Table 3, the acceptable value is 0.1 or less than 0.1, if the value is higher than acceptable value then it is necessary to re-calculate or re-develop the assessment.

8.List the rating results of each criterion to prioritize the criteria.

Table 3. Random Index (RI) (Saaty, 1980).

Matrix size	Random consistency index (RI)
1	0.00
2	0.00
3	0.58
4	0.90
5	1.12
6	1.24
7	1.32
8	1.41
9	1.45
10	1.49

4. Results

The selected borders are potential borders which are significant for development of road network for cross-border

shipment in each region of Thailand. These six selected borders cover all region of Thailand as followings; Baan Pang Ha temporary checkpoint Tambon Ko Chang, Amphoe Mae Sai, Chiang Rai (Northern region) opens daily at 6:00 - 18:00; Baan Sailomjoy temporary checkpoint Tambon Wiang Phang Kham, Amphoe Mae Sai, Chiang Rai (Northern region) opens daily at 6:00 – 18:00; Baan Boongkla temporary checkpoint Amphoe Boongkla, Nong Khai (North Eastern region), connected to Baan Pakkading, Pakkading District, Bolikhamsai opens at 8:00 – 18:00 on Tuesday and Friday; Baan Moh temporary checkpoint Amphoe Sri Chiang Mai, Nong Khai (North Eastern region), connected to Baan Dan Kam, Sri Kotabong District, Vientiane open at 8:00 – 17:00 Tuesday and Saturday; Ban Muen Dan temporary checkpoint Tambon Bo Ploy, Amphoe Bo Rai, Trat (Eastern Region), connected to Baan Sanjao Amphoe Sumlood, Phra Tabong open daily at 8:30 – 17:00; and Baan Khao Fhachee temporary checkpoint Moo 4 Tambon Bangkaew, Amphoe La-un, Ranong (Southern Region) opens daily at 8:00 - 16:00.

Rural roads in the radius of 50 kilometers from these six borders are analyzed by the AHP to select the best route contributed to development of road network for cross-border shipment in each region of Thailand. Nevertheless, there are seven factors contributed to the route selection;

4.1 Cross-border trade value

Trade value data from the past three years)2011 - 2013 (are classified into five levels, as shown in Table 4. Weight in each level derives from proportion of all cross border trade values studied by the Department of Rural Roads)2014.(For example, the "low trade value) "average trade value over three years of 16,500 –49,000 million Baht (has an importance weight of 0.3.

4.2 Distance from border to rural road

Distances from each border to the closest rural road are classified into five levels, as shown in Table 5 .Weight in each level derives from proportion of distance to border from all rural roads .For example, the "bad connection and accessibility) "distance from border to the closest rural road of 20–30 kilometers (has an importance weight of 0.2.

4.3 Agriculture and processed agriculture goods transported across the border

In this research, four types of important agriculture and processed agriculture goods with high import and export activities across each border were considered, including; rice, rubber oil, palm, and canned fruit.

Table 4. Weighting level of cross-border trade value (DRR, 2014).

Weight	Level	Average trade value over 3 years (Million Baht)
1.0	Very high trade value	More than 130,000
0.8	High trade value	82,001 - 130,000
0.5	Moderate trade value	49,001 - 82,000
0.3	Low trade value	16,500 - 49,000
0.1	Very low trade value	Less than 16,500

Table 5. Weighting level of distance from border to rural road (DRR, 2014).

Weight	Level	Distance from border to the closest rural road (Kilometers)
1.0	Very good connection and accessibility	0 – 5
0.8	Good connection and accessibility	5 – 10
0.5	Moderate connection and accessibility	10 – 20
0.2	Bad connection and accessibility	20 – 30
0.1	Very bad connection and accessibility	More than 30

4.4 Compatibility with national strategies :

Economic development plans and strategies were considered in this research, including (1 (the Thailand National Spatial Development Plan 2057, (2) the 2nd National Logistics Development plan (2013-2017), (3) the National Industrial Development Master Plan (2012–2031) (Ministry of Industry, 2011), and (4) the Special Border Economic Development Zone.

4.5 Area characteristics around the rural road :

Characteristics of each border area are classified into three levels as shown in Table 6.

Table 6. Weighting level of area characteristic (DRR, 2014).

Weight	Level	Area characteristic within 2 km radius around border
1.0	Low risk area	Class 5 watershed or normal area
0.5	Moderate risk area	Class 4 and 3 watershed or area near school hospital or place of worship
0	High risk area	Class 1 and 2 watershed, reserved forest, national park area or historical site

4.6 Truck volume in the radius of 50 kilometers from the border :

Volumes of truck are classified into three levels as shown in Table 7.

Table 7. Level of truck volume (DRR, 2014).

Level	Truck volume (number of truck per day)
Low volume	1,000 – 2,300
Moderate volume	2,301 – 3,000
High volume	More than 3,000

4.7 Number of rural roads in the radius of 50 kilometers from the border

Three levels are classified as shown in Table 8.

Table 8. Level of number of rural roads in the radius of 50 kilometers from the border (DRR, 2014).

Level	Number of rural roads in the range of 50 kilometers from the border
Low number of rural roads	Less than 10
Moderate number of rural roads	11 – 20
High number of rural roads	More than 20

The AHP factors are used for interview questions development .The interviewees are local experts from the Department of Rural Roads)DRR (in the northern and northeastern provinces .The interviewees are directors, mainly responsible for decision making related to road improvement . Each interview takes about two hours .The interviewees are asked to provide the score of each pair of statement using Saaty)1980 (score of 1–9 as shown in Table 9 .For example, if the interviewee considers the "cross-border trade value "as having an absolutely more important than "distance from border to rural road", then he gives the score of 9 .This, in turn, results in the score of 1 when consider the "distance from border to rural road "with the "cross-border trade value ". Example of interview questions is shown in the Appendix.

Data from interview were analyzed using the AHP method. The importance weight of each factor is achieved, as illustrated in Figure 1. It is clear that cross-border trade value is weighted the most followed by the distance from border to rural road, compatibility with national strategies, truck volume, agriculture and processed agriculture goods transported across the border, number of rural roads in the radius of 50 kilometers from the border, and area characteristics around the rural road respectively.

Table 9. Saaty (1980) rating scale.

Intensity of importance	Definition	Explanation
1	Equal importance	Two factors contribute equally to the objective
3	Somewhat more important	Experience and judgment slightly favor one over the other.
5	Much more important	Experience and judgment strongly favor one over the other.
7	Very much more important	Experience and judgment very strongly favor one over the other. Its importance is demonstrated in practice.
9	Absolutely more important.	The evidence favoring one over the other is of the highest possible validity.
2, 4, 6, 8	Intermediate values	When compromise is needed

Based on the "compatibility with national strategies "factor, the Special Border Economic Development Zone strategy is found the most important strategy, followed by the 2nd National Logistics Development plan)2013-2017(, the National Industrial Development Master Plan)2012–2031 ((Ministry of Industry, 2011(and, the Thailand National Spatial Development Plan 2057, respectively .In the "agriculture and processed agriculture goods transported across the border "factor, rice, rubber, palm oil and canned fruit are considered important products traded across the borders .Weights of each factor were used to calculate total weight of rural roads in the radius of 50 km from six selected borders .Then, 10 rural roads holding the most total weight value are ranked as shown in Table 10.

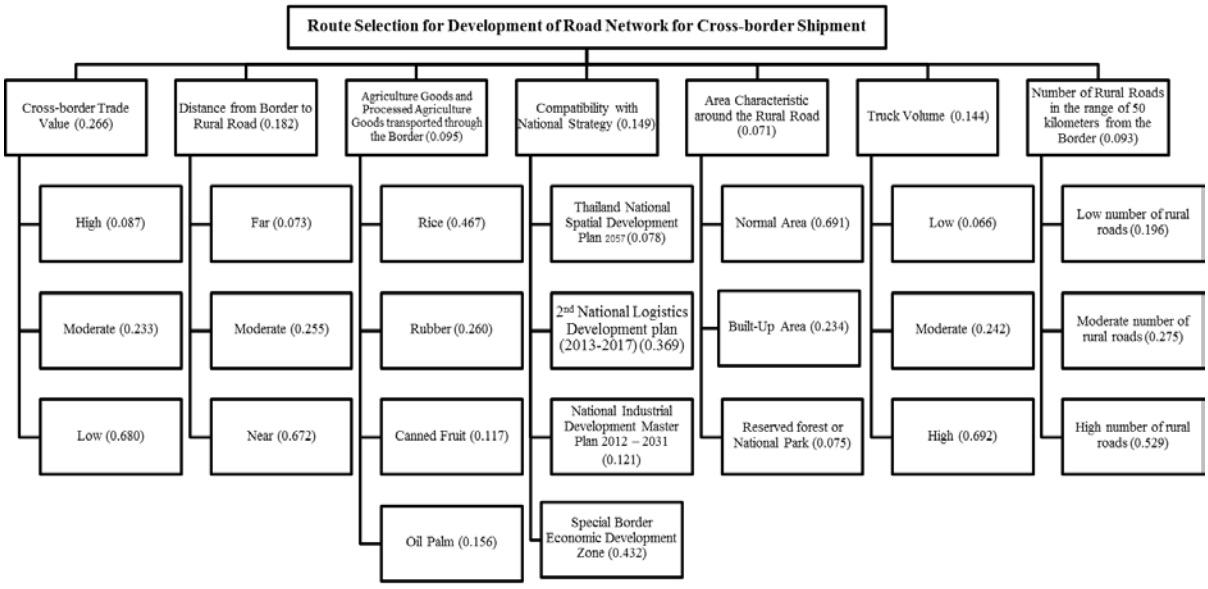

Figure 1. Geometric weight of each factor

Table 10 Top 10 most weighted rural roads.

Border	Province	Rural Road	Total weight
Baan Pang Ha	Chiang rai	Chiang Rai 4060	0.514
		Chiang Rai 4011	0.469
		Chiang Rai 4010	0.469
		Chiang Rai 5055	0.457
		Chiang Rai 4004	0.426
		Chiang Rai 4034	0.426
		Chiang Rai 3059	0.413
		Chiang Rai 1042	0.413
		Chiang Rai 1041	0.413
		Chiang Rai 4034	0.412
		Chiang Rai 4007	0.412
Baan Sailomjoy	Chiang rai	Chiang Rai 4060	0.514
		Chiang Rai 4010	0.469
		Chiang Rai 5055	0.457
		Chiang Rai 4004	0.426
		Chiang Rai 4034	0.426
		Chiang Rai 3059	0.413
		Chiang Rai 1042	0.413
		Chiang Rai 1041	0.413
		Chiang Rai 4052	0.412
		Chiang Rai 4007	0.412
		Chiang Rai 4049	0.412
		Chiang Rai 4052	0.412
Baan Boongkla	Nong Khai	Nong Khai 3043	0.426
Baan Moh	Nong Khai	Nong Khai 3005	0.426
		Nong Khai 4044	0.413
Ban Muen Dan	Trat	-	-
Baan Khao Fhachee	Ranong	Ranong 5011	0.479
		Ranong 4023	0.435
		Ranong 1008	0.435
		Ranong 1018	0.435
		Ranong 5036	0.435
		Ranong 1006	0.435
		Chumphon 2030	0.419
		Ranong 4001	0.416

An example of total weight calculation of the Chiang Rai 4060 road is shown below. Trade value level in this rural road is low. Thus, weight for this factor is 0.087 multiply by the weight of this category (trade value) which is 0.266, yielding 0.087 x 0.266 = 0.023. Distance from this rural road to the border is in moderate level. Thus, weight for this factor is 0.255 multiply by the weight of this category (distance) which is 0.182, yielding 0.255 x 0.182 = 0.046. This rural road is compatible with all of the national strategies. Thus, weight for this factor is a summation of strategies' weight (0.078 + 0.369 + 0.121 + 0.432) multiply by weight of this category, 0.149, yielding 1 x 0.149 = 0.149. Truck volume on this rural road is low. Thus, the weight is 0.066 multiply by the weight of this category (truck volume) which is 0.144, yielding 0.066 x 0.144 = 0.0410. Agriculture products in this area are rice, rubber, and canned fruit. Thus, the weight of this factor is (0.467 + 0.260 + 0.117) multiplied by weight of this category (goods), 0.095, yielding 0.844 x 0.095 = 0.080. The number of rural roads in radius of 50 kilometers from the border is in moderate level. Thus, the weight of this factor is 0.275 multiply by weight of this category (number of road) which is 0.093, yielding 0.275 x 0.093 = 0.026. Area around this rural road is normal. Thus, the weight for this factor is 0.691 multiply by weight of this category (area characteristics), 0.071, yielding 0.691 x 0.071 = 0.049. Sum of weights of all six factors equals 0.023 + 0.046 + 0.149 + 0.010 + 0.080 + 0.026 + 0.049 = 0.383. The maximum total weight of all six factors is 0.745. So, a percent conversion is needed in order to have maximum value equals 100 percent. The converted weight equals 0.383/0.745 = 0.514 or 51.%. The ten most ranked rural roads are suitable for development of road network for cross-border shipment in each region of Thailand.

5. Conclusions

The improvement of rural roads is necessary to support cross-border shipment to facilitate the AEC implementation. To select suitable routes in this study, seven factors are marked as criteria for route selection: (1) cross-border trade value, (2) distance from border to rural road, (3) agriculture and processed agriculture goods transported across the border, (4) compatibility with national strategies, (5) area characteristics around the rural road, (6) truck volume, and (7) number of rural roads in the radius of 50 kilometers from the border. Since significance of each factor is different, the AHP method, in which factors are geometrically weighted upon their significance, is used to simplify route selection. The results show that the cross-border trade value weighs the most, with an important weight of 26.6%, followed by the distance from border to rural road, compatibility with national strategies, truck volume, agriculture and processed agriculture goods transported across the border, number of rural roads in the radius of 50 kilometers from the border, and area characteristics around the rural road, respectively.

The seven key factors, with their importance weights, are then used to rank potential rural roads for cross-border shipment development. The Chiang Rai 4060 road is found the most significant route, as it achieves the highest total weight. This route serves truck transportation in two borders in Chiang Rai province: Baan Pang Ha and Baan Sailomjoy. These two borders are considered in the Special Border Economic Development Zone planned by the government. It is also a major route to transport agricultural products from the growing area to the processing plants. The Ranong 5011 road is ranked the second. This route serves truck transportation in Baan Khao Fhachee border. It is in the 10–30 kilometer range from the borders. However, this route is not included in the Special Border Economic Development Zone planned by the government.

There are a number of limitations in this study. Route selection, however, cannot be determined solely on the total weight. Road network and road characteristics must also be considered to select the most suitable road for the improvement. The study applied the radius for the primarily route selection of 50 kilometers from each border. This might result in one route serving a number of borders. To achieve a better result, this factor might be adjusted. Apart from that, the interviewees are majorly from the experts in the Department of Rural Roads (DRR). Interviewing the experts from different organizations, such as the Department of Highways,

the Ministry of Transport, and the Motorway, might bring various perspectives regarding factors affecting rural road selection. The majority of data acquired in this study is also based on Thailand economic and environment. The factors must, therefore, be adjusted before applying in other countries.

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Appendix

An example of an AHP survey form.

Cross-border trade value	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Distance from border to rural road
Agriculture and processed agriculture goods	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Number of rural roads in the radius of 50 kilometers from the border
Low cross-border trade value	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	High cross-border trade value
Rice	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Rubber