

Research Paper

Prioritizing rural roads projects in north-eastern Thailand by analytical hierarchy process (AHP)

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ARTICLE INFORMATION

Article history:

Received: 11 October, 2016

Received in revised form: 12 June, 2017

Accepted: 21 July, 2017

Publish on: 07 September, 2018

Keywords:

AHP

Decision analysis

Prioritization

Rural roads development

ABSTRACT

This paper presents the application of the Analytic Hierarchy Process (AHP) in rural roads prioritization. The paper exhibits the concept and process of the plan for rural road development and application of multiple criteria decision analysis using AHP for prioritizing rural roads on a rational basis. Rural road network was grouped on strategic issues and strategies of Department of Rural Roads. There are three main factors to be used as an indicator to assess the importance of routes of each type of road: Transport and Traffic engineering, Accessibility and Other. The result of criteria weights was determined by Expert Choice software according to the AHP model. The results of weight factor analysis can be divided into 2 groups: the Transportation and Traffic Engineering dominant road (Logistics, Traffic Reduction and Country's Border Road) and the Accessibility dominant road (Tourism and Rural Area Accessibility Road). This study will be able to prioritize rural roads and allocate limited budget for development in the future. The master plan obtained from AHP application shows that this plan is consistent, and links with the country strategic plan under the Department of Rural Roads year 2017-2026, which is a long-term plan (10 years), and the Strategic Plan Framework Development of Rural Roads year 2017 - 2020, which is a medium-term plan (4 years). The main goal of the Rural Roads Development Plan in the area is to develop a rural road network to connect the Development of National Infrastructure and the Northeast Development Plan perfectly.

1. Introduction

Nowadays, road network system is the most important infrastructure of transportation systems, with a high service demand because it is the most accessible and convenient system. The framework of the national

strategy of Thailand for the next 20 years is to develop the competitiveness by developing the investment of transport infrastructure, security and energy, special economic areas and cities to connect the regional economy with the world. Therefore, the road network is the core part to support the development of the country.

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Note: Discussion on this paper is open until March 2019

The road networks in Thailand currently exceeds 466,770 km. There are about 66,940 km networks (including Intercity Highway) under the supervision of Department of Highways (DOH), about 47,916 km network under the supervision of Department of Rural Roads (DRR), about 207 km network under the supervision of Expressway Authority of Thailand (EXAT) and about 352,157 km network under the supervision of the local administrative organization. In 2010, travel and goods transport demand on land was about 2.4 million person-trip-day and it was forecasted to be approximately 21.84% or 3.07 million person-trip-day in 2020 (Ministry of Transport, 2017).

Ministry of Transport (MOT) has identified its strategies to support and serve the national strategies. The key strategies are to connect the domestic transport networks with neighboring countries, to develop logistics and transport infrastructure systems thorough all economic areas, in both urban and rural areas. The goal of strategies is to help people to assess increasingly the public transport. Thus, the road network plays an important role to develop both country and the quality of life (Ministry of Transport. Annual Report 2015. Bangkok; Ministry of Transport. Annual Report 2016. Bangkok).

The DRR is mainly responsible for the transport infrastructure. Its missions are to develop and improve rural roads standards to support transport, tourism and development at the country's border, an integrated and sustainable urban development, alleviate traffic congestions by constructing missing links, bypasses, shortcuts and to take part a role as a mentor in road development for local administrative organizations.

Amidst the flow of change in Thailand and many other parts of the world, change is having a significant impact on the context, and the surrounding environment of DRR, both inside and outside. These are fast and intense dynamic changes, which inevitably impact and directly challenge the operation of DRR. Examples of major external changes include: government policy changes focusing on the effectiveness and achievement of projects. This has affected the DRR, who must prepare integrated budget and investment plans to produce a long-term budgeting plan, which is very different from the department's old style budgeting, due to the need for greater knowledge, and requiring expertise in budgeting, and a lot more coordination. Moreover, the DRR faces obstacles from social changes; for example, community expansion has caused the population of residential dwellings to increase on both sides of the roads, as a result the allocation of land ownership is ineffective, resulting in road extensions and improvements in safety operation becoming more difficult and being delayed, etc.

Examples of significant internal changes that are taking place include: the changing age structure of

government officials; currently the DRR has 317 civil engineers with an average age of 46 years, and 794 civil technicians with an average age of 47 years; in the future, many of these will retire, and there will be fewer workers. However, at the same time the amount of work is likely to increase continuously, this will make the work volume inconsistent with the number of people and negatively impact the quality of work, etc.

To prepare for the challenges, to adjust its contextual changes to keep up with the current and future global trends, and to carry out its missions sustainably, the DRR is required to change its strategies. The DRR has prepared development plans for 18 regional rural road offices as a roadmap, which are crucial in carrying out the missions of the DRR. Such plans encompass work plans for short, medium and long term projects, risk-uncertainty absorption projects, personnel development and applications of information technology to enable efficiency and quality of work.

But because the planning process has many steps and complex academic principles, the authors are therefore interested in the Analytic Hierarchy Process (AHP) as a tool to prioritize the project plans of the DRR. This will help the Rural Road Offices to provide good quality Rural Roads Development plans for their regions, based on academic principles that are reliable, and can be used for real change.

The objective of this research is to apply the AHP in rural roads prioritization of Bureau of Rural Roads 5 (Nakhon Ratchasima) in North-Eastern Thailand. This bureau was selected as a studied site due to two main reasons. Firstly, it is the largest bureau dealing with rural roads network covering 4 provinces: Nakhon Ratchasima, Chaiyaphum, BuriRam and Surin. There are over 237 routes of rural road network with a distance over 4,329 km. Secondly, the Bureau always receives the highest budget for rural road maintenance in Thailand (Department of Rural Roads, 2017). The Bureau of Rural Roads 5 has followed all strategies of DRR such as enlarging the roads for the growth of the cities, solving traffic problems, supporting tourism, promoting the tourism and enhancing border trade linking with neighboring countries. The paper demonstrates the concept and process of the plan for rural roads development and application of multiple criteria decision analysis using AHP for prioritizing rural roads on a rational basis. This study will be able to prioritize rural road for limited funds allocation.

2. Methodology and AHP Model

2.1 AHP Model

Table 1. Pair-wise comparison scale for AHP (Saaty, 1996).

Rating	Explanation
1	Two criterion contribute equally to the objective
3	Experience and judgment slightly favor one over another
5	Experience and judgment strongly favor one over another
7	Criterion is strongly favored and its dominance is demonstrated in practice
9	Importance of one over another affirmed on the highest possible order
2, 4, 6, 8	Used to represent compromise between the priorities listed above

Table 2. Random Index (Saaty & Vargas, 1991).

n	1	2	3	4	5	6	7	8	9	10
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

AHP is a multi-criteria decision making method developed by Saaty (Sharma et al., 2008). It is used to solve a complicated problem into a multilevel. Generally, the framework of AHP comprises all objective, criteria (and/or sub-criteria) and alternative in form of hierarchical structure (Saaty, 1996). AHP is an effective decision making technique to solve the biased problems (GÖRENER, 2012). AHP has been applied to a wide variety in civil engineering such as project management (Al-Harbi, 2001; Rodney A. et al., 2002), contractor selection and evaluation (El-Abbasy et al., 2013; Safa et al., 2015), SWOT analysis (Gao & Low, 2014; Lu et al., 2013; Yuan, 2013), transport (Diakaki et al., 2015), infrastructure development (Farah et al., 2007; Gkountis & Zayed, 2015; Ke et al., 2009) and road development (Dalal, Mohapatra, & Chandra Mitra, 2010; Najafi & Bhattachar, 2011).

The three main steps in the application of the AHP in project management reported by (Al-Harbi, 2001) were adopted and applied in this study. First step, created the hierarchy from top (the objective) through the intermediate levels (main criteria and/or sub criteria) to the lowest level (the alternatives). Next step, constructed a set of pair-wise comparison matrices for each level applied by using the scale measurement for AHP as shown in **Table 1**. Final step, applied hierarchical synthesis to weight the eigenvectors. It should be noted that the quality of the output of AHP depends on the consistency of pair-wise comparison. The Consistency Index (CI) can be calculated using the following formula.

$$CI = (\lambda_{max} - n) / (n - 1) \quad [1]$$

Where λ_{max} is maximum eigenvalue and n is order of matrix. The Consistency Ratio (CR) is used to justify the final evaluation of judgement. The consistency is acceptable if CR value does not exceed 0.1. The CR is defined as the ratio of the CI to the random index (RI) (**Table 2**). The potential of road in various aspects has been assessed. The results of such assessment were

then prioritized to develop the rural road network plan. The process of the plan for rural road development can be illustrated by **Fig. 1**.

The strategic direction and development of DRR and Bureau of Rural Roads were reviewed inclusive of vision, mission and strategy. The linkages of strategic issues of central and local authorities were also analyzed. Based on the review and analysis, the road networks were classified into 5 groups: Tourism, Logistics, Traffic Congestion Reduction, Rural Areas Access and Security along the Country's Border, which is shown in **Fig. 2**.

2.2 Group of road based on strategy of DRR

The linkage between 5 road groups and strategic issues and strategies of Department of Rural Roads is shown in **Table 3**. Two main strategies are issued by the DRR that the first strategy is to develop the rural road network thoroughly and safely, and to promote and support the local road authority to enhance the stability of nation. The second strategy is to connect the rural road network to promote economic development and prosperity of nation.

2.3 Route selection

This study had set guidelines for collecting information to develop plan for rural road network by developing a number of questionnaires, which were used to collect the data of routes and opinions. The collected data were the needs of stakeholders, which were used to develop the rural road network plan. The rural roads of the Bureau of Rural Roads 5 covering 4 provinces (Nakhon Ratchasima, Buriram, Surin and Chaiyaphum) in North-Eastern Thailand were selected in this study. Based on the collaboration of staff from the Bureau of Rural Roads 5 under the supervision and guidance of an expert panel as a group decision-making procedure, each route was assessed in accordance with the strategies of DRR. The number of routes in accordance with the strategies are summarized in **Table 3**.

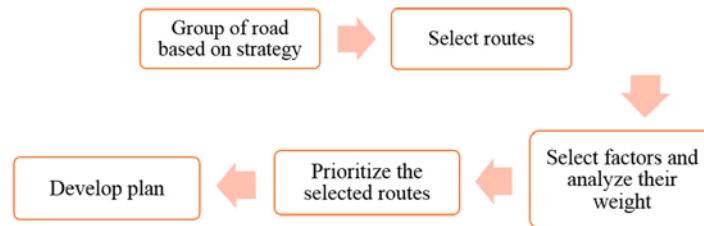


Fig. 1. Process of the plan for rural road development.

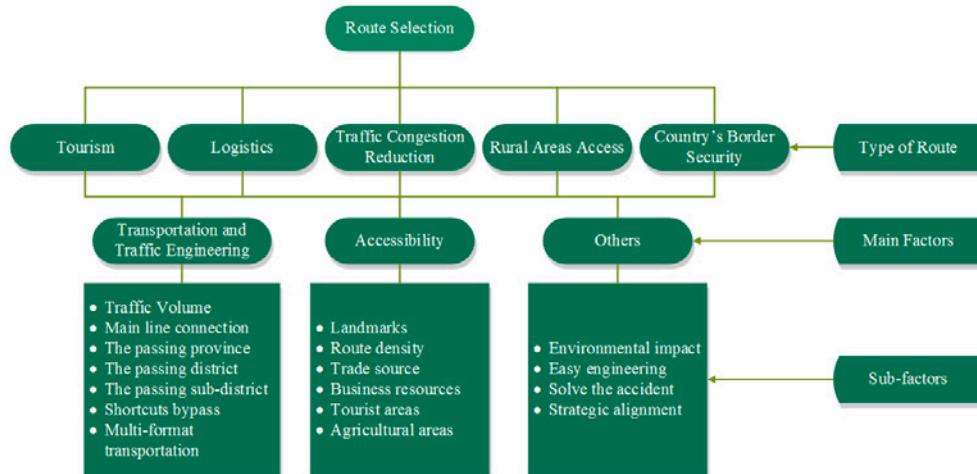


Fig. 2. Process of the AHP analysis.

2.4 Factor selection and weight factor analysis

This step aimed to select the factor to be used as an indicator to assess the importance of routes of each type of road. This study included a literature review and the

collection of factors related to the development of rural roads. The factors are summarized in **Table 4**. Initially, the staff from the Bureau of Rural Roads 5 have defined and measured each factor and assessed the factors.

Table 3. Relations between road groups and strategy and tactics of Department of Rural Roads.

Strategic Issues of DRR	Strategies	Road groups
1. Develop the rural road network thoroughly and to support the local road authority to enhance the stability of nation	1. Develop the rural road network thoroughly 2. Develop and promote the local road network	Traffic congestion reduction Rural areas access
2. Connect the rural road network to promote economic development and prosperity of nation	1. Traffic congestion reduction to enhance travel mobility in the city area 2. Develop logistics system to support tourism, agriculture, trade, and investment sectors	Traffic congestion reduction Tourism, Logistics, Rural area access, Security of country's border

Table 4. Factors to be considered in the planning process.

Main Factors	1. Transport and Traffic engineering	2. Accessibility	3. Other		
1.1	Travel demand	2.1	Number of landmarks	3.1	Environment
1.2	Connection to the main highway	2.2	Density of roads in the study area	3.2	Difficulty in engineering
1.3	Number of province	2.3	Number of stores	3.3	Accidents and safety
1.4	Number of district	2.4	Number of businesses and ports etc.	3.4	Consistent with the strategies
1.5	Number of sub-district	2.5	Number of tourist attractions		
1.6	Shortcut, by pass and traffic congestion reduction	2.6	Agricultural area		
1.7	Support multi-modal transport				

Then the staff made a proper assessment of factors in order to be chosen as the primary factors, and selected the factors to be used for each type of road. The study has prepared a questionnaire, which would be used for the collection data of factors and indicators of each route. The questionnaire was distributed to the working group of each province.

3. Results

The AHP method has been employed to determine the weights of each factor for each type of road. The result of criteria weights was determined by Expert Choice software according to the AHP model. The results of weight factor analysis are shown in **Tables 5**.

These data must be converted into a unit for the comparison. The data has been converted in the form of a score between 0.0 and 1.0 for the simplicity in the analysis. The conversion depended on the type of data and such factors resulted in a positive or negative score of the project selection. The project with the highest score was the most important.

In this study, a framework for prioritizing rural roads in Bureau of Rural Roads 5, DRR is developed using AHP-based approach in a group decision-making environment. The findings show the following ranking based on percentage of each main factor and minor factor for each type of rural road. The results can be explained based on 2 groups: the Transportation and Traffic Engineering dominant road (Logistics, Traffic Reduction and Country's Border Road) and the Accessibility dominant road (Tourism and Rural Area Accessibility Road). In the first main factor group, for the Logistic road group, the score for the Transportation and Traffic Engineering, Accessibility, and Other are 62%, 17%, and 21%, respectively. For the Traffic Reduction road group, the score for the Transportation and Traffic Engineering, Accessibility, and Other are 63%, 18%, and 18%, respectively. For the Country's Border road group, the score for the Transportation and Traffic Engineering, Accessibility, and Other are 44%, 27%, and 30%, respectively. In the second main factor group, for the Tourism road group, the score for the Transportation and Traffic Engineering, Accessibility, and Other are 38%, 41%, and 24%, respectively. For the Rural Area Access road group, the score for the Transportation and Traffic Engineering, Accessibility, and Other are 38%, 41%, and 20%, respectively. So, the concepts of the plan for rural road development will consider the priorities of each road project. A project with the highest priority would be the first order of the rural roads plan, and then followed by the projects with less importance.

The routes of rural road network in the study area were input into the AHP model to be prioritized into 5 road groups, which are 18 routes from Nakhon Ratchasima, 9 routes from Surin, 11 routes from Chaiyaphum, and 9 routes from Buriram were analyzed the priority by AHP. Then, the findings of study show the priority routes in network for setting as the rural road development plan, which being already linked to the strategic issues and strategies of the DRR and MOT in order to gain the most complete rural road network.

When the given routes were arranged the priority based on the indicated criteria, the study considered the main point that all developing routes must be linked to DRR's and the MOT's strategies in order to achieve the most complete network. So, the process of the study had linked between the five road groups and strategic issues and strategies of the DRR. Finally, the study can be summarized as follows.

Strategic issue 1: Development of rural road networks thorough remote areas and safety road enhancement by promoting and supporting rural road highways for the security of the country. The strategic issue consists of two strategies. The first strategy is rural road network development which is expanding road network thoroughly rural areas and the strategy can be moved forward by developing 22 routes for solving traffic problems.

The other strategy is to promote and support the rural road networks and the strategy can be conducted by constructing 5 routes to access the remote areas.

Strategic issue 2: rural road network connectivity to promote economic development and prosperity of the country. Likewise, the strategic issue can be completed by following the strategy: developing logistics system to support growth in tourism, agriculture, trade, and investment sectors. As the result, the 20 studied route of road for tourism, logistics, rural area access, security along the country's border must be set as the development plan to comply with the strategy.

Then, the results were amazed to develop the Rural Road Development Plan for the Bureau of Rural Road 5 during 2017 – 2020. The idea was to organize the development plan, which the most priority projects will be first included in the Rural Road Development Plan, and followed by the minor importance projects. The priority projects were organized based on the budget allocation in the first year by using a Pareto's 80/20 rule, which means that the priority projects are 80% and only 20% of things are worth considering. Therefore, about 20% of roads will be selected from each rural district for consideration in the Rural Road Development Action Plan year 2017. **Fig. 3** shows a master plan for rural road development (detailed map) of the various routes included in the Rural Road Development Plan in the

Bureau of Rural Road 5 in 2017 – 2020 according to the Strategic routes of the Department of Rural Roads.

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Table 5. Weight of factors from the assessment of Bureau of Rural Roads 5.

Main Factor	Weight of Main Factor					Minor Factor	Weight of Minor Factor				
	T	L	TR	RA	CB		T	L	TR	RA	CB
Transportation and Traffic Engineering	35%	62%	63%	38%	44%	1.1	26%	12%	18%	50%	11%
						1.2	20%	29%	13%	20%	30%
						1.3	7%	10%	6%	6%	9%
						1.4	8%	9%	7%	7%	8%
						1.5	8%	4%	7%	7%	7%
						1.6	31%	16%	37%		15%
						1.7		20%	12%	9%	20%
Accessibility	41%	17%	18%	41%	27%	2.1	27%		37%	38%	69%
						2.2			31%	18%	
						2.3	21%	40%			
						2.4	23%	60%	32%		
						2.5	29%				
						2.6				44%	31%
Other	24%	21%	18%	20%	30%	3.1	26%	16%		8%	16%
						3.2	20%	18%	13%	10%	14%
						3.3	42%	38%	52%	55%	37%
						3.4	12%	28%	35%	27%	33%

* T= Tourism, L= Logistics, TR= Traffic reduction, RA= Rural area access, CB= Country's border

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This will be considered to get the allocation of budget urgently, which is spread between all areas by population size. From **Table 5**, the weight values of the various important factors were analysed by the AHP method,

which the questionnaires were prepared and analysed separately for each type of road. The questionnaires were answered by 10 specialists at Bureau of Rural Road 5 (Nakhon Ratchasima), and then the pairwise comparison of questions in each group of 5 usage-features roads were performed according to strategic routes and strategic areas for the DRR. Finally, the data has been converted in the score format, which is simplify for the comparison analysis.

According to the AHP results based on Tourism Factor, Logistic Factor, and Traffic Reduction Factor as shown in **Table 6** obviously show that the route that gets the top score is the Sikhio Central City Planning Road, route A in Sikhio District, Nakhon Ratchasima Province, which its budget of 123.60 million Baht for a total distance of 6.16 kilometers. This is the route that supports the objectives for network development to connect other networks in the future, and to support the Motorway Construction Projects among the cities: Route Bang Pa In – Saraburi – Nakhon Ratchasima. The route that gets the second highest score is the Nakhon Ratchasima Central City Planning Road, route 21-22, Muang District, which its budget of 240.00 million Baht for a total distance of 12.00 kilometers. Its goal is to link up with the provincial railway network development, planned from Bangkok – Nakhon Ratchasima – Nhong Khai. The AHP result based on Rural Area Access Factor indicates that the first-highest score and the second-high score is the route of Huai Rat – Krasang, and the Intersection of Highway Buriram 4060 connecting to Highway Buriram

3005, respectively. Both routes are located in Buriram Province, which links between the Nakhon Ratchasima province and the country's border (Surin Province) as shown in **Fig. 3**. The AHP result based on Country's Border Security Factor as shown in **Table 6** shows that the priority province selected for security along the border is Surin Province, which obtained the highest score. Firstly, Highway Junction No. 24 – Ban Kra-ngern, Prasart District; distance 7.60 kilometers, budget 65.03 million Baht. The objectives of this route are to promote

and develop the rural road network, to provide complete access to all areas, and to support safety for the security of the country. Secondly, Highway Junction No. 2121 – Ban Roon, Panom Dongrak District; distance 20.43 kilometers, budget 145.81 million Baht. Objective, inter-connection of rural roads networks to support trade and investment. Moreover, the study has been planning to develop the rural network to be linked with other networks in advance between 2017– 2020.

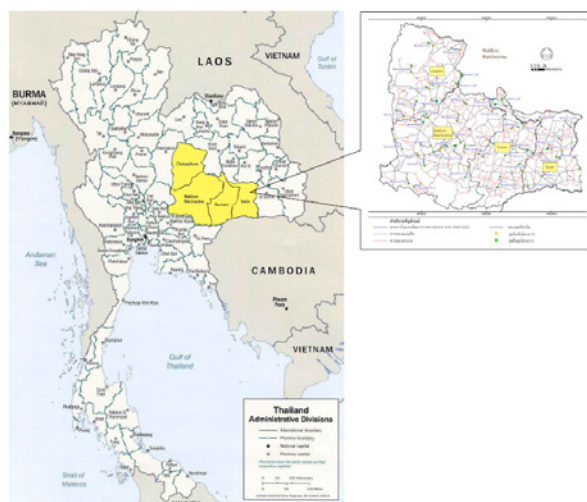


Fig. 3. The master plan for rural road development in 2017 – 2020

The study is about an urgent development plan to be connected with the national infrastructure development plan and Northeastern region development plan to support the growth of the provinces because of carrying out the project of Bang Pa-in – Nakhon Ratchasima intercity motorway, Bangkok – Nakhon Ratchasima –

Nong Khai double track railway and Bangkok – Nakhon Ratchasima high-speed railway. However, the result of route selection for the next development plan of rural road should be classified in format of short, medium and long term plans in further study.

Table 6. AHP results based on different factors.

Factors	DRRs	Reference No.	Project's name	Score	Priority
Tourism	Nakhon Ratchasima	KR2	Phangmuangruom Rd. Sikhio Route kor	0.117	1
	Nakhon Ratchasima	KR1	No Data	0.093	2
Logistic	Nakhon Ratchasima	KR2	Phangmuangruom Rd. Sikhio Route kor	0.045	1
	Nakhon Ratchasima	KR3	Phangmuangruom Rd. Korat Route 21-22	0.043	2
Traffic Reduction	Nakhon Ratchasima	KR3	Phangmuangruom Rd. Korat Route 21-22	0.053	1
	Nakhon Ratchasima	KR2	Phangmuangruom Rd. Sikhio Route kor	0.052	2
Rural Area Access	Buriram	BR4	Huai Rat – Krasang	0.064	1
	Buriram	BR3	Intersection of Highway No. 4060 with Highway No. 3005	0.055	2
Country's Border Security	Surin	SR9	Intersection of Highway 2121 – Ban Run	0.500	1
	Surin	SR2	Intersection of Highway 24-Ban Krangern	0.500	2

This study is another good example in the application of AHP to prioritize the Development Plans of the Department of Rural Roads in the area of responsibility by the office staff of the Rural Road Offices to take part in the operation to improve the quality of planning, survey, design, construction, maintenance and security services,

and to provide the highest quality for the Department of Rural Roads.

4. Conclusions

The concepts of the plan for rural road development in the area under the responsibility of the Bureau of Rural

Roads are presented as follows: (1) Consider the priorities of the project. A project with the highest priority would be the first order of the rural roads plan, and then followed by the projects with less importance. (2) Consider the continuation of the development of the road network. The continuous network projects will be allocated to the master plan of the same year or the next year. (3) Allocate the budget to urgent projects in proportion to population of each province. The results of the study show that the projects above are linked to the national strategy, to get the most complete rural road network. So, we propose a strategic plan for the Department of Rural Roads from year 2017 - 2020 that will be a medium-term plan (4 years) leading to the development of a master plan in year 2018, for the creation of a rural road network supporting the border cities. The main target of the master plan is to support economic growth in the Gateway area between Thailand and Cambodia, and to create competitive advantage in trading with neighboring countries.

Acknowledgements

The authors would like to thank Department of Rural Roads, Bureau of Rural Roads 5 for providing the facilities and support this study.

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