International Transaction Journal of Engineering, Management, & Applied Sciences & Technologies

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A Study on New Bypass Roadway Selection: Case Study of a Southern Part of Nakornratchsima Ring-Road, Thailand

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ARTICLE INFO

Article history:
Received 19 December 2016
Received in revised form 06 March 2017
Accepted 15 March 2017
Available online 16 March 2017

Keywords:
Google Earth; Remote Sensing; Highway and road selection, Transportation studies, Highway project, bypass project.

ABSTRACT

Remote sensing has been used as a tool to give information as it can facilitate bypass road selection, in association with economic and engineering factors. This study focuses on a case study of Southern Part Nakornratchsima Ring-Road, Thailand. Remote sensing image from Google Earth® program is used in connection with the 1:50,000 base map. Google Earth® streaming technology makes it possible to look at the map at different perspectives including 3D viewing. Road geometric design is considered for horizontal and vertical curves on each bypass road. Scoring system has been developed in order to assist the selection. The route with highest score is the best route.

1. Introduction

Building a new road today needs to consider multifaceted factors. What are the important criteria to be considered? The selection of a new roadway requires a thoroughly study. Collecting relevant information along the route is crucial. Even though field survey is still needed, applying remote sensing technology is a vitally important way to get most the needed data the proposed routes pass. Information can be acquired from remote sensing images/photos, available from space shuttle and satellites. The cheapest way to get remote sensing image is to get from Google Earth®.

1.1 Google Earth®

Google Earth®, formerly called EarthViewer 3D, is a virtual earth map. Google Earth applies

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superimposition of images from satellite imagery, aerial photography and geographic information system (GIS) onto a 3D globe. Google Earth and Google Earth Pro versions can be downloaded for free, with more than billion users. Resolution of Google Earth 2D aerial imagery is in ranges from 15m to 15 centimeters (Wikipedia/wiki/Google_Earth, 2016). This study applies remote sensing technology through the use of satellite image freely available from the Google Earth® program.

1.2 Factors Affected Route Selection

Proposing a new route must take into consideration engineering and economic factors. To collected Information, this work get information from field survey, digital satellite photo, Google Earth® photo, and obstacles information. Engineering factor composes of seven sub-factors: route distances, horizontal alignment, vertical alignment, water drainage, difficulty in construction, suitability of connecting point with existing roads, future road expansion. Economic factor composes of two sub-factors: construction cost and compensation for land and building expropriation.

This work applies remote sensing technology through the use of Google Earth ® together with field survey to analysis proposed routes for a bypass road of a southern part of Nakornratchsima ring-road, Nakornratchsima Province, Thailand. In order to find the best route, weights and multiplications are determined to compute score for each proposed route.

2. Literature Review

Gardner (2000) discussed about the advancements in image processing and the commercialization even more of remote sensing. He visualizes to the point that satellite images are used to capture traffic flow patterns and volumes and image processing coupled with fuzzy logic is used to project time-series information to long-term patterns.

Jha and Schonfeld (2004) studied Highway alignment optimization based on cost minimization that optimization algorithms work within a Geographic Information System (GIS) framework integrated with genetic algorithms. The study assessed the effects of various costs on alignment selection, and explored optimization in constrained spaces that indicate the limits on road improvement projects. The results indicated that the alignment optimization is hugely affected travel-time cost. The model could optimize alignments in mountainous terrain or areas with highly complex geography. Relevant geographic data was considered including land boundaries, environmentally sensitive regions, and topographic data.

Small et al. (1989) proposed a comprehensive highway pricing and investment policy to meet the goals of efficiency, equity, and financial stability, based on two economic principles: efficient pricing to regulate demand for highway services and efficient investment to minimize the total public and private costs of providing them. The suggestion aimed to reduce highway budgets in the long run.

Molenaar and Gransberg, (2001) presented six case studies of design-builder selection for small US publicly funded highway projects with participation of Indiana, New Jersey, Colorado, South Carolina, Arizona, and Washington State Departments of Transportation. The study compared critical components of design-builder solicitation and selection, as categorized into fixed-price, one-step, and two-step procedures. The authors offered guidance embarking on design-build.

This study does not consider accident factors (such as a study by Temrungsie et al., 2015) of a new road. This should be further considered.

3. Procedure

3.1 Project Location

This project connects the Nakornratchsima Ring-Road on the southern part (part 4). This project needs to join part 3 on the south, of Thailand Highway Route #226 (Amphoe Chakkarat in Nakornratchsima Province), and join part 3 on the north, of Thailand Highway Route #2 (Mittraphap Road portion between Nakornratchsima and Khon Kaen). Total distance of this project is 9.80km.

3.2 Base Map Linking with Google Earth® Digital Map

The study area base map is acquired with map scale 1:50,000. This base map produced in 2004 is the latest map available. The same area digital map has been founded in Google Earth®. Google Earth streaming technology makes it possible to look at the map at different perspectives including 3D viewing.

3.3 Field Data Collection and Site Survey with GPS

It is necessary to collect most of the needed information in the area. This information is used, all together with feasibility study and environmental impact assessment study, for choosing and designing the possible routes.

A GPS receiver has been brought to the site for finding the landmarks' positions (coordinates). This positioning information is later linked to Google Earth®. This site survey is also used to collect the updated information of the Google Earth® map.

3.4 Creation of Shape File

A shape file is created within the AutoCad®. The UTM (Universal Transverse Mercator) coordinates are transformed to Geo-referenced Coordinate System using Global mapper® the program. The shape file is then uploaded into the Google Earth® map. This facilitates the drawing of possible route lines as places that the routes pass can be readily observed.

3.5 Survey of obstacles

Even though all possible routes have been drawn on satellite image, it is still necessary to conduct field survey to find obstacles that might affect the design routes. The obstacles include

- government places and buildings, school districts,
- religious and historical places (churches, temples, mosques, cemeteries),
- dwellings (including type, dimensions, and number of floors of houses and buildings),
- watery place (waterways, marshes, ponds, fish pond),
- infrastructure (roads, bridges, irrigation canals, floodgate/floodway/spillway)
- Other information.

After having all the information and obstacles data, these are put on the Google Earth® satellite map, based on Universal Transverse Mercator (UTM) coordinates. A list of obstacles is made for each route, to calculate the compensation of the private and public properties (land and building) to be expropriated.

3.6 Criteria used to determine the route of the project.

All collected Information used to consider possible route included field survey, digital satellite photo, Google Earth® photo, and obstacles information. The criteria are

- Route must correspond and connect to other part of the ring road,
- Route must have good drainage without obstructing the flow of water. Flood must not be occurred
- Route must not disturb important historical places, religious sites, schools, hospitals, and government places.
- Route must have the least effects regarding the destructions of dwellings/buildings on the land expropriation. Geological ground profile and environmental factors must also be considered.

3.7 Detail of Route Section

Route of this project running in the north direction for six kilometers. The area composes of irrigation canal, natural waterway, and agricultural area. Next portion, the route shall run in the northwest direction to meet the Route#2 of the Nakornratchsima ring-road. The route also needs to connect the highway Route#226. For this study, there are four possible alternatives route, see Figure 2 for aerial photo and Figure 3 for a map scale 1:50000.

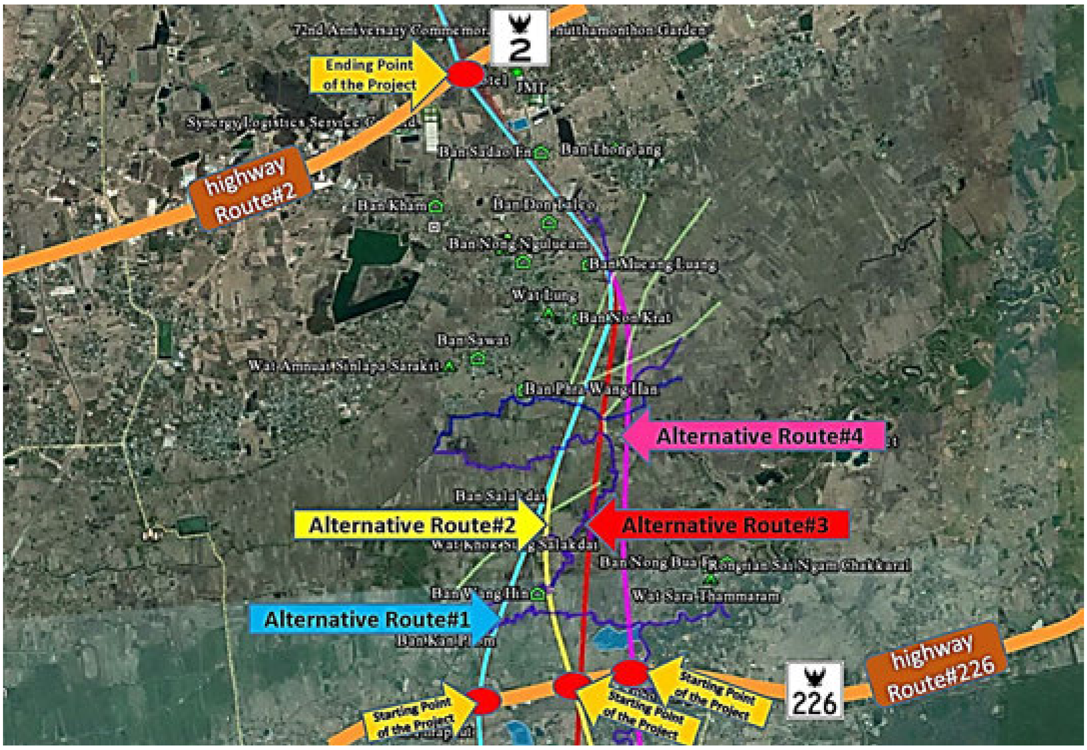

Figure 2: Proposed routes drawn on the aerial photo taken at altitude 166m on April 16, 2016.

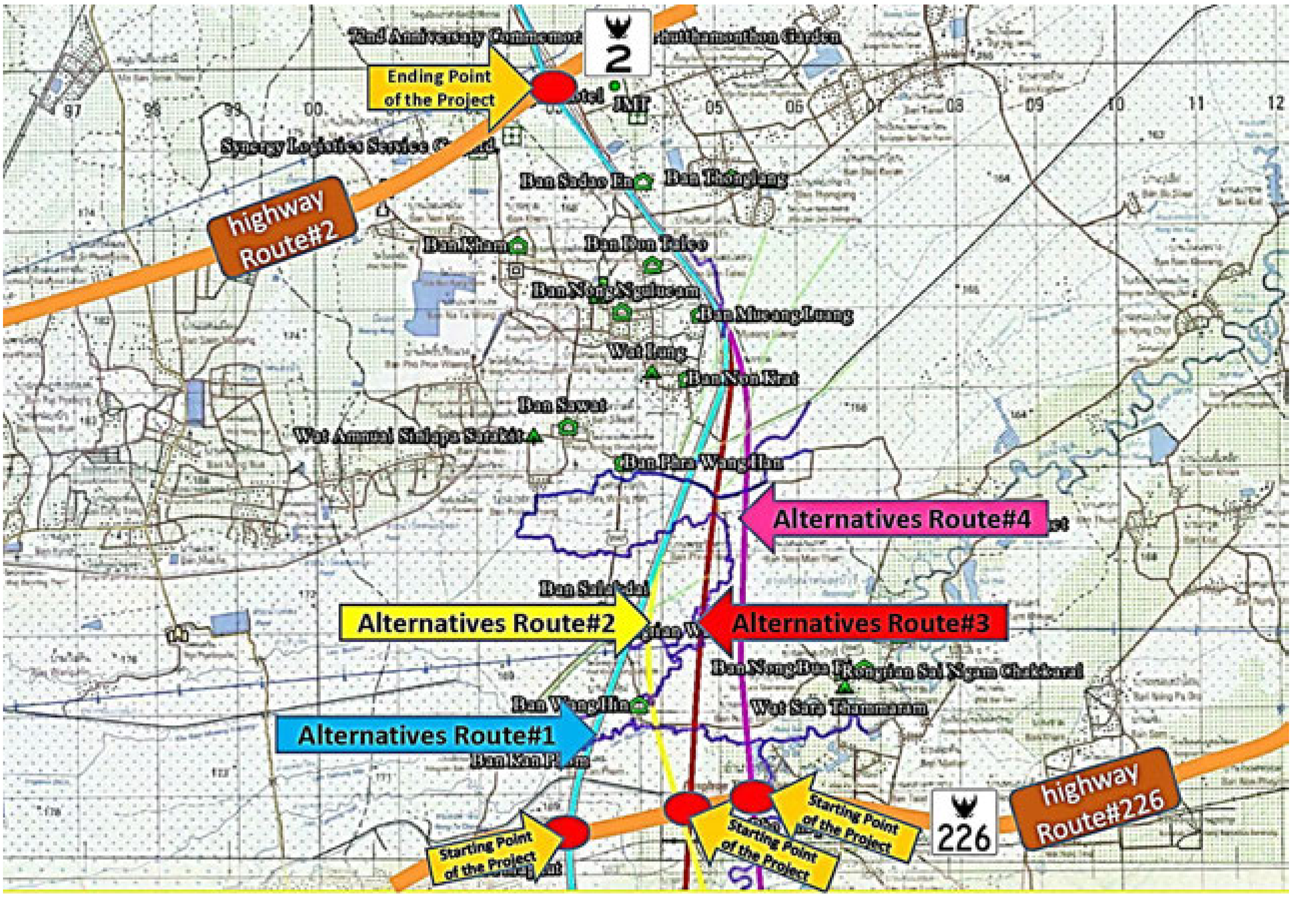

Figure 3: Proposed routes drawn on a map scaled 1:5000.

3.8 Starting Point of the Project

The starting point of the project connects the highway Route#226 at any point during stations

14+000 and 17+000. The highway Route#226 currently has four traffic lanes with a traffic median raised island. Area landscape and geography is surrounded by agricultural fields.

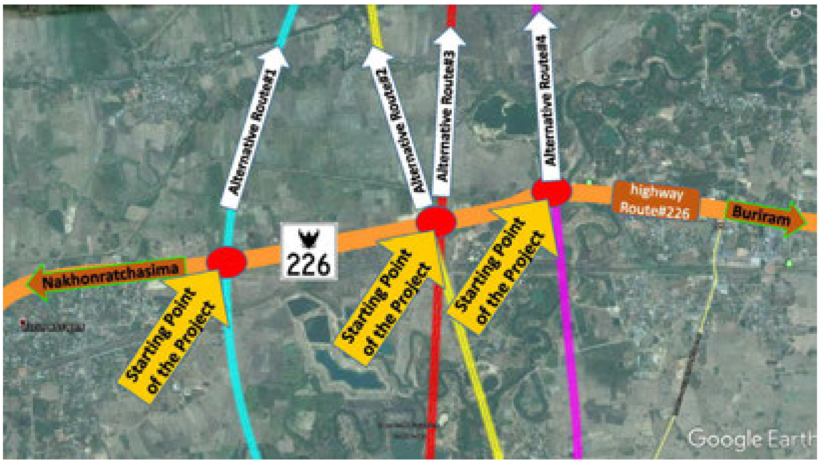

Figure 4: Starting points of all alternatives, from Highway route #226.

3.9 Ending Point of the Project

The Ending Point of the Project meet the highway Route#2 at station 168+550. The highway Route#2 is currently a four-lane street with depressed Median Island. Physical geography is the upland area with some developments of private sectors. Detail is given in Figure 5.

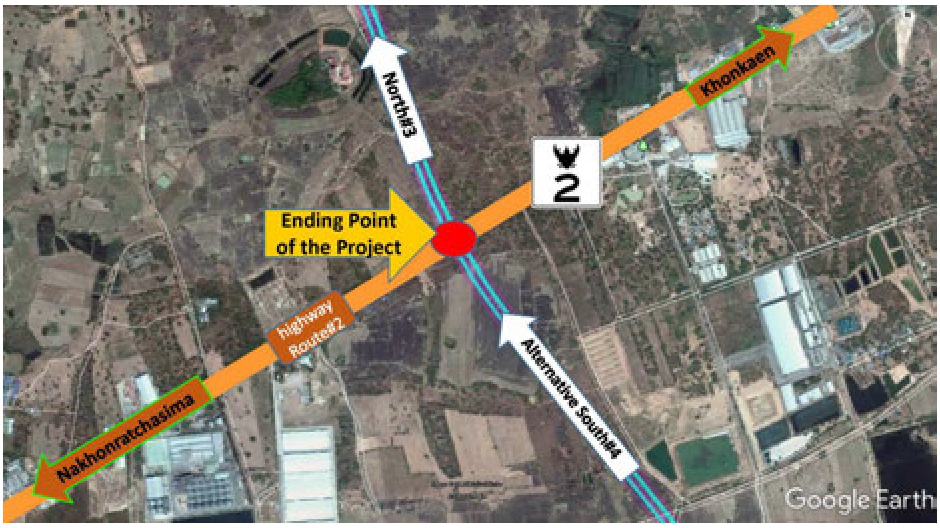

Figure 5: Ending point of the project

4. Route Selection Criteria and Scoring System

Selection of route is considered thoroughly under engineering and economic factors. For each factor, scores are set according to the importance of each sub-factor. For this study, factors and sub-factors with weighting are given in Table 1.

Table 1: Factors and Sub-factors with weighting.

Factors/Sub-factor	weighting
Engineering factor – total weighting = 60	

Route distances	10
Horizontal alignment	10
Vertical alignment	10
Water drainage	10
Difficulty in Construction	8
Suitability of connecting point with existing roads	6
Future road expansion	6
Economic factors – total weighting = 40	
Construction cost	20
Compensation for land and building expropriation	20

5. Comparison of Alternative Routes

5.1 Engineering Factor

5.1.1 Route Distance

The shorter route, the better as for driving in terms of fast, convenience, and save fuel cost. This sub-factor has weight equal to 10. Multiplication for route distance, for route *i*, is given as

$$M_{Dist,i} = 1 - \frac{D_i - D_{Min}}{D_{Min}} \tag{1}$$

D_i = distance the considered route

D_{Min} = minimum route distance

From this scheme (Equation (1)), the shortest route would has multiplier equal to 1.00. Other alternatives would have multipliers as in Table 2.

Table 2: route distance and multiplication for route distance

Alternative	Route#1	Route#2	Route#3	Route#4
Distance	10,310	9,917	9,730	9,571
$M_{Dist,i}$	0.92	0.98	0.96	1.00

5.1.2 Horizontal Alignment

This sub-factor focuses on safety of horizontal curves as well as comfortable driving. The route that possibly has good geometric design according to standard would provide better driving and safety to driver. This sub-factor has weight of 10. A straight route is better than curve route. A route with larger radius curve is better, as it provides better driving sight distance, thus Table 3. Multipliers for horizontal alignment $M_{H,i}$ have been set as in Table 4.

Table 3: Multipliers for horizontal alignment $M_{H,i}$

	Multiplier

A straight route or route with radius more than 3000meters	1.00
Portion of a route with radius between 2500-3000meters	0.80
Portion of a route with radius between 1500-2500meters	0.60
Portion of a route with radius between 500-1500meters	0.40
Portion of a route with radius less than 500meters	0.20

Table 4: Multipliers $M_{H,i}$ for each alternative route

Alternative	Route#1	Route#2	Route#3	Route#4
$M_{H,i}$	0.93	0.93	0.96	0.95

5.1.3 Vertical Alignment

This sub-factor is one of the most important engineering sub-factors to be considered, as its vertical change directly affects the driving safety. Good vertical curve would offer more driving convenience and safety. This sub-factor has a weight of 10. As road gradient reflects such driving convenience and safety, multiplier is set following Table 5 and multipliers $M_{V,i}$ for alternative routes are obtained in Table 6.

Table 5: Multiplier according to profile grade.

Profile grade	multiplier
0-1%	1.00
1-3%	0.80
3-4%	0.60
4-6%	0.40
6%	0.20

Table 6: Multipliers $M_{V,i}$ for each alternative route

Alternative	Route#1	Route#2	Route#3	Route#4
$M_{V,i}$	0.98	0.95	0.986	0.98

5.1.4 Water Drainage

Being one of the importance considerations, this sub-factor also has a score of 10. A route passing depression area which has frequent floods would affect construction cost and period. Therefore, it is more interested in the route that has minimum distance passing such depression flood areas. Multiplier $M_{W,i}$ for water drainage, for route *i*, is given as

$$M_{W,i} = 1 - \frac{W_i - W_{Min}}{W_{Min}} \quad (2)$$

W_i = Distance having frequent floods of the considered route (m)

W_{Min} = minimum route distance having frequent floods, compared with all proposed routes (m)

Table 7 with information of W_i, multiplication $M_{W,i}$ is computed using Equation (2).

Table 7: Frequent floods distance and multiplications for water drainage of all proposed route

Alternative	Route#1	Route#2	Route#3	Route#4

W_i	5500	5000	5100	5900
$M_{W,i}$	0.90	1.00	0.98	0.82

5.1.5 Construction Difficulty

This sub-factor reflects period and cost of the construction of a route according to construction difficulty. The route passing watery places would post more construction difficulty. This sub-factor weight is 8. Multiplier $M_{CD,i}$ for construction difficulty, for route i, is given as

$$M_{CD,i} = 1 - \frac{CD_i - CD_{Min}}{CD_{Min}} \qquad (3)$$

CD_i = construction difficulty of the considered route (m)

CD_{Min} = minimum construction difficulty, compared with all proposed routes (m)

From the study of period and cost of the construction, CD_i values for all routes can be summarized in Table 8 and $M_{CD,i}$ can be calculated using Equation (3).

Table 8: Frequent floods distance and multiplications for water drainage of all proposed route

Alternative	Route#1	Route#2	Route#3	Route#4
CD_i	120	180	170	215
$M_{CD,i}$	1.0	0.50	0.58	0.20

5.1.6 Suitability of Connecting Points with Existing Roads

Weight for this sub-factor is 6. There are two connecting points, the starting and ending points of a route. The ending point is rather fixed, therefore only the starting point is considered. There are four possible points to be the starting point. The starting point of Route#1 deems to be the most suitable point as it is an esplanade area in which an interchange can be constructed at ease. For Route#1, multiplier is set to 1.0.

The starting point of Route#2 and Route#3 is the same point. This point would pass commercial buildings and a religious place. For Route#2 and Route#3, multiplier is set to 0.6. The starting point of Route#4 is close to Mun River and a municipal place, which makes it difficult to build an interchange. For Route#4, multiplier is thus set to 0.2

5.1.7 Future Road Expansion

Road future development may face various challenges. The fewer obstacles would be more attractive. Weight for this sub-factor is set to 6. Multipliers for Route#1 and Route#2 are set to 1.0 while multipliers for Route#3 and Route#4 are both set to 0.8. Such given multipliers indicate difficulty in future road expansion.

5.1.8 Summarize Score for Engineering Factor

After having information about weight and multiplication M for each sub-factor, subtotal for engineering factor for each route can be obtained, *see* Table 9.

Table 9: Scores for engineering factor

Sub-factor	Weight	Alternatives							
		Route#1		Route#2		Route#3		Route#4	
		M	Score	*M*	Score	*M*	Score	*M*	Score
Route distances	10	0.92	9.20	0.98	9.80	0.96	9.60	1.00	10.00
Horizontal alignment	10	0.93	9.30	0.93	9.30	0.96	9.60	0.95	9.50
Vertical alignment	10	0.98	9.80	0.95	9.50	0.98	9.80	0.98	9.80
Water drainage	10	0.90	9.00	1.00	10.00	0.98	9.80	0.82	8.20
Difficulty in Construction	8	1.00	8.00	0.50	4.00	0.58	4.64	0.20	1.60
Suitability of connecting point with existing roads	6	1.00	6.00	0.60	3.60	0.60	3.60	0.20	1.20
Future road expansion	6	1.00	6.00	1.00	6.00	0.80	4.80	0.80	4.80
Subtotal 1	60		57.30		52.20		51.84		45.10

5.2 Economic Factors

5.2.1 Construction Cost

Cost of construction of a new route is the biggest budget of the project. Therefore the weight for this sub-factor is given rather high, to be 20. Estimated construction costs for all proposed routes are given in Table 9. Multiplication for construction cost, for route i, is given as

$$M_{C,i} = 1 - \frac{C_i - C_{min}}{C_{min}} \tag{4}$$

where

C_i = construction cost of the considered route

C_{Min} = minimum construction cost, compared with all proposed routes

Table 10: Estimated Construction Cost

	Route#1	Route#2	Route#3	Route#4
Construction Cost (Baht)*	569,500,000	572,350,000	567,500,000	622,550,000
$M_{C,i}$	0.996	0.991	1.000	0.903

Note: 35Baht ≈ $US1

5.2.2 Building and Land Expropriation Cost

To build a new road, it is necessary to take privately owned land and building. According to the Expropriation Act of Thailand BE 2530 (1987), it requires a fair reimbursement payment for buildings and lands to be expropriated. Table 10 shows the estimated building and land expropriation cost at time this study took place (2016). Similar to multiplication for construction cost, multiplication for building and land expropriation cost, for route i, is given as

$$M_{Ex,i} = 1 - \frac{Ex_i - Ex_{min}}{Ex_{min}} \quad (5)$$

where

Ex_i = expropriation cost of the considered route

Ex_{Min} = minimum expropriation cost, compared with all proposed routes

Table 11: Estimated building and land expropriation cost

Alternative		Route#1	Route#2	Route#3	Route#4
Land expropriation	Area (m^2)	618576	595040	583808	574272
	Cost (Baht)	72,468,062	74,848,987	72,037,868	70,487,431
Building expropriation	# of Building	2	2	2	3
	Cost (Baht)	3,168,000	3,168,000	3,168,000	9,018,000
Sum of expropriation cost		75,636,062	78,016,987	75,205,868	79,505,431
$M_{Ex,i}$		0.994	0.963	1.000	0.943

Note: 35Baht ≈ $US1

For economic factor, weighting is set to 40 percent. Half is for construction cost and another half is for compensation for land and building expropriation. Score for each route can then be computed, *see* Table 11.

Table 12: Scores for economic factor

Sub-factor	Weight	Route#1		Route#2		Route#3		Route#4	
		M	Score	*M*	Score	*M*	Score	*M*	Score
Construction cost	20	0.99	18.9	0.98	19.60	1.00	20.00	0.90	18.00
Compensation for land and building expropriation	20	0.99	19.8	0.96	19.20	1.00	20.00	0.94	18.80
Subtotal 2	40		38.7		38.80		40.00		36.80

5.3 Comparison and Discussion

After having all relevant information, scoring system has been created and computed. For engineering factors Table 9 (Subtotal 1), route #1 gets the highest score with the running up of route #2, route #3, and route #4. If looking at subtotal 1 of each route, the discrepancy of subtotal1 scores between route #1 and route #2 and #3 is more than 5. For economic factors Table 11, Route #3 gets the highest score, but if compared to route #1 and #2, the discrepancy of subtotal2 scores is about 1.3. Sum of scores from engineering factors (Subtotal 1) and economic factors (Subtotal 2) are added as given in Table 12. In this study case, it can be readily seen that route #1 has the highest sum of score, in which route #1 Subtotal 1 draws an attention.

Table 13: Total score for each alternative

	Route#1	Route#2	Route#3	Route#4
Subtotal 1	57.3	52.2	51.8	45.1
Subtotal 2	38.7	38.8	40.0	36.8
Total	96.0	91.0	91.8	81.9

6. Conclusion

This study applies remote sensing image freely available from Google Earth®, with the 1:50,000 base map, to give information to facilitate bypass road selection, along with economic and engineering factors. This case study is Southern Part Nakornratchsima Ring-Road, Thailand. Google Earth® streaming technology helps visualizing the map at different perspectives including 3D viewing. This study develops scoring system to assist the selection of possible routes. The best route with highest score is obtained.

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