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Article

The Integrated Appraisal Framework of Rural Road Improvement Projects

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Abstract. The government policy for Thailand to be a logistics and transportation hub presents challenges to the Department of Rural Roads (DRR). The Bureaus of Rural Roads (BRR) 11, 12, and 14 as subsidiaries of the DRR have been forced to reform their methods of appraising rural road improvement projects. Multi-criteria decision-making (MCDM) was first developed but was found to be inappropriate within the fiscal constraints since it was not based on monetary terms. This paper explores the DRR's attempts to overcome this problem. The DRR conducts a Benefit-Cost Analysis (BCA) to filter the improvement projects prioritized under the MCDM approach. While calculation is not a problem under BCA, the method cannot be readily adapted to incorporate all relevant parameters, particularly those relating to the social benefits of road improvement projects. These parameters are important in the Thai context and compatible with the characteristics of rural roads. The findings demonstrate that the incorporation of factors taken into account in MCDM but overlooked in traditional BCA is currently impracticable in view of the lack information and the difficulty of expressing those parameters in monetary terms. The paper discusses supplementing the DRR's improvement project appraisal process by BCA methods thus enhancing the effective and transparent allocation of the DRR's budget, while simultaneously providing regional benefits. This appraisal method coupled with discussion will enhance the capabilities of transport policy makers and agencies to perform their work, particularly, in developing countries.

Keywords: Benefit cost analysis, vehicle operating costs, value of saving travel time, accident costs.

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1. Background

The location of Thailand gives it an advantage in terms of trading accessibility within the Association of Southeast Asian Nations (ASEAN). The Thai government has announced the policy of making Thailand a logistics and transportation hub and this should increase Thailand's trading competitiveness due to the reduction of transportation costs [1]. At the same time, the Department of Rural Roads (DRR) has changed from a temporary to a permanent organization and has established the organizational strategic goals of stability, prosperity, sustainability, and high performance [2, 3]. To accomplish these policy goals, the criteria of project evaluation and selection for route improvement has been adopted by the DRR's management and the managements of its subsidiary organizations.

Normally, government transportation agencies face difficulties in selecting an appropriate subset of transportation projects to implement [4, 5, 6]. These difficulties include the agencies' bureaucracy and their financial strictures. The DRR also faces these challenges. However, the application of suitable evaluation criteria can help to bring about effective project selection and efficient management throughout the lifecycle of projects [7]. Therefore, the DRR has established a systematic program of route improvement project evaluation and selection to deal with these challenges. This program is illustrated in Fig. 1. The first three procedures in this process are quite clear. However, the remaining phases are still under development and adjustment.

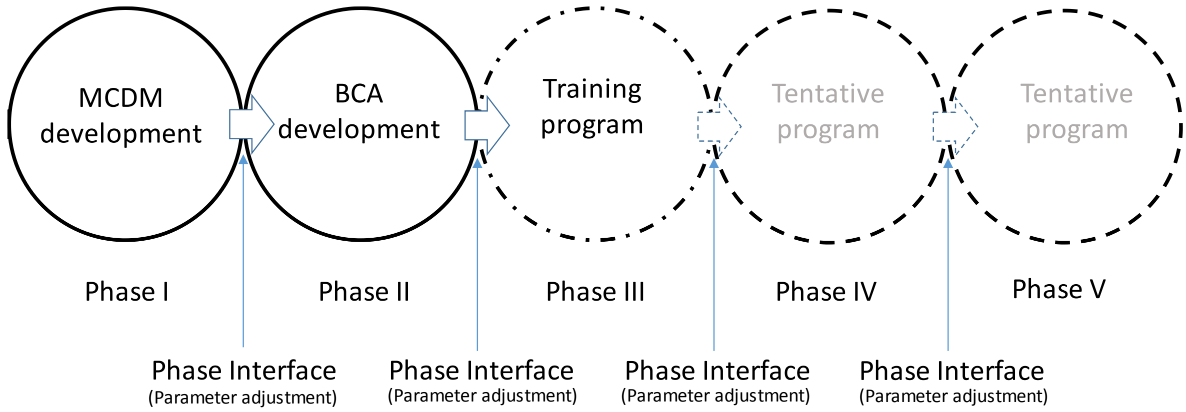

Fig. 1. The systematic program of route-improvement project evaluation and selection.

The evaluation and selection of route improvement projects began in 2017. Firstly, multi-criteria decision-making (MCDM) was developed using an analytic hierarchy process (AHP). The DRR assigned the Bureau of Rural Roads (BRR) in every region to work with local consultant teams, who are professionals in the fields of traffic engineering, bridge engineering, training, planning and traffic safety. They also included academicians working in regional universities classified into eight groups according to their location. They have developed regional criteria applied in the MCDM development phase with the regional BRR agencies providing current data relating to traffic volume, population size, land-use zones, industrial and agricultural areas, etc.

Nevertheless, after the compilation of the DRR's national improvement project, many different factors have led to difficulties in project selection [1]. The development of MCDM in the first phase was described in more detail by Suksuwan and Trangkanont [1] who focused on rural road improvement project evaluation and selection in the south of Thailand.

Before initiating the second phase, the DRR and the eighth consultant team developed new criteria for the MCDM approach and distributed these criteria to all the BRRs and the other consultant teams. Simultaneously, they developed a framework of economic analysis. From the lessons learned, they then asked all the consultant teams to study the feasibility of different methods for evaluating transportation project investments in order to investigate and integrate the various methods of economically appraising transportation improvement projects and adjusting them to meet the economic circumstances. The aim was to standardize economic analyses to be compatible with the DRR's route conditions. After that, the eighth consultant team cooperated with the other teams to apply the selected method of economic analysis. The seventh consultant team working with BRRs 11, 12, and 14 then used this method of economic analysis to appraise projects in the southern region.

This paper will describe the evolution of the DRR's economic appraisal method applied to transportation project investment, and the principles it entails. This includes the assumptions behind economic evaluation and the development of an economic evaluation formula. Finally, the pros and cons of the method are discussed. The results will help to overcome the weakness of the MCDM method in terms of the subjective weight and score provisions. This should assist the DRR in using its fiscal budget effectively within its financial constraints. Moreover, it is expected that the lessons learned by the DRR and the result of discussions will enhance the ability of policy makers and agencies, particularly, those in developing countries to establish transportation appraisal methods with budgetary effectiveness, transparency, and regional benefits.

Since project appraisal and selection had to be finally done by the BRR11, 12, and 14. It was necessary to have training programs for the BRR officers relating to the MCDM method and studying economic feasibility. The training program is the third phase of the program to improve the project evaluation and selection process and this has now been implemented. However, the final two tentative phases of this program will not be covered in this paper.

2. Literature Review

2.1. DRR's Rural Road Characteristics and Functions

Allowing access to and facilitating travelling to and from places (mobility) are the primary objectives of road improvement and development [5, 8, 9]. Accessibility implies opportunities for entry and exit to certain places, while, the mobility function of roads allows people to make journeys and goods to be carried from where they are produced to their destination or marketplace [8, 10]. The roads under the care of the DRR, are a network of feeder roads serving the needs of both accessibility and mobility [11]. The DRR's road network, therefore, takes on the collector role according to road function classification. This role is similar to the role of US collector roads as shown in Fig. 2 [12]. The service level of the collectors is at a lower speed and for shorter distances because the roads carry traffic from local roads linking them to arterial roads [13].

In order to maintain, improve, and construct collector roads, road administrations objectively consider many factors related to transportation and traffic engineering [5, 9, 13-17]. These factors include traffic volume, intermodal connections, functional purpose, route and traffic conditions, such as surface quality, shoulder width, the number of intersections, traffic load, congestion and stresses. In addition, the road safety system must be considered as must the realization of people's wishes to travel from one place to another. The impacts of route development must also be taken into account with particular regard to protecting communities and the environment, and the need to eliminate or /mitigate/ environmental impact affects route investment decisions. Therefore, in assessing any route development proposal, transportation and traffic engineering considerations coupled with environmental concerns should be firstly examined in order to ensure that the purposes of road accessibility and mobility will be met with no or minimal impact on the surrounding area throughout the road project's lifecycle.

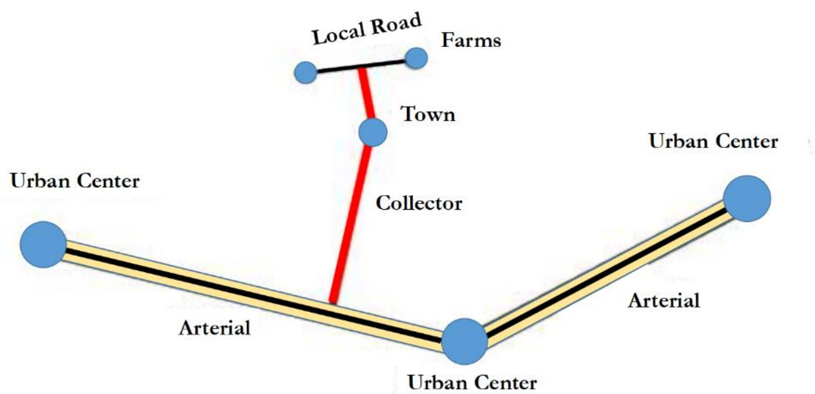

Fig. 2. Hierarchy of US highway system [12].

Accessibility, to an extent, determines social equality and quality of life. Accessibility to roads allows people to be connected to public facilities such as hospitals, schools, police stations, post offices, and to holy places such as temples, mosques, and churches. Moreover, accessibility to roads brings about changes in the relationship pattern between human beings and the environment [6, 9, 10, 17]. Building a better society is, thus, influenced by road development [5]. At the same time, road investment has an effect on poverty reduction and economic development [6, 17]. Local economies can be developed because of the improvement of transportation infrastructure, which gives communities access to resources, capital, know-how, goods and the labor market [5, 9, 10]. Furthermore, improvement of the transportation infrastructure increases the efficiency of production and the effectiveness of production systems and thus improves productivity. It also influences land use and market extension, and encourages investment and employment [10, 17]. Moreover, when there are no externalities which affect allocative efficiency in a local economy, the benefits of transportation project investment can be focused on facilitating travel or accessibility [10]. Where accessibility is defined as the ease with which goods and human beings are able to get to other places.

Mobility is a measure of the amount of resource movement [11] and this is also dependent on the volume of the vehicles delivering those resources. Moreover, the roads connecting cultivated zones and their primary marketplace may have considerable implications for agricultural productivity [10] along with other factors such as fertilizer usage per m^2, the number of machines per worker, and labor productivity [17]. Roads, linking major industrial districts, regions with plentiful resources, and coastal regions, affect both the distribution of raw materials and goods [17]. Therefore, the roles collector roads play in accessibility and mobility are interlinked and bring about regional and national socio-economic development. Further, the size of the population in agricultural areas and at tourist destinations may be indicative of the degree of accessibility, and the number of industrial and commercial centers including multimodal transportation ports imply the degree of mobility.

In short, the main characteristic of the DRR's roads is accessibility. The improvement of social equity and quality of life through transportation is the DRR's duty. Traffic conditions, road safety system, communities' accessibility and environmental protection are the prime objectives of the DRR's road development. Therefore, it is important to prioritize road improvement projects within budget constraints as a part of the project selection process, and the selection of appropriate appraisal methods and parameters for evaluating and prioritizing road improvement projects is important.

2.2. The framework of transportation project investment appraisal

The process of planning transportation systems normally employs appraisal as a tool to provide valuable information to decision-makers. The information gained from appraisal assists the prioritization of and selection among alternatives within a program. This includes determining whether or not chosen alternatives represent good social value in monetary terms and the optimal time to invest in the alternatives [18]. This paper therefore investigates how transportation project appraisal facilitates the prioritization process within the evolution of the DRR's appraisal method. The advantages and disadvantages of the methods employed are discussed.

There are two well-known appraisal approaches used to evaluate and prioritize transportation alternatives, namely MCDM or multi-criteria analysis (MCA) methods, and cost-benefit analysis (CBA) [18-20]. The former approaches are used to develop priority models while the latter is traditionally applied to examine policy efficiency [18, 20]. MCDM methods use a group of decision-making criteria to appraise the alternatives. These criteria are used to measure the benefits of the alternatives and the results of the measurement can be either quantitative or qualitative. MCDM methods are popular because they are able to deal with the effect of criteria, which is difficult to measure in terms of monetary value. Furthermore, it is able to incorporate diverse stakeholders' perspectives into the decision-making process and thus accommodate the diversified needs of a society with a complicated social system. Decisions regarding transportation project investment are, thus, considered and compared based on their advantages and disadvantages as they impinge on various stakeholders [20]. MCDM methods are now frequently applied and in Japan, the USA and many nations in Europe, transportation administrations apply MCDM methods to their national transportation project investment appraisal frameworks [18, 19, 22].

However, the weakness of MCDM is that the criteria applied in this method are subjective and difficult to score. Therefore, in measuring the impacts of a particular set of criteria, the results of the measurement depend on the attitudes of the decision-makers, and their validity may therefore be doubtful [21-22]. In fact, it has been suggested that the MCDM method is better used as a tool to make a decision rather than as a means of providing supporting information to the decision-makers [22]. As a result, CBA is therefore often integrated into the appraisal framework.

CBA is a well-developed, well-known and proven theory. The application of CBA eliminates or mitigates ambiguities in the various structures and procedures adopted, as well as reducing bias in the decision-making process [21]. The results of CBA focus on the goal of profit maximization, cost minimization and the net socio-economic value of investment in a project [20, 22]. CBA clearly, therefore, prioritizes the monetary value of project investment and indicates the efficiency of that investment and the expenditure required by the investing body, either private or governmental. As a result, CBA is widely used as an appraisal tool [21].

However, CBA is unable to deal with the diversity of societal needs within a complex social system [20], which MCDM methods are better able to accommodate. Thus there is a synergy between these two methods of appraisal which is able to provide solutions in project investment decision-making processes.

Since this paper focuses on the DRR's economic feasibility appraisal process, and CBA is in practice one of the most frequently used methods of economic appraisal in transportation project investment appraisal, CBA is firstly considered based both on relevant literature and also on its use in practical situations. In addition, other economic appraisal methods are also considered and examples of their use given.

2.3. The Study of Practical Economic Feasibility in Transportation Project Investment Appraisal

Although methods adopted for project appraisal are different from country to country due to their unique histories of theory development and practical implementation [19, 22] as shown in Table 1, CBA/BCA is the most well-known method applied to the study of economic feasibility in road project appraisal because it is theoretically explicit [21]. The fundamental principle underlying CBA is that its objective is maximizing the project's net socio-economic benefit [22]. CBA is used in most countries [20] in a variety of applications with different parameters considered.

In the UK, conventional CBA (COBA) is used to evaluate and rank alternatives. However, the final decision is determined by budget and other qualitative factors. The standard COBA evaluation process used for all potential projects is the same and is reported in an appraisal summary table (AST). This standardization aims to ensure transparency in the appraisal process. The parameters used for COBA calculations are derived from the UK government's five transport policy objectives: environmental impact, safety, economy, accessibility, and integration, and these are the criteria used in project appraisal. The criteria are, however, separated into sub-criteria or operational definitions which aim to measure the impacts influencing the alternatives. Some impacts are described qualitatively and are measured by a seven-point rating scale, ranging from large negative to large positive effects. Other impacts can be directly quantified through the COBA method and other similar approaches, depending on their characteristics. For example, local air quality is measured by the particle size of dust against the standard regulations of the public transport agency [18-19, 23-24].

Among the parameters used to calculate COBA are the safety scheme and the reductions in the number of accidents, journey time, and vehicle operation costs (VOCs). The cost savings from reducing accidents are relative to accident type, casualties, insurance administration, property damage, police costs, and the type of road. The value attributed to travel time depends on journey time, mode, i.e., working or non-working, occupancy, and type of vehicles. These benefits depend on the rigorous construction of a transport model used to assess the change in traffic volume due to different project decisions leading to different traffic volumes.

The project investment cost is composed of the costs of construction, disruption, land and property, maintenance, and vehicle operation [22]. The benefits and costs are considered based on the time-of-value concept and are presented in terms of present value benefit (PVB) and present value cost (PVC). These present values are derived from a discounted rate of 8% over a 30-year period [24]. After that, the cost-benefit ratio (CBR) and net present value (NPV) are calculated. Finally, the numeric PVB, PVC, CBR, and NPV are reported in the AST as the information based on which decision-will be made. In addition, recently, the internal rate of return (IRR) has been used as an economic appraisal indicator for ex-post evaluation which takes place sometime after the project has been completed [25]. The AST is created by the local government agency which also draws up an implementation plan for local and regional roads, which is then proposed to the national government in the form of the ministers and civil servants responsible for road policies. They then inspect and examine all the alternatives and give approval to projects where they are agreed [19].

Table 1. The appraisal methods and parameters considered [18, 19, 22, 26, 27].

Evaluation methods and considered parameters	Country															
	Austria	Belgium (road)	Denmark (road)	Finland	France	Germany	Greece (road)	Ireland	Italy	Netherlands	Portugal	Spain	Sweden (road)	United Kingdom (road)	Japan	United States
Appraisal Method of transportation projects																
MCDM/MCA (M)	√	√					√			√					√	√
BCA/CBA (B)	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Measured impacts (I)	√	√		√			√	√	√	√	√		√	√	√	√
Qualitative assessments (Q)	√			√	√	√	√	√	√	√	√	√	√	√	√	√
Considered parameters in appraisal methods																
Capital																
Construciton costs	M, B	M, B	B	B	B	B	M, B	B	B	M, B	B	B	B	B	B	B
Disruption costs		M, B					M, B					B		B		
Land & property costs		M, B	B	B		B	M, B	B	B		B	B	B	B		
Recurring																
Maintenance costs	M, B	M, B	B	B		B	M, B	B	B	M, B	B	B	B	B	B	B
Operating costs				B		B	M, B	B	B	M, B	B					B
Vehicle operating costs	M, B	M, B	B	B	B	B	M, B	B	B	M, B	B	B	B	B	B	B
Revenues	M, B			B			M, B	B	B		B	B			B	B
Passenger cost savings							M, B	I								B
Time savings	M, B	M, B	B	B	B	B	M, B	B	B	M, B	B	B	B	B	B	B, I
Safety	M, B	M, B	B	B	B	B	M, B	B	B	M, B	B	B	B	B	B	B, I
Service level	M, I						M, I	I	B			B	B		Q, I	B
Information							M, B		B							
Enforcement							Q									
Financing/taxation							M, B								I	B
Environment Impacts																
Noise	M, I	M, B	B	B	B	B	M, I	Q	I	M, I	I	B	I	I	B, I	I
Vibration		M, I		Q			I							I		
Air pollution-local	M, I	M, B	B	B	B	B	M, I	Q	I	M, I	B	Q	B	I	B, I	I
Air pollution-global	M, I	M, B	B	B	B		M, I	Q			B		B	I	B, I	
Severance	M, I		B	Q		B				Q	I	Q	I	I		
Visual intrusion				Q			M, I		Q					I	I	
Loss of important sites		M, I		Q	Q		Q	Q		Q	Q			I		B, I
Resource consumption				I			M, I			Q					B, I	
Landscape	M, I			Q		Q	Q	Q	I	Q			Q	I		
Ground/water pollution	M, I			I			M, I			Q				I	B, I	
Ecological system															Q	Q
Socio-economic impacts																
Land use	Q, M			I			M, I							Q	Q	Q
Economic development	Q, M	M, I		I	Q	B	M, B	I	Q	Q, M	I				Q	Q
Employment		M, I		I	Q	B	M, I	I	I	Q, M	Q	B				
Economic & Social cohesion							M, I				Q	B			Q	
International traffic					Q	B	M, I		I							
Interoperability							M, I									
Regional policy		M, I				B	M, I			Q, M				Q		
Conformity to sector plans		M, I					Q	Q				Q				
Peripherality distribution					Q		M, I									
Enhancement for public service availability/Back up function for emergence															Q	
upkeep of population															Q	
Increase in asset value															Q	
social equity															M, B	Q

The appraisal framework of transport projects in Western European nations is similar to that in the UK. Both monetary and qualitative issues are measured [18-19, 22]. During the late 1960s and early 1970s, the principles of CBA were applied to the entire transport project appraisal process with travel time, cost, and safety impacts being transformed into monetary terms. Recently, the context of appraisal has changed and environmental and socio-economic impacts have also been considered based on monetized values when projects are evaluated. Costs derived from direct impacts have been categorized into capital costs, recurring costs, environmental impacts, and socio-economic impacts.

The concept of capital and recurring costs is applied in most countries. However, there are differences in detail. For example, for direct capital impacts, all Western European countries consider construction costs. However, disruption costs are used to evaluate projects only in Belgium, Greece, and Spain. Moreover, Austria, France and the Netherlands do not consider land and property costs in their appraisal framework. In the case of environmental and socio-economic impacts, different sub-criteria of these impacts are used in CBAs in different countries. For example, noise is only used in CBAs in Belgium, Denmark, Finland, France, Germany, and Spain. Furthermore, ground/water pollution is not considered in any of the Western European countries.

For direct transport benefits, most countries in Western Europe use travel time savings and safety through the application of different sub-benefits. For example, with regard to journey time, a majority of them assess working and non-working time within the CBA with the time values depending on wage rates [19]. However, among these countries, the assumptions relating to working and non-working time values are distinct [22]. For example, the values for working and non-working time are not the same in France and Germany, where, besides working and non-working time, the type of vehicles is also considered [19]. For safety, accident costs are evaluated based on the widely accepted basis of monetary values assessed according to individuals' willingness-to-pay to avoid accidents [22] and based on the gross production method [19]. However, in the Netherlands, the human costs are excluded from the CBA but those costs are instead separately evaluated in the MCA. However, in Germany and France, the human costs are included [22]. In short, transport assessment practice is different from country to country although there are some points of commonality among them. The results of the CBA are reported in terms of a discounted net present value [4, 19, 21-22].

In Japan, CBA is applied as a supplement to MCA. The result of the CBA is only used in judging whether or not the project should be on the list as a candidate for execution [19, 26]. The Japanese government instead suggests using a benefit incidence table (BIT) since it provides an explanation of all the impacts of an investment and supports the consistency of implementation. In the BIT, monetary terms are considered under the paradigm of direct and indirect effects, including profitability [26]. The benefits are identified under the aspects of road use, environment, civil life, regional economy, fiscal expenditure, tax revenue, public subsidy, and toll revenue [26]. However, the main benefits are journey time, vehicle operating cost savings and accident reduction [19]. The costs consist only of the project cost. These benefits and costs are considered based on the impacts to the road corporation, road users, households, industry, road space occupiers, landowners, all levels of government agencies, and the world. The social discount rate is taken as 4% and the service life including the construction period as 30-50 years depending on the transportation facility [26]. A significant goal of the application of CBA is the achievement of social efficiency [19, 26]. The Japanese national government is in charge of overall policy-making and the funding of road investment. This includes the approval of investments proposed by local government who prepare annual plans for regional and rural roads [19].

For road investment appraisal in the USA, although variations of MCDM and other approaches are often used at a regional level, benefit-cost analysis (BCA) is mainly applied as the preferred method due to the federal government's recommendation. In addition, some federal funds are shared among the alternatives which politicians believe to be neutral or at least arguable. Most transportation projects are therefore appraised under evaluation guidance procedures recommended by the federal government [19, 27]. The basic framework of the BCA evaluation method starts by identifying the alternatives in order to compute their impacts [27]. The alternatives can then be separated into base alternative, project alternatives, and supporting action. The impacts are assessed in relation to costs, benefits, and transfers. The main part of the impacts relates to transfer impacts. The costs comprise the direct expenditures for the project, and operating, and maintenance costs may or may not be included. However, capital costs are included. The benefits derived from the facility construction considered are defined as "save time", "reduce user, agency and external cost", "improve safety", "improve quality", and "increase consumer surplus." The typical value of the discounted rate is 7% [27]. State and local authorities make project proposals but, they often lack BCA technical skills [19, 27].

Therefore, in practical applications, CBA or BCA is the main or supplementary process used in project evaluation depending on the national tradition and its history of project appraisal. However, there are commonalities among different countries as mentioned and shown in Table 1. The primary benefits considered are composed of journey time value, vehicle operating costs, and safety cost saving. Moreover, some environmental and socio-economic aspects are considered in monetary terms. The main costs considered are comprised of capital investment and other items which may be considered include operating and maintenance costs, and toll payments.

A variety of transport project appraisal methods and parameters have thus been investigated in previous studies, which the DRR tried to apply in its evaluation process based on the DRR's road characteristics and their roles, particularly, through the application of BCA.

3. Research Methodology

The objective of this paper is to report on and indicate the rationale and development of the economic appraisal methods of the DRR's transportation project investment process. The assumptions behind the economic evaluation and the development of economic evaluation formulae are investigated, and the pros and cons of the method are discussed. The DRR and the consultant teams start by reviewing the literature and practical project appraisal in several other countries. Then, the DRR and the consultant teams use conventional BCA to assess the economic feasibility of public sector projects. This method was adopted because BCA is normally used for appraising public facility investments. The BCA formula most often used [28] is as follows:

$$B/C = \frac{\text{Present Worth of benefits} - \text{Present Worth of disbenefits}}{\text{Present Worth of Costs}} \tag{1}$$

Where	Present Worth of Costs	=	The current estimated expenditures by the government entity for construction, operation, and maintenance of projects less any expected salvage value;
	Present Worth of Benefits	=	The current advantages experienced by the public and government entity;
	Present Worth of Disbenefits	=	The expected undesirable or negative consequences to the government entity, if the alternative is implemented. Disbenefits may be indirect economic disadvantages of the alternative.

The decision guideline is simple:
If $B/C \geq 1.0$, accept the project as economically acceptable at the estimates and discount rate applied.
If $B/C < 1.0$, the project is not economically acceptable.

Under this formula, the difficulties do not relate to calculation but to the process of collecting data relating to the parameters required to input into the formula. According to the transportation evaluation methods practiced in other countries, parameters such as vehicle operating costs (VOCs), travelling value of time (VOT), and accident costs (ACC) constitute the benefits since these costs and time are saved. These cost savings depend on the forecasted demand from a traffic model because with no passengers there are no benefits [27]. In other words, user benefit and demand forecasting are closely related to one another [26]. Moreover, the parameters regarding environmental and socio-economic aspects such as air pollution, noise, the impact on archaeological sites and landscape, improvements in quality of life etc. are also considered. On the other hand, the costs consist of the capital investment required together with operating and maintenance costs, and any other costs which might be entailed in the project. The benefits and costs included depend on the assumptions made within the method. In addition, the service life and social discount rate depend on the facility type and economic circumstance of each country.

As a result, the DRR and the consultant teams developed the assumptions relating to these parameters based on the Thai traffic engineering and socio-economic situations. Since the authors were members of the seventh consultant team undertaking the project evaluations in the south part of Thailand, the parameters and examples of calculations presented are those appropriate for road projects in that area. The development of these parameters is described in the following section:

3.1. Traffic Model for Traffic Demand Forecasting

The DRR and consultant teams developed simple traffic models assuming a constant growth rate depending on the region and road service in terms of industry, agriculture, travel, and general purposes. For the southern region, the growth rate assumed was 1% for all routes and purposes. This growth rate was based on data from the Department of Highway (DOH). Although the route characteristics provided by the DOH relate to arterial roads providing mobility, while the roads for which the DRR are responsible are collector roads, most passengers and freight travelling from an origin to a destination use both kinds of routes. In other words, to use an arterial road, most users will also travel along collector roads. Therefore, based on this assumption, the following traffic model formula was used to forecast traffic demand:

$$AADT_{t+n} = AADT_t \times (1+g)^n \tag{2}$$

Where	$AADT_{t+n}$	=	Annual Average Daily Traffic at year t+n (pcu)
	$AADT_t$	=	Annual Average Daily Traffic at year t or based year (pcu)
	t	=	base year (2017)
	g	=	Constant Traffic Growth Rate (%)
	n	=	Year at Time Forecast

3.2. Present Worth of Benefits

The DRR and the consultant teams used the saving in VOCs, VOT and ACCs as the tangible benefits of the DRR's route-improvement projects since these benefits are used globally to calculate BCAs [18]. They applied the results of the study by Juisoei and Pravinvongvuth [29] to calculate these benefit values. The VOCs were calculated using the HDM-4 computer software, which is a, highway development and maintenance management system. Vehicle prices, fuel, oil, lubricant and tire costs and the costs of maintenance were used to determine the VOCs. The values of the VOCs depended on the average speed on a roadway section. For the southern region, the traffic growth rate was 1%. The VOC unit used to calculate the BCA was 13.35 Baht per passenger car unit (pcu)-kilometer for a 2-lane road which represents the characteristic road in this area. Therefore, according to this assumption, the VOC formula for the present year is as follows:

$$VOC_{at\ present\,year} = 13.35 \times dis\tan ce \times \sum_{n=1}^{N} \left(\frac{AADT_{at\ present\,year} \times (1+g)^n}{(1+discount\ rate)^n} \right) \tag{3}$$

Where	$VOC_{at\ present\ year}$	=	Vehicle Operating Costs in present year or 2017(Baht)
	Distance	=	Project road distance (km)
	$AADT_{at\ present\ year}$	=	Annual Average Daily Traffic in present year (2017) (pcu)
	N	=	20 years in which road service life ends
	g	=	Constant Traffic Growth Rate (1%)
	n	=	Year at Time Forecast

For the VOT, the parameters used were, household income per capita, household size, and the average working hours per week as the inputs, and the wage rate method was used to calculate the VOT value. The household income was converted to individual income by region based on monthly revenue and that monthly figure was then converted to an hourly revenue. Income factors, number of trips, and the type of vehicle were then used to compute the VOT according to each region. In the southern region, the VOT unit was 110 Baht per pcu-kilometer. Therefore, based on these assumptions, the VOT formula for the present year is as follows:

$$VOT_{at\ present\ year} = 110 \times distance \times \sum_{n=1}^{N} \left(\frac{AADT_{at\ present\ year} \times (1+g)^n}{(1+discount\ rate)^n} \right) \quad (4)$$

Where	$VOT_{at\ present\ year}$	=	Value of Time in present year or 2017 (Baht)
	Distance	=	Project road distance (km)
	$AADT_{at\ present\ year}$	=	Annual Average Daily Traffic in present year (2017) (pcu)
	N	=	20 years at which time road service life ends
	g	=	Constant Traffic Growth Rate (1%)
	n	=	Year at Time Forecast

With regard to the assumptions of the ACC calculation, these are based on the human cost, property damage cost and general costs. The human cost is composed of loss of productivity, quality of life and accident/health care costs in terms of short and long-term care. The property damage cost comprises vehicle/non-vehicle damage costи. The general costs consist of the administrative costs of insurance and the police, the cost of the judicial system, emergency rescue service costs, and the travel delay cost. In the southern region, the ACC value is 0.06 Baht per pcu-kilometer for a 2-lane road which is the characteristic type of road in the area. Therefore, according to this assumption, the ACC formula for the present year is as follows:

$$ACC_{at\ present\ year} = 0.06 \times distance \times \sum_{n=1}^{N} \left(\frac{AADT_{at\ present\ year} \times (1+g)^n}{(1+discount\ rate)^n} \right) \quad (5)$$

Where	$ACC_{at\ present\ year}$	=	Accident Cost in present year (2017) (Baht)
	Distance	=	Project road distance (km)
	$AADT_{at\ present\ year}$	=	Annual Average Daily Traffic in present year (2017) (pcu)
	N	=	20 years at which time road service life ends
	g	=	Constant Traffic Growth Rate (1%)
	n	=	Year at Time Forecast

As regards environmental and socio-economic aspects such as air pollution, noise, impacts on archaeological sites and the landscape, and improvement in the quality of life, the DRR and the consultant teams rarely considers these issues because the DRR assumes that their roads will improve quality of life with no disturbance to the environment and archaeological sites. Most DRR roads are developed based on the needs of communities and local government. The quality values of life improvement are assumed to be accounted for in terms of VOCs, VOT and ACCs. Most rural people work in agricultural, natural resource, industries or in ecotourism. Savings of traveling time and vehicle costs automatically increase their productivity and income, thus improving their quality of life. Therefore, the values of environmental and socio-economic aspects were not included in the models.

As a result, the tangible benefits are calculated based on the forecasted demand gained from the traffic model. The forecasted demand is converted to present demand to establish the present benefit value in Baht per pcu-kilometer. The present values are finally used to compute the BCA ratio.

3.3. Present Worth of Disbenefits/Costs

The DRR and the consultant teams did not separate the disbenefits and the costs of improvement projects because they assumed that the disbenefits represent a cost. They, therefore, consider the two headings aggregated under costs. The costs considered in order to calculate the BCA ratio are composed of construction and maintenance costs only, since they can be quantified based on the DRR's database. Those costs are presented in Table 2.

Table 2. Cost data* for Benefit-Cost Analysis (BCA) based on 2017.

Facility characteristics	costs
1. Road construction	
1.1 4th Class – 2-lanes, each lane width is 4 m. with no shoulder and gravel surface	3.2 million Baht per kilometer
1.2 4th Class – 2-lanes, each lane width is 3 m. with no shoulder and Asphalt surface	5.9 million Baht per kilometer
1.3 4th Class – 2-lanes, each lane width is 3 m. with no shoulder and concrete surface	9.1 million Baht per kilometer
1.4 3rd Class – 2-lanes, each lane width is 3 m., shoulder width is 1.50 m. and asphalt surface	8.8 million Baht per kilometer
1.5 3rd Class – 2-lanes, each lane width is 3 m., shoulder width is 1.50 m. and concrete surface	13.1 million Baht per kilometer
1.6 2nd Class – 2-lanes, each lane width is 3.5 m., shoulder width is 1.50 m. and asphalt surface	9.6 million Baht per kilometer
1.7 2nd Class – 2-lanes, each lane width is 3.5 m., shoulder width is 1.50 m. and concrete surface	14.4 million Baht per kilometer
1.8 1st Class – 4-lanes, each lane width is 3.25 m., shoulder width is 1.50 m. and asphalt surface	11.7 million Baht per kilometer
1.9 1st Class – 4-lanes, each lane width is 3.25 m., shoulder width is 1.50 m. and concrete surface	19.5 million Baht per kilometer
2. Bridge construction	
2.1 2-lanes bridge across road intersection	130,000 Baht per meter
2.2 2-lanes bridge across river/canal	150,000 Baht per meter
2.3 4-lanes over pass bridge across river/canal or Loop Ramp (its length is more than 6 m.)	250,000 Baht per meter
2.4 2-lanes tunnel under pass road intersection	250,000 Baht per meter
2.5 4-lanes under pass tunnel (its length is more than 6 m.)	430,000 Baht per meter
2.6 Interchange	700,000,000 Baht per each
3. Road maintenance	
3.1 Gravel surface maintenance	26,000 Baht per kilometer per year
3.2 Asphalt surface maintenance	53,000 Baht per kilometer per year
3.3 Asphalt surface maintenance for bypass/shortcut road	96,000 Baht per kilometer per year
3.4 Concrete surface maintenance	28,000 Baht per kilometer per year
3.5 Concrete surface maintenance for bypass/shortcut road	94,000 Baht per kilometer per year

*Data gained from Bureau of Location and Design, and Bureau of Maintenance (2017)

The construction costs depend on the road lane and shoulder width, road distance, and bridge type and length. The construction costs were provided by the Bureau of Location and Design. The maintenance costs were considered based only on road surface maintenance. The maintenance costs were provided by the Bureau of Maintenance. These costs were collected in 2017. The construction costs of bridges and roads depend on bridge/under- or over- pass types and road surface and are input only once. The total construction cost is equal to the road construction cost per kilometer (depended on road surface) multiplied by the road distance plus the bridge construction cost per meter (dependent on bridge type) multiplied by the bridge length. Therefore, the formula of construction costs for the present year is as follows:

$$Construction\ costs = (B \times UB) + \sum_{x=1}^{4}[(G_x \times UG_x) + (A_x \times UA_x) + (C_x \times UC_x)] \quad (6)$$

Where Construction costs = Costs of construction in present year (2017) (Baht)
B = Bridge length (m) or number of bridges
UB = Unit construction cost of bridge (dependent on bridge type) (Baht/unit or m)
G = Gravel surface road distance (km)
UB = Unit construction cost of gravel surface road (Baht/km)

A = Asphalt surface road distance (km)
UA = Unit construction cost of asphalt surface road (Baht/km)
C = Concrete surface road distance (km)
UC = Unit construction cost of concrete surface road (Baht/km)
x = Road class

The maintenance cost per year depended on road surface and was calculated as the number of kilometers per year (dependent on road surface) multiplied by the service life of the facility or 20 years. The formula for maintenance costs for the current year is as follows:

$$Maintenance\ costs = \{[(MG_2 \times UMG_2) + (MA_2 \times UMA_2) + (MC_2 \times UMC_2)] + [(MG_4 \times UMG_4) + (MA_4 \times UMA_4) + (MC_4 \times UMC_4)]\} \times 20 \quad (7)$$

Where Maintenance costs = Costs of maintenance in present year (2017) (Baht/year)
$MG_{2,4}$ = Gravel surface road distance for 2-lane or 4-lane roads (km)
$UMG_{2,4}$ = Unit maintenance cost of 2-lane or 4-lane gravel surface roads (Baht/km)
$MA_{2,4}$ = Asphalt surface road distance for 2-lane or 4-lane roads (km)
$UMA_{2,4}$ = Unit maintenance cost of 2-lane or 4-lane asphalt surface roads (Baht/km)
$MC_{2,4}$ = Concrete surface road distance for 2-lane or 4-lane roads (km)
$UMC_{2,4}$ = Unit maintenance cost of 2-lane or 4-lane concrete surface roads (Baht/km)

However, the costs of surveying and designing the facility, property surveys, expropriating land and conducting an environmental impact study are not included in the BCA, even though they are used for estimating the DRR's fiscal budget, because the roads for which the DRR are responsible are on public land and most expenditure is undertaken for the improvement of roads. This means that the present worth costs are only derived from the construction and maintenance costs of road improvements.

Furthermore, the DRR and the consultant teams apportioned the criteria for road improvements into classes ranging from lower to upper according to the level of the annual average daily traffic (AADT) as presented in Fig. 3. When the AADT of a road exceeds 300 pcu, the road is upgraded to third class. The construction and maintenance costs are used to calculate the present worth of the costs. In case of a road already being third class, the project improvement cost is represented only by the maintenance cost. Similarly, when the AADT of a road exceeds 1,000 pcu, the road is upgraded to second class and when it exceeds 8,000 pcu, the road is improved to first class. Apart from the type of road surface and any bridges, these improvements based on road classes result in a variety of project improvement costs.

3.4. Service Life of Rural Roads

The DRR and the consultant teams specified the service life of a rural road according to its conceptual design. Since the role of the roads for which the DRR are responsible is that of collectors, mainly serving a variety of small communities, they are rarely used by heavy trucks based on the live traffic load specified by the director of the Bureau of Rural Roads (BRR). The design speed ranges from 60-90 kilometers per hour. The number of traffic lanes, the width of the road, traffic lanes and shoulder, the elevation and gradient etc. depend on the road class [30]. Furthermore, the DRR considers that their roads will be developed according to the growth of the regional economy and the degree of urbanization. As a result, the DRR designs its roads based on a projected service life of 20 years.

3.5. Social Discount Rate

Social discount rate is one of the most common terms used to identify the rate of return of public sector investments [28]. This discount rate is a percentage rate explaining the rate at which the worth of equivalent benefits and costs will decrease in the future compared to the present [31]. The Asian Development Bank (ADB) has suggested that the market interest rate is the most suitable social discount rate in an ideally competitive market. In the developing nations, the social discount rate ranges from 8% to 15%, while in developed nations, the social discount rate used ranges from 3% - 7% [32]. This range of discount rates is similar to that suggested by Hayashi and Morisugi [19]. In addition, the World Bank has suggested a typical value of the discount rate for transport project investment of 12% [33]. Since Thailand is a developing nation, the DRR and the consultant teams therefore used a discount rate of 12% to evaluate the BCA for road improvement project investments.

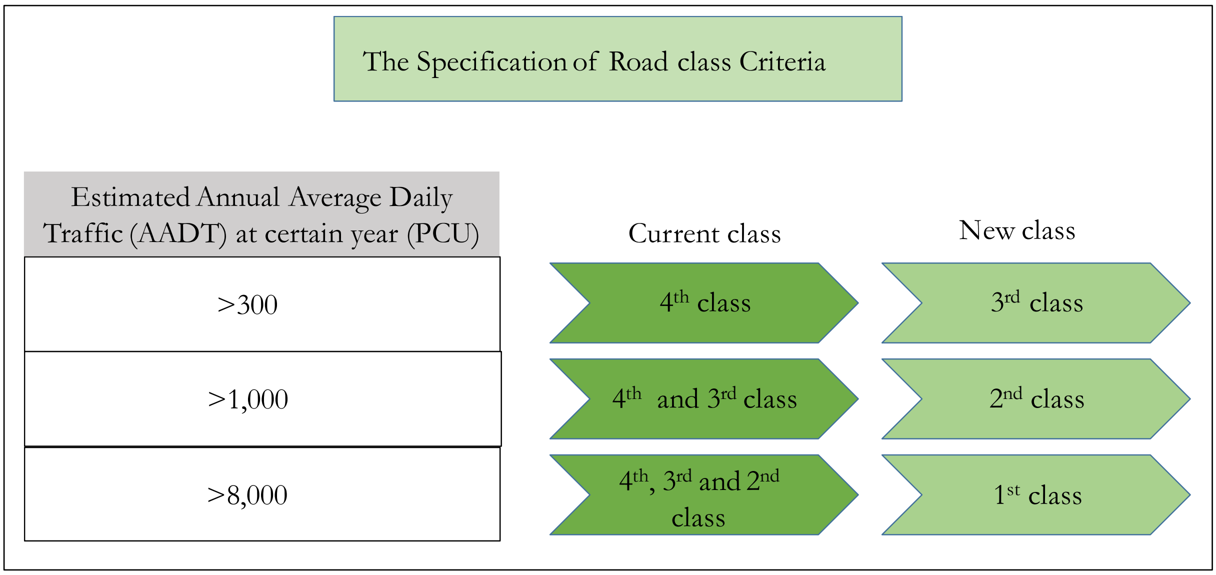

Fig. 3. The criteria of road class upgrading.

4. Results and Discussion

Using BCA and the equations and parameters set out above, the DRR and the eighth consultant team developed BCA calculations as shown in Table 3 which includes only the calculation of BCA for some of the routes under the responsibility of BRR 11 as examples. This methodology was then used for evaluating all the road projects undertaken by the DRR with the aim of achieving standardization across all regions. Based on the BCA results, for BRR 11, the BCA values of only 6 routes from 166 routes were higher than 1. For BRR 12, 4 routes from 214 routes had values greater than 1. The results for BRR 14 were similar to those of BRR12, with 4 routes from 156 routes for which the values exceeded 1. A summary of the projects with BCA values exceeding 1 is shown in Table 4. The results are, in fact, not surprising since all those projects with BCA values, above 1 had not been upgraded for more than 20 years and the forecasted demand did not imply a change in the route class. All the costs were therefore related to annual maintenance, making the BCA values high. These maintenance costs were therefore those normally allocated. As a result, the DRR faces difficulty in using BCA as a route improvement appraisal tool on which to base its proposals for improvement projects in terms of budget allocation efficiency. In addition, the allocation of government investment budgets now tends to consider tangible benefits which can be measured monetarily. Therefore, the results of BCA show how things are considered and identify advantages which are self-explanatory in the light of public involvement [27]. The project appraisal and selection practice adopted is similar to the USA's method of transport project investment appraisal.

These findings were then compared to the results of MCDM adjusted during the phase interface. Some results of the comparison are shown as examples in Table 5. The MCDM evaluations were performed in terms of a priority index (PI). The results of MCDM and BCA were compared but showed that two methods did not produce the same results. The failure of the two methods to identify the same options prompted the seventh consultant team to re-investigate the evaluation criteria and process. According to the results of the comparison and following parameter adjustment, it was found that the MCDM results based on the determinants of traffic engineering and socio-economic issues brought about the quality of life improvements but it was not possible to measure project efficiency as was possible using BCA [27]. Therefore, according to the final results of the DRR's project appraisal based on MCDM, the range of results from the highest values to the lowest represents the project significance, while the BCA indicates the project's feasibility based on its financial efficiency.

From the point of view of government policy in terms of budget allocation, it is necessary that the DRR makes project investment proposals supported by project feasibility studies. Therefore, a BCA is a necessity. Some determinants of MCDM were able to be computed in pecuniary terms, such as the AADT which was calculated based on the benefits to users through the VOCs, VOT, and ACCs as illustrated in Fig. 7. These benefits are only those directly accruing to transport users so they make the benefits from the project investment appear less widespread than may actually be the case. For instance, important social benefits in terms of accessibility are not mentioned. Perhaps, as Vickerman comments [24], the accessibility criteria are not a part of a rigorous assessment of impacts but these criteria are refinements of other existing indicators that evaluate the extent to which a road scheme has any effects on the use of other modes of transportation. This results of the BCA explicitly exclude regional and local economic impacts due to concerns about the double counting of such effects in the direct transportation benefits [24]. In fact, the calculation of BCA should be framed in such a manner that it takes into consideration all the benefits and costs which accrue to different groups and at different locations [27].

Therefore, a discussion was initiated among the seventh consultant team members to try to identify the benefits relating to other aspects than those purely concerned with transportation. This discussion focused on the calculation of the monetary value of each parameter in the MCDM to render that process compatible with the BCA. In many countries, BCA is used to supplement quantitative and/or qualitative evaluation approaches [18]. The discussion of costs is excluded since they are treated as fixed or controllable variables.

Initially, the monetary value of socio-economic dimensions had to be quantified. From an economic perspective, this entailed placing a value on accessibility to industrial and other productive facilities, tourist attractions and investment zones, and other transportation modes were considered. This included deciding which operational definition of measured variables would be used if investment in the project were to be agreed. Bristow and Nellthorp [18] suggested that, in most countries, the impact of transport project investments on output and employment are perhaps of most policy relevance. Therefore, the discussion of monetized socio-economic variables was considered in terms of output and employment. In order to place monetary values on the impacts on output and employment, and to ensure that in the project appraisal, regional benefits accrued to local communities, several variables were identified and quantified in monetary terms. These benefits, based on the traffic engineering and socio-economic parameters are shown in Table 6 and can be explained as follows:

- For accessibility to industrial facilities and special economic zones, new occupations created and increases in existing occupations related to those industrial facilities and special economic zones, the number of employees and their wage rate per capita per month were included as representing the benefits of accessibility. However, there were some arguments among the team members that these benefits might already have been counted in terms of VOT in the traffic engineering aspect since those occupations would be related to increases in the working and non-working time of road users included in the demand forecast. The inclusion of these parameters may thus lead to double-counting the benefits under the heading of both the traffic engineering and economic perspective. In addition, some members of the team argued that the increase in permanent employment in the area of a road improvement project does not accrue from increased travelling but arises from urbanization in that area. This urbanization is reflected in population density and implies that there are social benefits from living in the urbanized areas. Finally, after discussion, the team agreed that the benefits of accessibility should be omitted since they were already reflected in the AADT forecast as a part of the traffic engineering benefits, with population density being one of the social variables.
- For accessibility to agricultural areas, the improvement of the transportation system brings about better distribution of agriculture-supportive products such as fertilizers and pesticides, and is likely to lead to an increase in agricultural production, in turn leading to the economic growth in agriculture-based communities. The market price (mp) of products and their marginal product (MP), could therefore, be calculated and included in the financial benefits accruing from a project. Some members argued that the volume of the vehicle delivering the agriculture-supportive products or the cultivated products should be substituted for these benefits through VOT and VOCs. Others suggested that the linking of cultivation areas and their markets by roads would improve the distribution channel and thus provide more benefits to local farmers than VOT and VOCs. Moreover, since most Thai farmers rely on agents to distribute their products to their markets, it is likely that the logistics sector would gain more benefits from improvements in the road system than the agricultural sector and that those outside the area might gain more advantage than local communities. Consequently, for this aspect, the team members agreed that the financial benefits should be calculated from mp and MP.

- For accessibility to tourist attractions, the better the transport system, the more visits from tourists could be expected. In addition, the new and existing services may encourage increased tourist demand. However, similarly to agricultural area accessibility, although some members argue that this benefit is embedded in the traffic engineering dimension, others pointed out that businesses acting as travel agents are more likely to gain benefit than local people directly gain from tourists' expenditure in terms of accommodation, dining, and shopping. Thus, the anticipated benefits derived from the marginal number of tourists (MNT) and the tourists' expenditures per person per day (TEPPPD) for each particular area were considered, including marginal regions of tourism development. Consensus among the team members on these issues was finally reached.
- For accessibility to other modes of transportation, after a debate, all the team members agreed that this issue should not be considered as it would be taken into account in the traffic engineering dimension since travelling by other modes of transportation directly affects the number of road users.

With regard to the social perspective, the operational definition of population density and accessibility to public welfare facilities were determined based on output and employment as follows.

Under the MCDM conceptual framework, the higher the population per square kilometer, the higher PI score is gained. This implies that the DRR views communities relying on the use of vehicles as a benefit since travelling is a basic need. The growth in population density is accounted for through the demand forecast. Therefore, the benefits of this social aspect are included in the VOT, VOCs, and ACCs through the travel demand forecast.

- Accessibility to public welfare facilities, was broadly discussed since linking people to different public welfare places via the DRR's roads has many benefits. These public welfare places consist of government offices, educational institutes, hospitals, and religious sites. For example, giving access to government offices such as courts, police stations, district offices, and municipalities via DRR roads, could save the community time in conducting its public affairs. The benefits of these connections could be substituted by VOTs. Furthermore, the ability to travel to schools or technical institutes may result in better salaries and wages. The disparity between workers' wage rates based on blue-collar (unskilled workers) and white-collar (skilled workers) employment (DWRBW) and the marginal number of employees falling within the definition of white-collar workers or the marginal number of educated people (MEPs) could suggest a marginal benefit from the DRR's roads from connecting people to educational institutes. Further, by linking people to hospitals, the number of fatalities and the severity of injuries or incapacity resulting from non-traffic accidents and diseases could be reduced. This in turn might reduce the cost of providing health care. This cost saving could perhaps be estimated by multiplying the expected reduction in the number of fatality and injured severity (RNFIS) by the average cost of health care per person per day (CHCPPPD) according to the severity of certain disease. Finally, roads connecting people to religious places might have an effect on crime which could also result in reductions in property damage and fatalities and injuries from civil disturbance. This cost saving could perhaps be estimated by multiplying the expected reduction in the number of crimes (NCR) by the average property lost or damage per crime (ACPD). However, this effect was decided to be too remote and impossible to quantify. If these benefits were to be included in any calculation of the social benefits of road improvements, it would take considerable time to collect the data necessary to generate a model of the social impacts resulting from transportation improvements. Moreover, tentative variables would need to be defined and assumptions formulated before the benefits of accessibility could be calculated.

To incorporate these social benefits, information from a variety of government officials would need to be gathered by the DRR and the eighth consultant team in order to develop and propose a new financial evaluation framework. However, the information currently available is unsuitable for this purpose. For example, in the case of agricultural area accessibility, the MP could be calculated based on crops such as oil palm or rubber trees, and the existing and expected production rate per unit of land area, and their market price. However, the area under cultivation of these crops which would be connected by DRR roads has not been quantified. The information currently available only relates to areas close to DRR roads. This makes it difficult to compute the benefit in monetary terms. The existing and expected productivity per unit of land area also depends on the quality, type and cost of pesticides and fertilizers. However, for this aspect, assumptions could be made based on the difference between "do nothing" and "do the project" with no consideration for either quality or type, with the cost being fixed at the current market price. To the extent that accessibility is a determinant, the average production rates for the "do the project" and "do nothing" options could then be compared.

Another challenge is accessibility to tourist attractions, which is similar to the challenge involved in assessing the benefits from accessibility to agricultural areas. The information available to the DRR and the eighth consultant team only indicates the number of the tourist attractions within a specified distance of the DRR's roads. This includes the distance between the tourist attraction and the road. However, this ignores tourist attractions which are located beyond the specified distance, even though, in order to reach those attractions, the visitors would have to use the DRR's roads. This issue was also discussed in relation to accessibility to other transportation modes, which is taken into consideration in the traffic engineering benefits. However, in the case of accessibility to tourist attractions, the benefits in terms of tourists' expenditure on accommodation, dining, and shopping are not currently taken into consideration, despite the fact that they benefit the regional economy and can be calculated in monetary terms. It is worth noting that information about the number of tourists visiting each attraction are available from the regional office of the Tourism Authority of Thailand (TAT), while the information about which of the DRR's roads must be used to reach them could be obtained from the regional BRR. Therefore, it ought to be possible to calculate the pecuniary benefits in this aspect.

The most difficulty aspect to transform into monetary terms is that of social benefits. Public welfare facility accessibility could be broken down according to the type of facilities. However, collecting data relating to both quantified variables and the unit of financial benefits is quite demanding and the results of data analysis relating to social benefits may not isolate the effects of road improvements, and may involve other latent factors. In addition, most quantified variables are uncontrollable. As a result, there was no agreement about how these aspects could be included in the evaluation process.

In short, the results of BCA failed to agree with the MCDM results complicating the project appraisal and selection process. Decisions relating to road improvement projects must be taken in relation to their appraisal in monetary terms in light of the government's budget allocation. In an effort to try to solve the problem of the limitations which a purely financial costs and benefits appraisal implies, the monetary values of other relevant aspects were discussed. Nevertheless, it was found that the available information was not sufficient and they could not therefore be incorporated into the calculation of the BCA. Furthermore, some of the assumptions which had to be made entailed difficulties due to uncontrollable and latent factors.

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Table 3. Example of BCA calculations in case of BRR 11 applying the appraisal methods.

	(1)	(2)	(3)	(4)	(5)	(6)										(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
No.	Region code	Route code	Distance (km)	No. of traffic lanes	Speed limit (km./hr.)	Present AADT (pcu) at 2017	Forecasted demand (pcu) in each year based on Eq. (2), Traffic growth rate (g) = 1%									$\sum_{n=1}^{20}\left(\frac{AADT_{2017}\times(1+g)^n}{(1+discount\ rate)^n}\right)$ at discount rate 12%, g = 1%	Class upgrading		VOC (Baht) based on Eq.(3) =13.35x(3)x(7)	VOT (Baht) based on Eq.(4) =110x(3)x(7)	ACC (Baht) based on Eq.(5) = (0.06x(3)x(7)	Total Benefits (Baht) (10)+(11)+(12)	Total costs (Baht) = (A) + (B)	BCA (13)/(14)
							Year 1 2018	Year 2 2019	Year 3 2020	Year 4 2021	Year 16 2033	Year 17 2034	Year 18 2035	Year 19 2036	Year 20 2037		Present	Future						
1	8	CPN.1001	13.350	2	80	5,409	5,463	5,518	5,573	5,629	6,342	6,406	6,470	6,535	6,600	43,382	3	2	7,731,691.453	63,706,820.963	34,749.175	71,473,261.59	152,211,000.00	0.47
2	8	NST.2001	6.356	2	90	3,608	3,644	3,681	3,717	3,754	4,231	4,273	4,316	4,359	4,402	28,938	4	2	2,455,425.064	20,231,966.822	11,035.618	22,698,427.50	70,754,960.00	0.32
3	8	RNG.4001	23.980	2	60	1,461	1,476	1,490	1,505	1,520	1,713	1,730	1,748	1,765	1,783	11,718	4	2	3,751,247.007	30,909,151.372	16,859.537	34,677,257.92	293,426,800.00	0.12
4	8	RNG.1002	5.410	2	60	811	819	827	836	844	951	960	970	980	990	6,505	4	3	469,779.852	3,870,845.221	2,111.370	4,342,736.44	62,792,600.00	0.07
5	8	CPN.4002	18.300	2	80	2,834	2,862	2,891	2,920	2,949	3,323	3,356	3,390	3,424	3,458	22,730	4	2	5,552,993.983	45,755,006.604	24,957.276	51,332,957.86	204,378,000.00	0.25
6	8	NST.4002	19.235	2	90	427	431	436	440	444	501	506	511	516	521	3,425	4	3	879,419.989	7,246,157.215	3,952.449	8,129,529.65	215,157,100.00	0.04
7	8	CPN.1003	28.300	2	80	2,452	2,477	2,501	2,526	2,552	2,875	2,904	2,933	2,962	2,992	19,666	3	2	7,429,903.423	61,220,178.016	33,392.824	68,683,474.26	369,778,000.00	0.19
8	8	RNG.1003	10.900	2	60	797	805	813	821	829	935	944	953	963	972	6,392	4	3	930,167.340	7,664,300.182	4,180.527	8,598,648.05	111,374,000.00	0.08
9	8	RNG.1004	13.400	2	60	1,142	1,153	1,165	1,177	1,188	1,339	1,352	1,366	1,380	1,393	9,159	4	2	1,638,502.731	13,500,771.565	7,364.057	15,146,638.35	154,844,000.00	0.10
10	8	CPN.4004	16.978	4	80	496	501	506	511	516	582	587	593	599	605	3,978	3	3	901,663.466	7,429,436.797	4,052.420	8,335,152.68	17,996,680.00	0.46

	(2)										(A)	(B)	(14)
	Route code	Brigde or underpass length (m. or unit)						Road surface distance (km.)			Costs (Baht)		Total costs = (A) + (B)
		2 lane Rd intersection	2 lane Rd across river	4 lane Rd over pass	2 lane tunnel Rd intersection	4 lane Rd under pass	Interchange	Gravel	Asphalt	Concrete	Maintenance cost based on Eq.7	Construction cost based on Eq.6	
		130,000 Baht/m.	150,000 Baht/m.	250,000 Baht/m.	250,000 Baht/m.	430,000 Baht/m.	700,000,000 Baht/unit	(baht/km)	(baht/km)	(baht/km)			
4th class construction cost unit								3,200,000	9,100,000	5,900,000			
3rd class construction cost unit									13,100,000	8,800,000			
2nd class construction cost unit									14,400,000	9,600,000			
1sth class construction cost unit									19,500,000	11,700,000			
2-lanes maintenance cost unit								26,000	28,000	53,000			
4-lanes maintenance cost unit									94,000	96,000			
1	CPN.1001		66							13.350	14,151,000	138,060,000	152,211,000
2	NST.2001		20							6.356	6,737,360	64,017,600	70,754,960
3	RNG.4001		252							23.980	25,418,800	268,008,000	293,426,800
4	RNG.1002		63							5.410	5,734,600	57,058,000	62,792,600
5	CPN.4002		62					3.325		14.975	19,398,000	184,980,000	204,378,000
6	NST.4002		170							19.235	20,389,100	194,768,000	215,157,100
7	CPN.1003		454							28.300	29,998,000	339,780,000	369,778,000
8	RNG.1003		26							10.900	11,554,000	99,820,000	111,374,000
9	RNG.1004		80							13.400	14,204,000	140,640,000	154,844,000
10	CPN.4004		184							16.978	17,996,680	-	17,996,680

Table 4. The results of the BCA higher than 1.0 sorted in descending order of BCA value for projects undertaken by each BRR.

	(1)	(2)	(3)	(4)	(5)	(6)										(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
No.	Region code	Route code	Distance (km)	No. of traffic lanes	Speed limit (km./hr.)	Present AADT (pcu) at 2017	Forecasted demand (pcu) in each year based on Eq. (2) Traffic growth rate (g) = 1%									$\sum_{n=1}^{20}\left(\frac{AADT_{2017}\times(1+g)^n}{(1+discount\ rate)^n}\right)$ at discount rate 12%, g = 1%	Class upgrading		VOC (Baht) based on Eq.(3) =13.35x(3)x(7)	VOT (Baht) based on Eq.(4) =110x(3)x(7)	ACC (Baht) based on Eq.(5) = (0.06x(3)x(7)	Total Benefits (Baht) (10)+(11)+(12)	Total costs (Baht) = (A) + (B)	BCA (13)/(14)
							Year 1	Year 2	Year 3	Year 4	Year 16	Year 17	Year 18	Year 19	Year 20		Present	Future						
							2018	2019	2020	2021	2033	2034	2035	2036	2037									
BRR 11 Suratthani																								
1	8	SNI.3060	9.165	4	80	9,417	9,511	9,606	9,702	9,799	11,042	11,153	11,264	11,377	11,491	75,528	1	1	9,241,049.722	76,143,480.855	41,532.808	85,426,063.38	17,472,880.00	4.89
2	8	SNI.3062	9.350	2	80	4,061	4,102	4,143	4,184	4,226	4,762	4,809	4,858	4,906	4,955	32,571	2	2	4,065,564.613	33,499,034.268	18,272.201	37,582,871.08	9,911,000.00	3.79
3	8	CPN.5056	2.228	4	80	3,683	3,720	3,757	3,795	3,833	4,319	4,362	4,405	4,449	4,494	29,539	1	1	878,603.993	7,239,433.649	3,948.782	8,121,986.42	4,277,760.00	1.90
4	8	CPN.4058	5.280	4	80	3,554	3,590	3,625	3,662	3,698	4,167	4,209	4,251	4,294	4,337	28,504	1	1	2,009,220.559	16,555,375.390	9,030.205	18,573,626.15	10,137,600.00	1.83
5	8	NST.5077	3.325	4	90	2,853	2,882	2,910	2,939	2,969	3,345	3,379	3,413	3,447	3,481	22,882	1	1	1,015,709.907	8,369,145.303	4,564.988	9,389,420.20	6,384,000.00	1.47
6	8	NST.4104	1.300	2	90	1,335	1,348	1,362	1,375	1,389	1,565	1,581	1,597	1,613	1,629	10,707	2	2	185,823.607	1,531,130.842	835.162	1,717,789.61	1,378,000.00	1.25
BRR 12 Songkhla																								
1	8	YLA.5031	1.480	4	80	5,070	5,121	5,172	5,224	5,276	5,945	6,004	6,064	6,125	6,186	40,663	1	1	803,426.111	6,619,990.428	3,610.904	7,427,027.44	2,782,400.00	2.67
2	8	YLA.3006	19.744	2	70	2,789	2,817	2,845	2,874	2,902	3,270	3,303	3,336	3,369	3,403	22,369	2	2	5,896,033.248	48,581,547.365	26,499.026	54,504,079.64	20,928,640.00	2.60
3	8	YLA.3015	16.793	2	80	1,716	1,733	1,750	1,768	1,786	2,012	2,032	2,053	2,073	2,094	13,763	2	2	3,085,473.628	25,423,378.207	13,867.297	28,522,719.13	17,800,580.00	1.60
4	8	SKA.1058	4.225	4	60	1,343	1,356	1,370	1,384	1,398	1,575	1,591	1,606	1,622	1,639	10,771	2	2	607,545.758	5,005,995.014	2,730.543	5,616,271.31	4,478,500.00	1.25
BRR 14 Krabi																								
1	8	TRG.5036	5.749	4	60	9,511	9,606	9,702	9,799	9,897	11,152	11,264	11,377	11,490	11,605	76,282	1	1	5,854,566.692	48,239,875.363	26,312.659	54,120,754.71	10,880,120.00	4.97
2	8	PLG.4055	6.134	4	80	6,761	6,829	6,897	6,966	7,036	7,928	8,007	8,087	8,168	8,250	54,226	1	1	4,440,490.803	36,588,313.729	19,957.262	41,048,761.79	11,531,920.00	3.56
3	8	PKT.4010	3.500	4	80	3,572	3,608	3,644	3,680	3,717	4,188	4,230	4,273	4,315	4,359	28,649	1	1	1,338,615.230	11,029,788.412	6,016.248	12,374,419.89	6,580,000.00	1.88
4	8	PKT.4023	4.802	2	80	1,440	1,454	1,469	1,484	1,498	1,689	1,705	1,722	1,740	1,757	11,549	2	2	740,390.632	6,100,596.968	3,327.598	6,844,315.20	5,090,120.00	1.34

Table 5. Examples of project route appraisal results through the MCDM through PI and BCA methods.

No	BRR	Route code	Distance (km)	Priority Index (PI)	Present		At year 20		BCA
					AADT (pcu)	Route class	AADT (pcu)	Route class	
1	11	CPN.3066	0.788	83.00	8,175	2	9,975	1	0.44
2	11	SNI.2007	25.000	81.70	3,908	3	4,769	2	0.27
3	11	SNI.3060	9.165	74.50	9,417	1	11,491	1	4.89
4	11	SNI.3062	9.350	69.60	4,061	2	4,955	2	3.79
5	11	CPN.1001	13.350	67.20	5,409	3	6,600	2	0.47
6	11	NST.4037	13.544	65.50	9,560	4	11,665	1	0.57
7	11	SNI.6038	20.990	65.50	2,173	4	2,651	2	0.14
8	11	CPN.3009	8.186	65.40	3,699	3	4,513	2	0.26
9	11	CPN.2063	10.143	63.60	3,053	3	3,725	2	0.27
10	11	CPN.5065	0.886	63.50	8,705	4	10,622	1	0.63
11	11	CPN.5056	2.228	60.60	3,683	1	4,494	1	1.90
12	11	NST.5028	8.129	60.00	5,025	4	6,131	2	0.44
13	11	NST.3050	15.270	59.50	3,767	4	4,596	2	0.29
14	11	NST.3027	5.040	58.90	4,344	3	5,301	2	0.40
15	11	NST.5077	3.325	58.80	2,853	1	3,481	1	1.47

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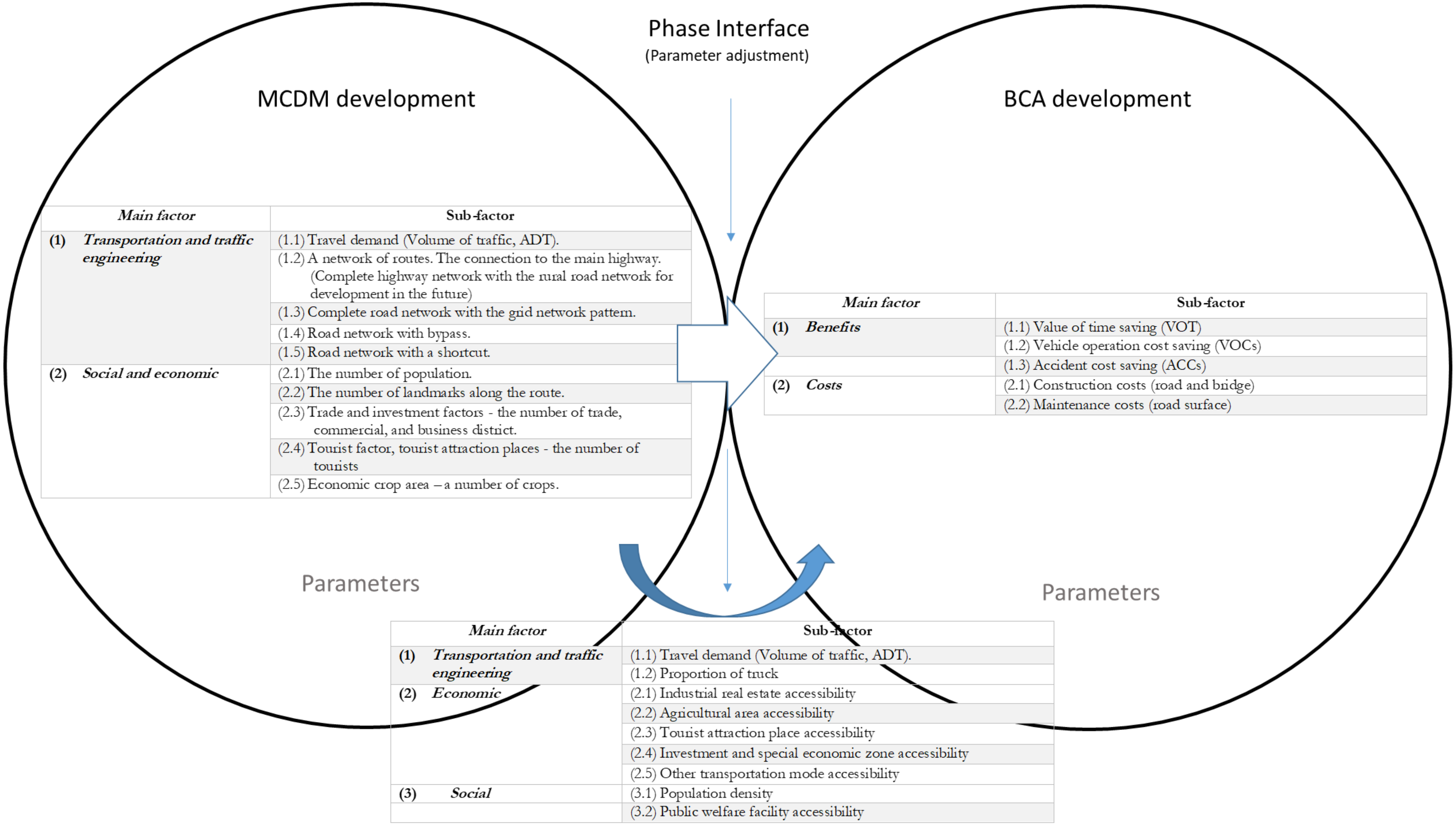

Main factor	Sub-factor
(1) ***Transportation and traffic engineering***	(1.1) Travel demand (Volume of traffic, ADT).
	(1.2) A network of routes. The connection to the main highway. (Complete highway network with the rural road network for development in the future)
	(1.3) Complete road network with the grid network pattern.
	(1.4) Road network with bypass.
	(1.5) Road network with a shortcut.
(2) ***Social and economic***	(2.1) The number of population.
	(2.2) The number of landmarks along the route.
	(2.3) Trade and investment factors - the number of trade, commercial, and business district.
	(2.4) Tourist factor, tourist attraction places - the number of tourists
	(2.5) Economic crop area – a number of crops.

Main factor	Sub-factor
(1) ***Benefits***	(1.1) Value of time saving (VOT)
	(1.2) Vehicle operation cost saving (VOCs)
	(1.3) Accident cost saving (ACCs)
(2) ***Costs***	(2.1) Construction costs (road and bridge)
	(2.2) Maintenance costs (road surface)

Main factor	Sub-factor
(1) ***Transportation and traffic engineering***	(1.1) Travel demand (Volume of traffic, ADT).
	(1.2) Proportion of truck
(2) ***Economic***	(2.1) Industrial real estate accessibility
	(2.2) Agricultural area accessibility
	(2.3) Tourist attraction place accessibility
	(2.4) Investment and special economic zone accessibility
	(2.5) Other transportation mode accessibility
(3) ***Social***	(3.1) Population density
	(3.2) Public welfare facility accessibility

Fig. 4. The transformation of the MCDM parameters to the pecuniary terms applied in the BCA methods.

Table 6. The benefits of the BCA assumption based on the traffic engineering and socio-economic parameters of the MCDM.

Main factor	**Sub-factor**	**Quantified variables**	**Monetary units of benefits**	**Benefits**
(1) Transportation and traffic engineering	(1.1) Travel demand (Volume of traffic, ADT).	AADT	(1.1) Value of time saving (VOT)	$= VOT \times AADT$
	(1.2) Proportion of truck		(1.2) Vehicle operation cost saving (VOCs)	$= VOCs \times AADT$
			(1.3) Accident cost saving (ACCs)	$= ACCs \times AADT$
(2) Economic	(2.1) Industrial real estate accessibility	(Embedded in AADT)	-	-
	(2.2) Agricultural area accessibility	The Marginal product (MP)	The market price of certain plant (mp)	$= MP \times mp$
	(2.3) Tourist attraction place accessibility	The Marginal number of tourists (MNT)	Tourists' expenditures per person per day (TEPPPD)	$= MNT \times TEPPPD$
	(2.4) Investment and special economic zone accessibility	(Embedded in AADT)	-	-
	(2.5) Other transportation mode accessibility	(Embedded in AADT)	-	-
(3) Social	(3.1) Population density	(Embedded in AADT)	-	-
	(3.2) Public welfare facility accessibility			
	(3.2.1) Link to government offices	(Embedded in AADT)	-	-
	(3.2.2) Link to educational institutes	Marginal educated persons (MEPs)	The different wage rate of blue collar (unskilled worker) and white collar (skilled worker) (DWRBW)	$= MEPs \times DWRBW$
	(3.2.3) Link to hospitals	The reduced number of fatality and injured severity (RNFIS)	The cost of health care per person per day according to certain disease severity (CHCPPPD)	$= RNFIS \times CHCPPPD$
	(3.2.4) Link to religious places	The number of crime reduction (NCR)	The average cost of property damage (ACPD)	$= NCR \times ACPD$

5. Conclusions

The DRR appraises route-improvement projects in order to standardize the project approval process and to ensure transparency, within budget constraints. The dimensions of traffic engineering and socio-economic issues are particularly highlighted. Within the framework of MCDM, the issues involved are examined in order to specify the most important parameters which are then incorporated into a PI calculation. These parameters are refined to establish the monetary variables calculated based on net present values, and are then used to calculate the BCA, which is necessary to meet the requirements of government budget allocation. Unfortunately, the results of the MCDM and BCA are not the same and the DRR has not established criteria to decide between MCDM and BCA as to which one should be used to evaluate alternative proposals. A discussion was therefore initiated among the seventh consultant team members to try to find ways of incorporating, by way of monetary terms, factors identified in the MCDM which had been overlooked in the BCA calculation. However, the information available from the DRR is currently insufficient and there is little chance of incorporating those overlooked factors when computing the incremental BCA value. Moreover, even allowing for the lack of current information, there are particular difficulties associated with incorporating the social aspect of road developments derived not only from the problem of the quantification of those social parameters but also the impossibility of controlling them. These problems pose a challenge to the DRR and the consultant teams to find ways to improve the BCA method and to make it more consistent with the MCDM, or at least, to use the results of BCA as a safety net to support the MCDM results.

Based on the results of discussions, it is suggested that the DRR could provide benefits by way of accessibility to rural areas beyond VOCs, VOTs and ACC through their road improvement program. The regional economic benefits include an increase in the marginal number of tourists and their expenditure per capita. This includes the MP produced and the mp of certain plants. Information about these aspects could be obtained from the regional offices of the TAT and local district offices respectively. Regarding the benefits of social issues, the accessibility to educational institutes, hospitals and religious places should bring about benefits through higher wages, and savings in the costs of health care and property loss/damage respectively. However, it would take considerable time to collect and analyses data relating to these possible benefits.

Although, the results achieved were based on many assumptions and evaluations which were too regionally specific, particularly those relating to the economic environment, to be applied in considering similar issues nationally in Thailand, the different appraisal methods and parameters considered were standard and could be applied more broadly in Thailand since, as with other countries Thailand has its own history of concept evolution and project assessment and execution [19, 22]. However, the results could usefully guide policy makers, transport authorities and other practitioners in the field in other countries, particularly, in developing nations. The research methodology relating to the appraisal methods are relevant to those practitioners who could learn lessons from the outcome reported in relation to developing their transport project appraisal processes.

The results were successful in measuring the regional benefits in monetary terms and provided much useful and practical information. Most previous studies have described only their methods, the parameters used and their values. They have not generally shown in detail how the values were arrived at, nor the methods of data collection and analysis. In addition, they have rarely mentioned the social benefits, primarily reporting the benefits by way of VOTs, VOCs and ACC. This study will therefore be of benefit to practitioners in other contexts who would be able to avoid the *trial and error* process which occurred in the development of the appraisal system described herein.

The authors acknowledge the DRR's great efforts in developing and formalizing the project appraisal and approval process, and moving to a more open and transparent system of project investment decision-making which is able to measure the value of projects in monetary terms. Whilst it is important for Thai people to recognize the value of the DRR's investment program, as matters stand it is not possible for the social equity benefits provided through accessibility to be converted to monetary variables and they are not therefore taken into account in the project approval process. However, the DRR's route investment appraisal program is only in its early stages of development, and is still in a phase entailing trial and error based on making assumptions, with a view to finding a suitable approach. Once the appraisal method is established, then the BRR and DRR officers will need to be trained to conduct on-the-job appraisals by applying the method's rationale and principles. To gather information for the selection and evaluation of improvement projects, the DRR needs to cooperate with other government offices and the BRRs have to collaborate with local administrators. In this way, the DRR's proposals for budget allocations for the projects they approve will be acceptable to the government and will convince local people of the benefits of those projects, benefits which are both measurable and transparent.

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