# OPTIMAL TOLL COLLECTION STRATEGIES FOR INTER-CITY ROUTE: A CASE STUDY OF NEW BANGKOK-CHONBURI MOTORWAY AND BANGNA-CHONBURI ELEVATED EXPRESSWAY

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**Abstract:** Bangna-Chonburi Elevated Expressway (BCEE) and New Bangkok-Chonburi Motorway (NBCM) are two inter-city toll road projects that were opened for service in 1998 to serve as main routes for handling the traffic demand towards the eastern region of Thailand. These two projects are operated by two different agencies. In addition, there is a non-toll road that is parallel and located underneath the BCEE route. The competition for the reducing traffic demand after the economic crisis in Thailand significantly affects the viability of the BCEE and NBCM projects. The main purpose of this paper is to determine optimal toll collection strategies for each of the inter-city routes. Twenty-four strategies including the existing cases are investigated in terms of financial and economic viability. Recommendations on different toll collection strategies are presented in this paper.

**Keyword:** Project Evaluation, Toll Collection Strategy, and Diversion Rate Method

## 1. INTRODUCTION

Highway transportation has played a significant role among various kinds of surface transportation in both developed and developing countries. Many governments have tried to develop the transportation system and build more facilities to better serve the public demand. However, improving highway systems requires enormous investments as well as high annual costs of operation and maintenance whereas most governments are finding it difficult to raise enough public funds for such improvements. Because of this situation, toll highways, in which private sectors are usually involved, are permitted as an alternative to government funding sources. Granting concessions to the private sector to construct and operate toll facilities allows the exploitation of business experience in maximizing the efficiency of an enterprise. It is necessary for the toll operator to establish a project that shows a sensible return on investment over its service life. The specific toll collection system used is considered as one of the key factors that affect the viability of a toll highway project. The study of toll variation is then useful for setting the optimal toll rate of the project.

## 2. PROBLEM STATEMENT

In Thailand, many toll road projects have been implemented not only in Bangkok, but also in other regions outside Bangkok due to the increase of the inter-city traffic. These projects are termed "Inter-City Toll Roads". Eastern region is one of the most rapidly growing areas of Thailand where the Thai government has planned to develop this area to be the industrial base of Eastern Seaboard Region. Despite three routes towards the eastern region (i.e., Sukhumvit Road, Ram-Indra Road and Bangna-Trad Highway (BTH)), the government concerns that the existing routes may not be able to handle the increasing traffic demand and it is recommended that high standard highway must be constructed. Therefore, New Bangkok-Chonburi Motorway (NBCM) and Bangna-Chonburi Elevated Expressway (BCEE) are implemented and opened in the same year (1998) on which NBCM was opened two-month earlier. Both NBCM and BCEE projects are toll roads that are designed to serve the traffic demand in the

eastern region of Thailand. Figure 1 illustrates the location map of BCEE, BTH and NBCM project at which BCEE was constructed on the median of BTH whereas NBCM was located in the north corridor of BCEE route. The approval of the NBCM and BCEE at the same time makes these two projects compete against each other. The actual corridor traffic is not as predicted in the planning process after the economic crisis in Thailand (~1997-present). This scenario creates the competition between the non-toll road & toll roads and between toll-roads themselves. Table 1 presents the existing corridor traffic connecting between Bangkok and eastern region.

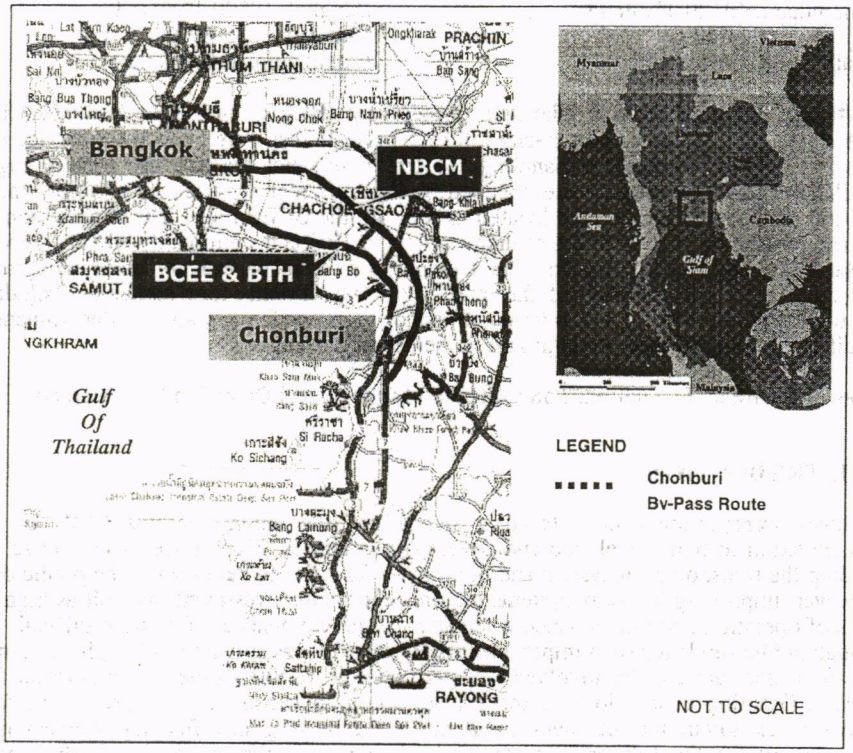



Figure 1 Location Map of Study Route

Table 1 Average Daily Traffic on Corridor between Bangkok and Eastern Region (Year 1999)

| Route | ADT (veh/day) | Share of Volume (%) | Remark |
|---|---|---|---|
| Sukhumvit Road | 14,700 | 12.3% | Traffic volume as shown is the average volume in two directions |
| Bangna-Trad Highway | 51,900 | 43.5% | |
| Ram-Indra Road | 24,300 | 20.4% | |
| New Bangkok-Chonburi Motorway (NBCM) | 23,100 | 19.4% | |
| Bangna-Chonburi Elevated Expressway (BCEE) | 5,200 | 4.4% | |
| Total | 119,200 | 100% | |

Source: DOH (1999a) and ETA (1999)

Table 1 shows the average daily traffic on the corridor between Bangkok and eastern region of year 1999. According to Table 1, BCEE is taking a higher risk than NBCM since the average traffic volume is much lower. Toll collection system is considered to be one of the key factors that affect the viability of the toll highway project. The existing toll collection

system of both projects may or may not be suitable for inter-city route in case of demand reduction. The main objective of this research is to perform the post-financial and economic evaluation of the existing inter-city toll routes and study different toll collection strategies to best suit the inter-city route of Thailand by selecting the NBCM and BCEE project as case studies.

## 3. EXISTING TOLL COLLECTION SYSTEM OF BCEE AND NBCM ROUTES

NBCM route was fully opened in February 1998. It is operated as a special type of zonal system at which the users pay fee at a fixed rate regardless of the distance they travel, but the full toll payment is divided into half and each half is collected two times at different toll plazas. The zonal system is the combination of open and closed system (Vichapatana, 1999). The users pay fee at fixed rate, but the fixed rate is changed according to entry zone. Therefore, user who enters in different zone pays different rates. There are two toll plazas in each direction at which the users of NBCM route have to pay twice in each direction. Figure 2a shows the location of on-ramps and off-ramps on NBCM. The existing toll fee for passenger car is 30 baht per plaza at which the users have to pay 60 baht if they have to travel on the full section. However, there are many local roads linked to NBCM route and no tollgates at the entry or exit ramps are provided. The local roads that run parallel to the NBCM provide the opportunity to the road users to come in and out of the NBCM routes. In some cases, the road users can avoid paying the full payment of 60 baht due to such opportunity.

BCEE route is now operating as the closed system at which the users pay the toll fee according to the distance they travel. The closed system applies the distance-proportional toll rate at which toll rates are set in accordance with the distance traveled and types of vehicle. Each user must stop at the entry to get the coded ticket and stop again at the exit to pay the toll fee in which it is calculated based on the distance between the entry and exit. The closed system is suitable for roads of medium to relatively long lengths or for the large and complex expressway networks where many route choices are available since it gives more flexibility for toll revenue collection (ETA, 1996a).There are a total of 26 ramps on this route which are 13 on-ramps and 13 off-ramps as shown in Figure 2b. BCEE was partially opened in April 1998 with only two on-ramps and two off-ramps and was fully opened in February 2000. The existing toll rate of BCEE for passenger car is "1 baht per kilometer" with minimum charge of "20 baht" at which the payment is rounded to the whole number nearest to five or zero for convenient payment.

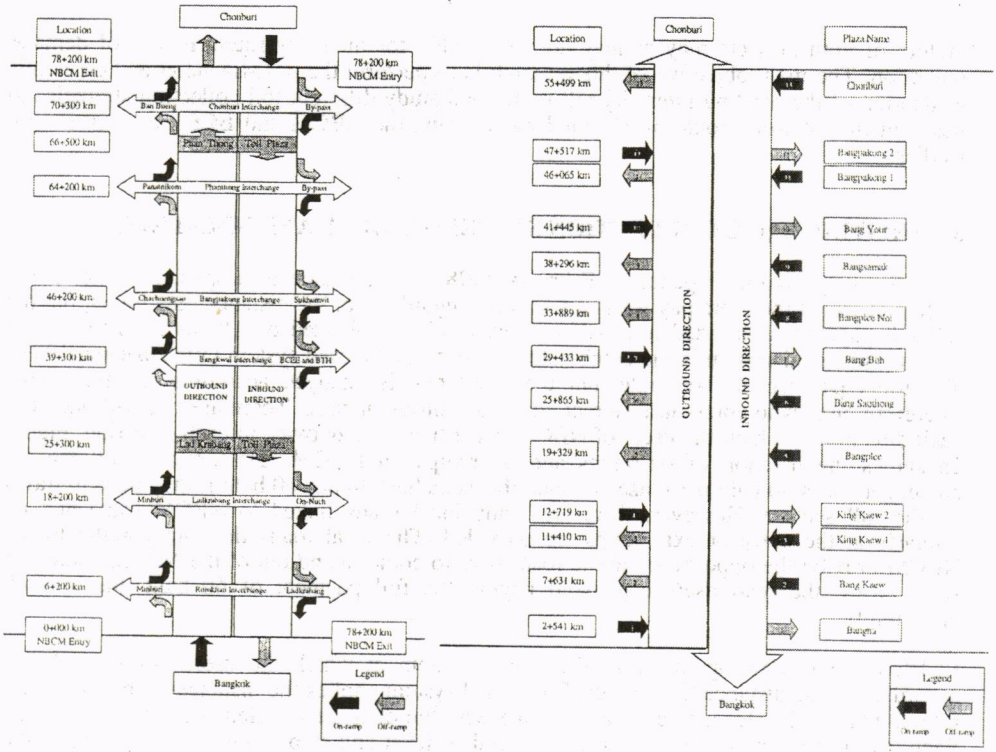
## 4. METHODOLOGY

The main objective of this research is to determine the most suitable toll collection of the intercity route in Thailand by applying to NBCM, BCEE and BTH highways as the case studies. Figure 3 presents the general framework of this research.

### 4.1 Field Data Collection

Field data collection of this study is used to determine the average travel time and acquires the required parameters for user benefit estimation, which are travel time survey and questionnaire survey, respectively. The floating car technique is used to measure the travel time. The survey was set on three different days (Thursday, Friday, and Saturday) within two durations (10.00-12.00 hr and 16.00-18.00 hr) on BTH, BCEE and NBCM route. An additional questionnaire survey is used in this study in order to estimate several parameters as described below:

- average working hours and earnings of road users on BTH, BCEE and NBCM
- trip purpose of road users on BTH, BCEE and NBCM
- average car occupancy on BTH, BCEE and NBCM




(a) NBCM Project (b) BCEE Project

Figure 2 Locations of On-ramps and Off-ramps in BCEE and NBCM Projects

### 4.2 Traffic Forecast of Existing Toll Collection System

In this study, the project life of BCEE and NBCM routes is planned to be 30 years starting from the construction period. The construction of NBCM route was implemented in 1994 whereas BCEE route was constructed in 1995. However, it is assumed that the beginning of construction period for both projects started in 1995 at which all relevant costs of NBCM project prior to the year 1995 will be converted to 1995 price by using the discount rate. Therefore, the planning horizon used in this study is in the 30-year period between year 1995-2024. The traffic forecast of BCEE and NBCM projects during 1998-2024 are required since both BCEE and NBCM routes were opened for service in 1998.

The traffic demand of BCEE during 1998-2024 is taken from the traffic forecasting of BCEE during 1998-2042 made by (ETA, 1999). BCEE route is divided into 13 sub-zones and its traffic model is developed to estimate the traffic volume among sub-zones in both inbound and outbound directions (ETA, 1999). In addition, (ETA, 1999) considered the effect of partial open for service (in 1998 and 1999) and produced the traffic volume in 1998, 1999 and 2000 in trip matrix form. The traffic volume during 2001-2042 was forecasted by projecting from the traffic volume in year 2000 with the growth rate of 6 % per annum.

The traffic volume of NBCM route during 1998-2024 can be obtained from the existing traffic data in 1998-1999 collected by DOH and use the annual growth rate to estimate the future traffic volume in 2000-2024. Traffic forecast of motorway was performed by (JICA, 1991). (JICA, 1991) uses the four-step model to estimate the traffic volume of 14 routes in

2000 and 2010. However, the growth rate of 6 % per annum was used in some sections of traffic estimation based on the study of (JICA, 1991).

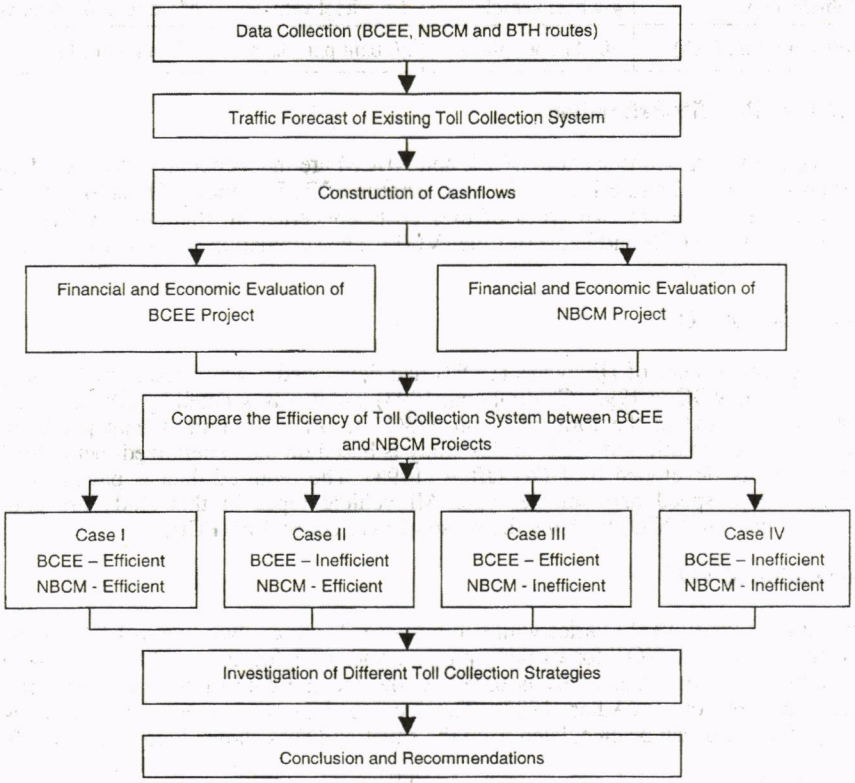



Figure 3 The Overall Research Framework

### 4.3 Construction of Cash flow

To compare the efficiency of the toll collection system of BCEE and NBCM routes, the cash inflow and cash outflow of each project are constructed. Project revenue is defined as cash inflow in financial aspect whereas user benefit is defined as cash inflow in economic aspect. Cash outflow is any disbursements or expenditures occurred before construction throughout the project life. For both BCEE and NBCM projects, the cash inflow and outflow are calculated on an annual basis of the planning horizon of 30 years (1995-2004) with the discount rate of 12% per annum.

#### 4.3.1 Project Revenue Calculation

Project revenue is the product between traffic volume and toll rate. The toll rate of BCEE and NBCM is different in terms of different toll collection methods and vehicle classification. Table 2 and 3 present the existing toll rate of BCEE and NBCM routes, respectively.

Table 2 Existing Toll Rate of BCEE Route Classified by Vehicle Type (ETA, 1999)

| Vehicle Type | 4-wheel vehicle | 6-10 wheel vehicle | > 10 wheel vehicle |
|---|---|---|---|
| Minimum Charge (baht/veh) | 20 baht | 40 baht | 60 baht |
| Additional Rate (baht/veh) | 1 baht per km | 2 baht per km | 3 baht per km |

Table 3 Existing Toll Rate of NBCM Route Classified by Vehicle Type (DOH, 1999c)

| Vehicle Type | 4 wheel vehicle | 4-6 wheel vehicle | More than 6 wheel vehicle |
|---|---|---|---|
| Toll Rate (baht/veh) | 30 baht per plaza | 50 baht per plaza | 70 baht per plaza |

### 4.3.2 User Benefits Estimation

As stated in the previous section, BCEE and NBCM are independently considered. Savings in user costs of BCEE and BTH are the user benefits of BCEE since BTH is located underneath BCEE route. There are two types of user costs concerned in this study which are vehicle operating costs (VOC) and value of time (VOT). The summation of VOC and VOT is defined as generalized costs.

### Calculation of VOC

Thailand Department of Highways (DOH) had developed a generalized methodology for the calculation of VOC in 1993 (Chidtrakoon, 1993) and it was updated by (JICA, 1995) in 1995. VOC is expressed in the form of "Unit VOC" at which its unit is baht per kilometer per vehicle. The calculation of VOC in this study is based on the generalized methodology which was originally developed by DOH (JICA, 1995). The required data is pavement condition, average travel speed and vehicle type. All vehicle types in this study are converted to passenger car unit (PCU) by using the passenger car equivalent (PCE).

### Calculation of VOT

The value of time (VOT) varies with trip purpose. There are two types of VOT considered in this study which are VOT for working purpose and VOT for non-working purpose. The VOT measurement used in this study is based on the income data of the users who travel along three specified routes (Adler, 1987). The income data is obtained from the questionnaire survey. The VOT can be calculated from the equation (1) as shown below (Thach, 1992):

$$VOTj = \left[a_{1j} + a_{2j} \times 0.25\right] \times \frac{AMI_j}{AWH_j} \times Car\ Occupancy_j \quad (1)$$

where $VOT_j$ = user's value of time for route $j$ (baht/hr/pcu)
$a_{1j}$ = proportion of user on route $j$ with working purpose
$a_{2j}$ = proportion of user on route $j$ with non-working purpose
$AMI_j$ = average monthly income for user on route $j$ (baht/month/person)
$AWH_j$ = average working hour per month for user on route $j$ (hour/month)
$Car\ Occupancy_j$ = average number of passenger in one vehicle for route $j$ (person/pcu)

In general, VOT for working and non-working purpose should be different. Pearman (1984) and Thach (1992) recommended that the VOT for working purpose should be estimated from the average income per hour whereas the VOT for non-working purpose be estimated at 25 % of average income per hour. When the user costs of each route are calculated, the user benefits can be obtained.

### Project Costs Estimation

The project costs consist of financial costs and economic costs. Financial costs are the actual costs of the project acquired in the open market (PWD, 1993). They are composed of design costs, land acquisition and compensation costs, construction and supervisory costs, operation and maintenance costs, interest during construction, and taxes. Table 4 summarizes the financial costs of BCEE and NBCM projects.

Table 4 Financial Costs of BCEE and NBCM Projects (Unit: Million Baht)

| Route | Year | Investment Costs | | Operation and Maintenance Costs | |
|---|---|---|---|---|---|
| | | Land Costs | Construction Costs | Routine | Periodic |
| BCEE | 1995 | 188.12 | 963.83 | | |
| | 1996 | | 4,851.34 | | |
| | 1997 | | 7,209.78 | | |
| | 1998 | | 5,416.93 | 356.00 (annually) | 415.00 (every 7-year) |
| | 1999 | | 2,691.04 | | |
| | 2000-2024 | | | | |
| NBCM | 1995 | 2,270.55 | 6,937.34 | | |
| | 1996 | | 4,649.09 | | |
| | 1997 | | 1,325.16 | | |
| | 1998 | | 67.60 | 65.00 (annually) | 76.00 (every 7-year) |
| | 1999 | | | | |
| | 2000-2024 | | | | |

Source: (ETA (1996b), ETA (1999), DOH (1997) and DOH (1999b))

The economic costs reflect the real value of the utilized resources in the project. Some transfer items such as taxes and duties are not the resource costs, but they are included in the financial costs (PWD (1993), JICA (1995)). Thus, all transfer items must be deducted from the financial costs when the economic costs are considered. The relationship between economic costs and financial costs are analyzed in terms of economic conversion factor (PWD, 1993). Table 5 presents the economic conversion factor of BCEE and NBCM projects used in this study (PWD, 1993).

Table 5 Economic Conversion Factors of BCEE and NBCM Route

| Project | Right-of-way Compensation | Construction | Operation and Maintenance |
|---|---|---|---|
| BCEE | 100.00 % | 82.46 % | 84.30 % |
| NBCM | 100.00 % | 82.46 % | 84.30 % |

### 4.4 Financial and Economic Evaluation of BCEE and NBCM projects

The purpose of financial evaluation is to investigate whether each project route is financially viable or not. The economic evaluation assesses the degree of contribution of the projects to the national economy and investigates whether the implementation of the projects are justified or not from an economic point of view (JICA, 1995). In this study, financial and economic evaluation is the key factor to measure the effectiveness of each toll strategy. The optimal toll strategy is the one that is justified in both financial and economic terms. Three indicators are used in this study which are Net Present Worth (NPW), Benefit-Cost Ratio (B/C) and Internal Rate of Return (IRR). The decision criteria that would yield an attractive investment are presented in Table 6.

Table 6 Decision Criteria of the Attractive Project Investment (PWD, 1993)

| Index | Financial Analysis | Index | Economic Analysis |
|---|---|---|---|
| FNPW | Positive | ENPW | Positive |
| R/C | $\geq 1$ | B/C | $\geq 1$ |
| FIRR | $\geq$ 12% p.a. | EIRR | $\geq$ 12% p.a. |

### 4.5 Comparison of the Efficiency of Toll Collection System between BCEE and NBCM Projects

The NBCM project is operated as the special type of zonal toll collection system since the full payment of 60 baht is divided in half and the road users have to pay the half full payment at the first and second toll plazas. However, the BCEE project is operated as the closed toll collecting system at which the user pays the fee twice both at the entry and exit, and the fee is relevant to the traveled distance. Once the financial and economic evaluation of each project (NBCM and BCEE) is completed, several scenarios are assumed as shown in Table 7.

Table 7 Possible Outcomes from Project Evaluation

| Case | Toll System of BCEE | Toll System of NBCM |
|---|---|---|
| 1 | Efficient | Efficient |
| 2 | Inefficient | Efficient |
| 3 | Efficient | Inefficient |
| 4 | Inefficient | Inefficient |

[Note: Efficient case is referred to the project that is both financially and economically justified and vice versa].

### 4.6 Proposition of other toll collection strategies in each project

Alternation of toll collecting strategies is not required in case 1 since both projects are considered to be efficient. However, the case of one or both toll systems is/are inefficient, different toll collection strategies are proposed as presented in Tables 8, 9, and 10. Tables 8, 9 and 10 provide the alternative toll collecting strategies for all possible cases except the first case. The proposed toll strategies of BCEE route cover three types of toll collecting system. However, the proposed toll collection strategies of NBCM cover only zonal system since both the existing traffic operation of NBCM route and its toll collection pattern make it very difficult to identify the proportion of outgoing and incoming traffic at each ramp.

Table 8 Proposed Toll Collection Strategies-Case 2

| **Project** | **Toll Collecting Strategies** | |
|---|---|---|
| BCEE | Closed System | 20+0.50, 20+0.75, 20+2, 20+3 |
| | Open System | 20 baht, 40 baht, 60 baht, 80 baht, 100 baht |
| | Zonal System | 50/30 baht, 60/40 baht, 70/50 baht |
| NBCM | Existing system is suitable for this route | |

Table 9 Proposed Toll Collection Strategies-Case 3

| **Project** | **Toll Collecting Strategies** | |
|---|---|---|
| BCEE | Existing system is suitable for this route | |
| NBCM | Zonal System | (10,10), (20,20), (40,40), (50,50), (20,30), (40,30), (50,30), (30,10), (30,20), (30,40) |

Table 10 Proposed Toll Collection Strategies-Case 4

| **Project** | **Toll Collecting Strategies** | |
|---|---|---|
| BCEE | Closed System | 20+0.50, 20+0.75, 20+2, 20+3 |
| | Open System | 20 baht, 40 baht, 60 baht, 80 baht, 100 baht |
| | Zonal System | 50/30 baht, 60/40 baht, 70/50 baht |
| NBCM | Zonal System | (10,10), (20,20), (40,40), (50,50), (20,30), (40,30), (50,30), (30,10), (30,20), (30,40) |

**Remarks and Notations:**

- The symbol "20+1" stands for toll rate at 1 baht per kilometer and minimum fee is 20 baht.
- The symbol "40 baht" stands for toll fee is fixed at 40 baht at every toll plaza.
- The symbol "50/30 baht" for BCEE project stands for toll fee of zonal system at which those who enter within shaded area pays 50 baht and 30 bath for nonshaded area (Figure 4).
- The symbol "(40,30) baht" for NBCM project stands for toll fee at Ladkrabang toll plaza is fixed at 40 baht whereas toll fee at Phanthong toll plaza is fixed at 30 baht (Figure 4).

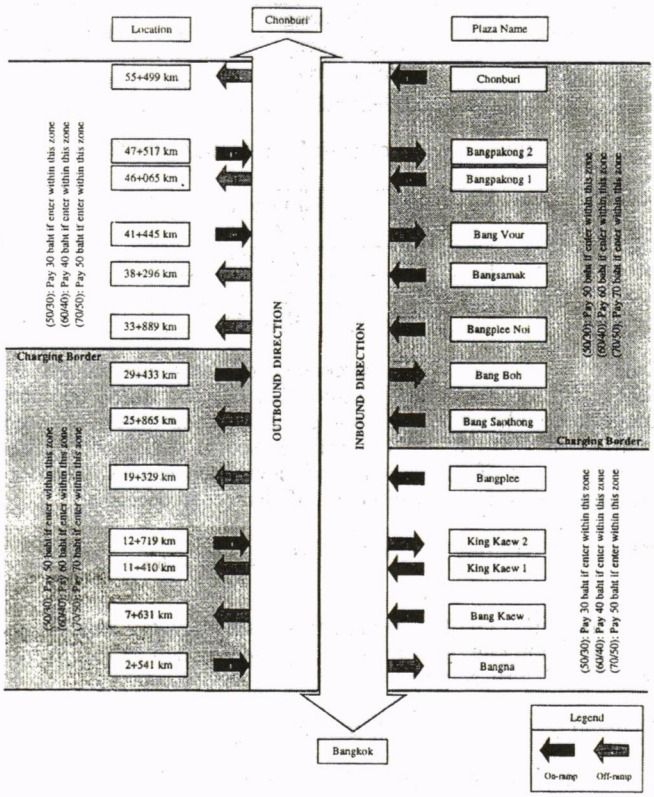



Figure 4 Schematic Diagram of Toll Collection for Zonal System (BCEE Project)

According to the proposed toll collection strategies discussed above, each strategy affects the demand function differently. The diversion rate method proposed by JICA (1991) is used in this study in order to estimate the percentage change in traffic demand when the toll and travel time saving is known. The formula of diversion rate developed by JICA is presented below. Tables 11 and 12 present the value of parameter a, b and c and value of shift factor (S)

$$P = \frac{K}{1 + \frac{a \times \left(\frac{C}{TS}\right)^{b}}{T^{c}}} \qquad (2)$$

where P = diversion rate
K = maximum diversion rate (assumed K = 0.90)
C = trip fare (baht)
T = time difference in minutes

S = shift factor
a, b, c = parameters

Table 11 Value of Parameter a, b, c Categorized by Vehicle Group (JICA, 1995)

| Vehicle Group | Vehicle Category | a | b | c |
|---|---|---|---|---|
| Passenger Vehicle | Passenger Car<br>Light Bus<br>Heavy Bus | 0.616 | 1.073 | 1.035 |
| Light Truck | Pick-up Passenger<br>Light Truck | 0.978 | 1.068 | 1.088 |
| Truck | Medium Truck<br>Heavy Truck | 0.049 | 1.505 | 0.542 |

Table 12 Value of Shift Factor (JICA, 1995)

| Year | Shift Factor (S) |
|---|---|
| 1993 | 0.024624 |
| 2000 | 0.032157 |
| 2010 | 0.058296 |
| 2020 | 0.102337 |

The diversion rate of BCEE means the percentage of users that will divert from BTH to BCEE route. Changes in toll rate affect the diversion rate and traffic demand. The diversion rate of the same route with same toll strategy is changed when time goes by. This is considered from different shift factor (S) in different year is used. In this study, it is assumed that changes in diversion rate of one route are considered as changes in traffic demand of that route. Equations 3 and 4 illustrate the estimation of changes in demand.

$$\%\ \text{Change in Traffic Demand} = \frac{P_{2j} - P_{1j}}{P_{1j}} \times 100 \quad (3)$$

where $P_{2j}$ = diversion rate of route j after proposing new toll collecting system
$P_{1j}$ = diversion rate of route j before proposing new toll collecting system
$j$ = BCEE, NBCM route

$$\text{Traffic Demand}_{(new)} = K * \text{Traffic Demand}_{(existing)} \quad (4)$$

where $K = (1 + \%\ \text{Change in Traffic Demand})$

## 5. RESULTS AND DISCUSSIONS

### 5.1 Analysis of Financial and Economic Evaluation of Existing Toll Collection System

The results of financial and economic evaluation of BCEE and NBCM project are presented in Table 13 and 14, respectively, for the existing toll collection system.Based on Table 13, the financial and economic indices of BCEE project are inconsistent with the required criteria. This indicates that the existing toll collection system of BCEE project or closed system at "20+1" baht is inefficient in terms of both financial and economic justification. Similarly, the financial and economic indices of NBCM project as shown in Table 14 are also inconsistent with the required criteria. This indicates that the zonal system at (30,30) baht or 30 baht per toil plaza is inefficient in terms of both financial and economic justification. It can be concluded that the existing toll collection systems of both projects are not viable.

The inefficiency of both BCEE and NBCM projects falls into case 4 as discussed in Table 7. Several proposed toll collection strategies are presented for case 4 as shown in Table 10. Once

different toll rates are proposed, the traffic demand has to be recalculated since the change in toll rate affects the change in traffic demand. The diversion rate as shown in equation 2 is used to calculate the change in traffic demand when toll rate is changed.

Table 13 Financial and Economic Evaluation of BCEE Project for the Existing Toll Collection System ("20+1" baht)

| Strategy | Financial Index | | | Economic Index | | |
|---|---|---|---|---|---|---|
| | FNPW (million baht) | B/C | FIRR (%) | ENPW (million baht) | B/C | EIRR (%) |
| 20+1 Baht | -13,259.73 | 0.27 | -4.83% | -5,181.36 | 0.64 | 8.15% |
| Required Criteria | >0 | ≥1 | ≥12 % | >0 | ≥ 1 | ≥12% |

Table 14 Financial and Economic Evaluation of NBCM Project for the Existing Toll Collection System ((30,30) baht)

| Strategy | Financial Index | | | Economic Index | | |
|---|---|---|---|---|---|---|
| | FNPW (million baht) | B/C | FIRR (%) | ENPW (million baht) | B/C | EIRR (%) |
| (30,30) Baht | -3,908.64 | 0.69 | 7.85% | -1,877.66 | 0.83 | 10.55% |
| Required Criteria | > 0 | ≥ 1 | ≥ 12 % | > 0 | ≥ 1 | ≥ 12 % |

The diversion rate for each toll strategy of each project is compared with the diversion rate for the existing toll collection system. In the case of BCEE route, the diversion rate for closed system at "20+1" baht is used to compare with the diversion rate of other alternatives. In case of NBCM route, the diversion rate for zonal system at 30 baht per plaza or (30,30) baht is used to compare with the diversion rate of other cases. Finally, the forecasted traffic volume of the proposed toll strategy can be obtained to calculate the financial and economic indices.

### 5.2 Analysis of Financial and Economic Evaluation of Proposed Toll Collection Systems

As discussed in the previous section, the existing toll collection system of both BCEE and NBCM projects are inefficient in both financial and economic evaluation. Therefore, other toll collection systems are proposed in this research.

#### 5.2.1 Analysis of Proposed Toll Collection Strategies of BCEE Project

Table 15 presents the financial and economic indices of BCEE project for different proposed toll strategies. Three types kinds of evaluation indices, which are NPV, B/C and IRR are calculated. The shaded strategy in the table is the existing toll collection system of BCEE project.

Based on Table 15, all proposed toll collection strategies of BCEE route are inconsistent with the required criteria in both financial and economic justifications. In addition, the financial indices of all alternatives are very close to each other whereas the values of economic indices of each alternative are quite different compared each other. The ENPW indices vary from -1,340.43 million baht in "20+0.50 baht" strategy to -11,595.31 million baht in "100 baht" strategy.

According to Table 15, it should be noted that the existing toll collection system or closed system at "20+1 baht" is the most profitable strategy in terms of financial aspect whereas the closed system at "20+0.50 baht" is the worst. In economic consideration, the closed system at "20+0.50 baht" is the most beneficial strategy whereas the open system at "100 baht" is the worst. In addition, it is found that no proposed strategy is more profitable in terms of financial aspect than the existing case. However, "20+0.50 baht", "20+0.75 baht" and "20 baht" are those proposed strategies that are more viable in terms of economic aspect than the existing case.

Table 15 Financial and Economic Indices of the Existing and Proposed Toll Collection Strategies of BCEE Project

| Case | Toll Strategy | Symbol | FNPW (Million Baht) | B/C | FIRR (%) | ENPW (Million Baht) | B/C | EIRR (%) |
|---|---|---|---|---|---|---|---|---|
| 1 | Open System 20 baht | 20 baht | -13,586.04 | 0.25 | -7.93% | -1,513.34 | 0.89 | 10.90% |
| 2 | Open System 40 baht | 40 baht | -13,552.65 | 0.25 | -7.28% | -7,632.82 | 0.47 | 5.29% |
| 3 | Open System 60 baht | 60 baht | -13,570.36 | 0.25 | -7.13% | -9,758.75 | 0.32 | 2.41% |
| 4 | Open System 80 baht | 80 baht | -13,599.13 | 0.25 | -7.18% | -10,924.14 | 0.23 | 0.20% |
| 5 | Open System 100 baht | 100 baht | -13,633.49 | 0.25 | -7.26% | -11,595.31 | 0.19 | -1.44% |
| 6 | Closed System 0.50 baht/km (min 20 baht) | 20+0.50 | -14,014.78 | 0.22 | -9.45% | -1,340.43 | 0.91 | 11.08% |
| 7 | Closed System 0.75 baht/km (min 20 baht) | 20+0.75 | -13,681.27 | 0.24 | -7.39% | -3,865.72 | 0.73 | 9.15% |
| 8 | Closed System 1 baht/km (min 20 baht) | 20+1 | -13,259.73 | 0.27 | -4.83% | -5,181.36 | 0.64 | 8.15% |
| 9 | Closed System 2 baht/km (min 20 baht) | 20+2 | -13,606.85 | 0.25 | -7.06% | -9,242.05 | 0.35 | 3.08% |
| 10 | Closed System 3 baht/km (min 20 baht) | 20+3 | -13,640.19 | 0.24 | -7.14% | -10,753.36 | 0.25 | 0.21% |
| 11 | Zonal System 50 baht and 30 baht | 50/30 | -13,584.04 | 0.25 | -7.21% | -8,531.88 | 0.40 | 4.16% |
| 12 | Zonal System 60 baht and 40 baht | 60/40 | -13,559.15 | 0.25 | -7.11% | -9,548.47 | 0.33 | 2.71% |
| 13 | Zonal System 70 baht and 50 baht | 70/50 | -13,644.33 | 0.24 | -7.11% | -10,258.07 | 0.28 | 1.50% |

If the subsidy from government is considered, the strategy "20 baht", "20+0.50 baht" and "20+0.75 baht" are more practical than the existing toll system since they require less subsidy to make BCEE project become viable in both financial and economic aspects. This can be seen from the summation of FNPW and ENPW of each strategy. However, the strategy "20 baht" is more attractive than closed system at "20+0.50 baht" and "20+0.75 baht", if the change of net benefits per net profit is considered as shown in Table 16. In other words, if the existing toll system is changed to "20 baht" instead of other strategies, the net benefit will increase with higher rate than others.

Table 16 Change of FNPW and ENPW of the Proposed Toll Strategies Compared to FNPW and ENPW of the Existing Toll Strategy of BCEE Project

| Toll Strategy | Change of FNPW (MB) | Change of ENPW (MB) | Change of Net Benefits per Net Profit |
|---|---|---|---|
| 20+1 Baht | 0 | 0 | - |
| 20+0.50 Baht | -755.05 | 3,840.93 | 5.09 |
| 20+0.75 Baht | -421.54 | 1,315.64 | 3.12 |
| 20 Baht | -326.31 | 3,668.02 | 11.24 |

The discussions below summarize all the findings of different toll collection strategies for BCEE route.

(1). The existing toll collection strategy of BCEE route is operated as a closed system at 1 baht/km/pcu with minimum charge of 20 baht (or "20+1 baht"). Based on the assumptions in this study, its operation is inefficient in terms of both financial and economic justification.

(2). None of proposed toll strategies are profitable. The existing toll collection strategy (20+1 baht) is the most profitable alternative. Therefore, the best way to maintain the profitability of BCEE project is to operate as a closed system at 1 baht/km with minimum charge of 20 baht.

(3). Zonal system is not efficient for BCEE route comparing with the closed and open system. In financial consideration, high toll rate of open system is more profitable than high toll rate of closed system. In economic consideration, high toll rate of closed system is more efficient than high toll rate of open system.

(4). Increasing toll rate cannot increase the project revenue of BCEE route in all cases compared with the existing case as well as it significantly reduces the net benefits. Meanwhile, reducing toll rate cannot increase the project revenue of BCEE route in all cases compared with the existing case, but the net benefits are increased when the reduced toll rate is applied.

(5). If both financial and economic viability are required, the strategy "20 baht", "20+0.50 baht" and "20+0.75 baht" are more practical than the existing case since they require less subsidy. Among these three alternatives, the "20 baht" is the most attractive toll strategy in terms of highest incremental net benefits per one baht reduction of net profit as shown in Table 16.

### 5.2.2 Analysis of Proposed Toll Collection Strategies of NBCM Project

Table 17 presents the financial and economic indices of NBCM project for the proposed toll collection strategies. The shaded strategy in the table is the existing toll collection system of NBCM project.

Table 17 Financial and Economic Indices of the Existing and Proposed Toll Strategies of NBCM Project

| Case | Toll Strategy | Symbol | FNPW (Million Baht) | B/C | FIRR (%) | ENPW (Million Baht) | B/C | EIRR (%) |
|---|---|---|---|---|---|---|---|---|
| 1 | Zonal System 10 baht at both plazas | (10,10) | -6,747.77 | 0.45 | 1.83% | 5,876.20 | 1.52 | 16.21% |
| 2 | Zonal System 20 baht at both plazas | (20,20) | -5,010.51 | 0.60 | 5.91% | 506.98 | 1.04 | 12.39% |
| 3 | Zonal System 30 baht at both plazas | (30,30) | -3,908.64 | 0.69 | 7.85% | -1,877.66 | 0.83 | 10.55% |
| 4 | Zonal System 40 baht at both plazas | (40,40) | -3,875.59 | 0.69 | 7.73% | -4,251.69 | 0.63 | 8.30% |
| 5 | Zonal System 50 baht at both plazas | (50,50) | -3,929.85 | 0.69 | 7.70% | -5,574.95 | 0.51 | 6.85% |
| 6 | Zonal System 20baht at Ladkrabang and 30 baht at Phanthong plaza | (20,30) | -4,964.13 | 0.60 | 6.04% | -945.25 | 0.92 | 11.25% |
| 7 | Zonal System 40 baht at Ladkrabang and 30 baht at Phanthong plaza | (40,30) | -4,080.18 | 0.67 | 7.48% | -3,491.07 | 0.69 | 9.06% |
| 8 | Zonal System 50 baht at Ladkrabang and 30 baht at Phanthong plaza | (50,30) | -4,141.12 | 0.67 | 7.35% | -4,314.17 | 0.62 | 8.21% |
| 9 | Zonal System 30 baht at Ladkrabang and 10 baht at Phanthong plaza | (30,10) | -4,974.26 | 0.60 | 6.01% | 2,064.49 | 1.18 | 13.54% |
| 10 | Zonal System 30 baht at Ladkrabang and 20 baht at Phanthong plaza | (30,20) | -4,475.46 | 0.64 | 6.90% | -943.95 | 0.92 | 11.27% |
| 11 | Zonal System 30 baht at Ladkrabang and 40 baht at Phanthong plaza | (30,40) | -4,385.36 | 0.65 | 7.04% | -3,287.35 | 0.71 | 9.24% |

Based on Table 17, it is shown that all proposed toll collection strategies of NBCM route are inconsistent with the required criteria in financial viability. However, three of proposed strategies are consistent with the required criteria in economic viability, which are "(10,10) baht", "(20,20) baht" and "(30,10) baht".

According to Table 17, it is found that (40,40) baht is the most profitable strategy in terms of financial aspect whereas (10,10) baht is the worst. In economic consideration, (10,10) baht is the most beneficial strategy whereas (50,50) baht is the worst. It should be noted that no proposed strategy is more profitable in terms of financial aspect than the existing case except the strategy (40,40) baht. However, there are five strategies that the economic aspects are more viable than the existing case which are (10,10), (30,10), (20,20), (30,20) and (20,30) baht.

Based on Table 17, the strategy "(40,40) baht" seems to be efficient especially in viewpoint of financial viability, but the significant reduction of benefit makes this strategy very risky to

implement. Having compared among (20,20), (20,30), (30,10) and (30,20) baht in Table 18, it is found that (30,10) baht is the most attractive strategy because of the highest increased net benefits per reduced net profit. In addition, it should be noted that the total payment of two toll plazas of (30,10) and (20,20) alternative is the same and it equals 40 bahts. This indicates that if the existing toll fee of NBCM (60 baht at both plaza) is expected to reduce by 20 baht for the whole section, it is better to decrease 20 baht at Phanthong plaza only instead of decreasing 10 baht at both plazas. In case of (10,10) baht, it shows high economic justification compared with the existing case. However, the net profit is reduced by almost 3,000 million baht or about 70% profit reduction of the existing case at which it will put the project at high risk.

Table 18 Change of FNPW and ENPW of the Proposed Toll Strategies Compared to FNPW and ENPW of the Existing Toll Strategy of NBCM Project

| Toll Strategy | Change of FNPW (MB) | Change of ENPW (MB) | Change of Net Benefits per Net Profit |
|---|---|---|---|
| (30,30) Baht | 0 | 0 | - |
| (40,40) Baht | 33.05 | -2,374.03 | -71.83 |
| (10,10) Baht | -2,839.12 | 7,753.86 | 2.73 |
| (30,10) Baht | -1,065.62 | 3,942.15 | 3.70 |
| (20, 20) Baht | -1,101.86 | 2,384.65 | 2.16 |
| (30, 20) Baht | -566.82 | 933.71 | 1.65 |
| (20,30) Baht | 1,055.49 | 932.41 | 0.88 |

If both financial and economic viability are required, (20,20), (30,10) and (30,20) baht are more practical than the existing case since they require less subsidy. This can be seen from the summation of FNPW and ENPW. However, (30,10) baht is more efficient than other proposed strategies if the change of net benefits per net profit is considered as shown in Table 18. The discussions below summarize all the findings of different toll collection strategies for NBCM route.

(1). The existing toll collection system of NBCM route is operated as the special type of zonal system at which the users pay fee at fixed rate regardless of the distance they travel, but the full toll fee is collected twice. The toll rate is 30 baht per plaza or "(30,30) baht". Based on the assumptions in this study, its operation is inefficient in terms of both financial and economic justification.

(2). Two patterns of zonal system are proposed in NBCM route which are toll rate at both plaza is equal and toll rate at each plaza is unequal. The results show that none of proposed alternatives is financially viable and only three strategies are economically viable which are (10,10), (20,20) and (30,10).

(3). In financial consideration of NBCM route, high toll rate of equal rate zonal system is more profitable than high toll rate of unequal rate zonal system. In economic consideration, high toll rate of unequal rate zonal system is more efficient than high toll rate of equal rate zonal system.

(4). Increasing toll rate is not the practical strategy for NBCM route since it cannot increase the revenue in all cases except only (40,40) case as well as it greatly reduces the net benefits. Despite increasing net profit in (40,40) case, the net benefits are reduced by about 70 times per one baht of increased profit compared with the existing case. Meanwhile, reducing toll rate in NBCM cannot increase the project revenue in all cases compared with the existing case, but the net benefits are increased when the reduced toll rate is applied.

(5). Having compared with the existing case, (30,10) baht is the most attractive among all proposed strategies. If both financial and economic viability are required, (30,10) baht is more practical than the existing case since it requires fewer subsidies.

## 6. CONCLUSIONS AND RECOMMENDATIONS

The main purpose of this research is to determine the optimal toll collection strategy for the inter-city route of Thailand by adopting the New Bangkok-Chonburi Motorway (NBCM), Bangna-Chonburi Elevated Expressway (BCEE), and Bangna-Trad Highway (BTH) as the case studies. BCEE route is operated as a closed system at which the users pay the toll fee according to the distance they travel. However, NBCM route is operated as a zonal system at which the users pay the fee at a constant rate regardless the traveled distance and the full toll payment is made at twice. The results have shown that the existing toll collection system of both BCEE and NBCM routes are inefficient in both financial and economic justifications. Twelve and ten strategies are proposed for BCEE and NBCM routes, respectively, to help determine the most suitable toll collection strategy. However, it can be concluded that the optimal toll collection strategy for BCEE and NBCM project is the existing strategy or, in other words, 1.00 baht/km with minimum charge of 20 baht for BCEE and 30 baht/plaza for NBCM.

In addition, it should be noted that the increased toll strategy is not practical for toll operation of inter-city expressway in Thailand since the net profits are not increased in both projects whereas the net benefits are significantly reduced. Reduced toll collection strategy is more practical than increased toll collection strategy since the net benefits are increased although the net profits are decreased. Several recommendations are made below:

- Other inter-city toll routes from other regions of Thailand should be considered in order to compare the toll rate with each other and determine the most practical toll rate for each route. In addition, other toll routes from other countries should be considered in order to estimate the optimal toll rate for inter-city route of developing countries.

- Many interchanges are connected to the NBCM route, but there is no tollgates provided at either entry or exit ramps. Users can choose to travel at some sections of NBCM route with free of charge and travel in other routes for another section. This is considered as the loophole on NBCM route at which it is difficult to apply the closed system in NBCM route. Therefore, the traffic volume at each on-ramp and off-ramp should be collected in order to apply various toll collection strategies and obtain better results. In addition, the NBCM route should restrict users from free entry and exit by fencing along the route. Effect of restricted area on project revenue and user benefits should be considered.

- In this study, the value of time for non-working purpose is considered at 25 % of average income per hour. The value of time for non-working purpose should be varied in various ranges for the future work in order to examine the effect on project viability.

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