Investigation of infrastructure maintenance cost of intercity railway in Thailand

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Abstract. Infrastructure in the rail system requires considerable investment in construction and maintenance. In many countries, railway operators have been able to share the capacity of the railroad to achieve efficient infrastructure usage. For the development of Thailand’s railway network system in the future, it is possible for separating management between infrastructure and the rolling stock operations. Therefore, it is necessary to know the costs and factors that affect the cost of infrastructure, including government budget subsidies, to be the basis for track utilization charges. In this study, the costs of infrastructure construction and maintenance on 5 route sections representing different traffic characteristics were studied by using records from 5 years. It was found that the maintenance cost of the telecommunication and signalling system ranges from 1.3 to 1.7 million baht per year per station. The average annual maintenance cost of the railway track was 280,000 to 310,000 baht per track per kilometre. The traffic density was found to be the main factor that influenced the maintenance cost.

1. Introduction

Rail transport has many advantages over other modes of transport, such as lower transport unit cost comparing to transport on roads, faster than transport on waterways, less environmental impact than air transport [1]. Currently, Thai government has put tremendous investment on improving the services and expanding the network of rail transport to gain competitiveness over other modes of transport [2]. In the future, utilization of the railway network at the full capacity will be needed to gain the worthiness from the government investment [3]. To allow for multiple operators sharing the railway infrastructure usage and finance, it is necessary to understand the cost components and factors that include in the construction and maintenance of infrastructure [4]. Costs incurred in the maintenance of infrastructure used in regional railways in Thailand have been carried by State Railway of Thailand (SRT). While the road transport mode has received the government budget for infrastructure maintenance [5].

There are differences in the agreement of infrastructure usage charge in each country. It depends on railway organization structure and the factors in consideration. Railway infrastructure charge should represent the actual cost carried by infrastructure managing authorities to make their financials viable. In addition, there should be an agency supervising the charges to ensure fairness amongst the infrastructure providers and users. Some example cases are presented as follows.
In France, the railway charge is calculated from the administration fee maintenance and railway rehabilitation costs. This fee is charged annually and the charge is split into 2 categories: freight and passenger transportation. However, the fee is only charge to the passengers [6].

In Spain, the railway charge cost is calculated annually like in France. And there is a separation of the fee with freight train and passenger train. But the source of the calculation is not clearly stated [6].

In Slovenia, railway charge depends on the total cost of track maintenance. It does not include profit. There is a designated public agency regulating and determining the infrastructure charge cost. It is calculated from the coefficient of train weight, track deterioration and the facility cost for traffic management service [6].

The main concept of infrastructure charge is to consider all costs involved that are close to reality and must be consistent with the current situation. The cost should be broken into category appropriately to keep in order and manageable [7].

There was a study of cost estimation using modelling prototypes that could be modelled for access cost estimation. The infrastructure access cost was calculated from the maintenance fee and management fee. The goal of the prototype was to find the relative relation of the cost to the resulting cost. Those mentioned factors affecting the cost of infrastructure provider can be used to calculate the access charge cost. The selection of some or all of the factors in order to calculate the cost to collect from the infrastructure users would depend on the measures and agreement of the organization [8,9].

The purposes of this study are to compile and analyse the cost of construction and maintenance of railway infrastructure. The infrastructure consists of railway, bridge, and signalling and telecommunication system. The factors that influence the costs will be included in this study.

2. Research methodology

In this study, the infrastructure cost was separated into two parts: construction cost of railway and signalling system; maintenance cost of railway and signalling system. The construction cost consisted of a new railway track and station. The railway was designed to carry 20-ton axle load. The railway track included bridges, embankment, substructure, and superstructure such as rails, sleepers fastening devices, ballast, switches, and additional components which provided safety such as guard rail and safety rail etc. [10]. The station was designed mainly for passengers. The signalling systems used to control the traffic was based on three-aspect wayside signalling system.

Railway maintenance cost comprised of monitoring and maintenance activities that occurred on the infrastructure so that all track components remained within the standard tolerance. Activities included track inspection, rail maintenance, track geometric maintenance, ballast sleeper and fastening maintenance, and emergency services.

This study determined the costs of railway infrastructure by investigating the actual costs of constructing and maintaining railway and signalling system including influencing factors. The construction cost and maintenance cost of five representative routes of State Railway of Thailand (SRT) were studied. The five routes covered passenger and freight traffic. They were selected from SRT railway network to cover various traffic density from low level to high level. The five routes were ballasted tracks with BS100 rails on mono-block concrete sleepers. They were under the same maintenance standard [11]. Based on data collected from SRT in the fiscal year of 2015, the average traffic density of train operation of SRT was 26 trains per day per track as shown in Figure 1. And the five routes were selected to represent various traffic density as shown in table 1.
Figure 1. Traffic density of SRT routes.

Table 1. The representative routes of the intercity railway used in this study.

| Route                                | Density (trains/day/track) | Traffic type  |
|--------------------------------------|----------------------------|---------------|
| Nong Pla Duk junction – Ratchaburi   | 38                         | Passenger     |
| Bua Yai junction – Khon Kean         | 41                         | Passenger & freight |
| Thonburi – Taling Chan junction      | 22                         | Passenger     |
| Nakhon Ratchasima – Bua Yai junction| 18                         | Passenger     |
| Lat Krabang – Laem Chabang           | 17                         | Passenger & freight |

3. Analysis and discussion

3.1. Construction cost

The construction costs of the five routes were obtained based on the past construction project document from SRT in 2009-2013. The average costs per kilometre of single track are shown in table 2. The brief details of each route are as follows.

Table 2. Construction cost of 5 intercity railway route.

| Route                                | Construction cost (million baht/km-track) | Percentage by components |
|--------------------------------------|------------------------------------------|--------------------------|
|                                      |                                          | Track and signalling     | Station | Bridge | Switch | Others |
| Nong Pla Duk junction - Ratchaburi   | 77.26                                    | 71%                      | 21%     | 5%     | 2%     | 1%     |
| Bua Yai junction - Khon Kean         | 72.39                                    | 76%                      | 11%     | 9%     | 1%     | 3%     |
| Thonburi - Taling Chan Junction      | 116.99                                   | 46%                      | 29%     | 12%    | 4%     | 9%     |
| Nakhon Ratchasima - Bua Yai junction| 68.00                                    | 81%                      | 13%     | 5%     | 1%     | <1%    |
| Lat Krabang - Laem Chabang           | 74.31                                    | 71%                      | 11%     | 16%    | 2%     | <1%    |

The construction costs varied due to different conditions. For examples, some routes had longer distance of bridges than other routes. It made the construction cost higher. Number and size of stations on some route were bigger than the others. By average, the construction cost of railway infrastructure was 72.9 million baht per kilometre per one track.

3.2. Maintenance cost of signaling system

The maintenance cost of signalling system was broken down according to the group of works, such as communication work, level crossing, traffic signalling and overhead. The overhead part included staff cost and overhead office costs. In each fiscal year, the costs were allocated differently depending on the needs and work priorities in that year. The maintenance costs for each route were as follows:
- Nong Pla Duk Junction - Ratchaburi in the range of 10,653,923 to 13,899,912 baht per year.
- Bua Yai Junction - Khon Kaen in the range of 11,985,669 to 15,637,401 baht per year.
- Thonburi - Taling Chan Junction in the range of 2,663,482 to 3,474,978 baht per year.
- Nakhon Ratchasima – Bua Yai Junction in the range of 15,980,892 to 20,849,868 baht per year.
- Lat Krabang - Laem Chabang in the range of 15,980,892 to 20,849,868 baht per year.

This research has presented the maintenance cost of signaling and telecommunication system per station, because most of maintenance and supervisory activities occur at the station [12]. Table 3 presents the average maintenance costs per station from 3 years.

Table 3. Signalling and telecommunication maintenance costs.

| Year | Signalling & telecommunication cost (million baht/year/station) | Percentage by components |
|------|---------------------------------------------------------------|--------------------------|
|      |                                                               | Overhead    | Level crossing | Signalling    | Communication |
| 2013 | 1.74                                                          | 24%         | 18%           | 48%           | 10%          |
| 2014 | 1.74                                                          | 28%         | 21%           | 41%           | 10%          |
| 2015 | 1.33                                                          | 39%         | 17%           | 31%           | 13%          |

3.3. Railway maintenance costs

Railway maintenance activities were conducted to keep the operation continuous safe and effective. The study found that the maintenance costs were varied year by year. It was found that in 2012, the cost of maintenance was lower than those of other years. In 2012, the State Railway of Thailand had lacked of liquidity so it was necessary to cut off some budgets. Therefore, in cost analysis some cost items of this year did not appear. The railway maintenance costs of five routes is shown in figure 2.

![Figure 2. Average railway maintenance costs of the five routes.](image)

The railway maintenance cost of SRT consisted of four main expenses: staff cost, contracting-out cost, material cost and miscellaneous cost. It was found that the staff cost was the largest portion. The details of maintenance costs are as follows. Nong Pla Duk Junction

- Ratchaburi has an average railway maintenance cost of 313,448 baht/ km per one track.
- Bua Yai Junction – Khon Kaen has an average railway maintenance cost of 318,330 baht/ km per one track.
- Thonburi – Taling Chan Junction has an average railway maintenance cost of 629,067 baht/ km per one track.
Nakhon Ratchasima – Bua Yai Junction has an average railway maintenance cost of 260,537 baht/ km per one track.

Lat Krabang – Laem Chabang has an average railway maintenance cost of 364,004 baht/ km per one track.

3.4. Factors affecting railway maintenance costs

In this study, there were three parameters that could be collected from the past data and were likely to have influences on railway maintenance cost [11]. Those three parameters were load tonnage, traffic density, and track quality index.

3.4.1. Load tonnage. Tonnage is a measure of the cargo-carrying capacity of the train. Tonnages on the five routes are shown in table 4.

3.4.2. Traffic density. According to the sensitivity of the railway system rises as the capacity utilisation increases in traffic demand [13]. It has been found that number of train density is one of all factor affects the cost of maintenance work. If one route is used more than other routes, the structural maintenance cost of that route is higher than other routes. Traffic density on the five routes are shown in table 4.

| Route                        | Load (tons/day/track) | Density (Train per day per one track) |
|------------------------------|-----------------------|---------------------------------------|
| Nong Pla Duk - Ratchaburi    | 29,440                | 38                                    |
| Bua Yai junction – Khon Kaen | 43,520                | 41                                    |
| Thonburi – Taling Chan Junction | 14,080            | 22                                    |
| Nakhon Ratchasima – Bua Yai junction | 16,640  | 18                                    |
| Lat Krabang – Laem Chabang   | 15,872                | 17                                    |

3.4.3. Track quality index (QI). SRT has surveyed geometry conditions of its railway track network by using track survey vehicles. At one sample point on a railway track section, five parameters are measured including track gauge, cross level, twist, longitudinal alignment, and vertical alignment. The measured data of sampling points in a given track segment distance is used to calculate QI [14, 15] QI is percentage of probability that a number of sampling points whose geometry parameter measurements fall outside ±3 mm to the mean value of all sampling points in a track segment. By definition, QI expresses the amount of track geometrical deviation from the allowance criteria. The larger the QI, the worse the track segment in some quality aspect. Table 5 illustrates a general guide for track condition used by SRT. SRT has planned the track maintenance works based on QI values obtained from track inspection once or twice a year.

| Level of track maintenance | QI (%) |
|----------------------------|--------|
| Immediate maintenance      | > 40   |
| Rapid improvement          | 31-40  |
| Poor                       | 21-30  |
| Good                       | 11-20  |
| Very Good                  | < 10   |

Figure 3 illustrates QI graphs of the five routes during 2009-2015. The graph shows that QI of Thonburi – Taling Chan route in 2011 is missing because the major flood in that year had obstructed the track survey. The route had been rehabilitated after the flood crisis. So, the QI value had returned to the acceptable level.
3.4.4. Results of statistical analysis. Since it was likely that railway maintenance cost was influenced by various factors, the multiple regression analysis was conducted using the data from 5 routes in 6 years. The railway maintenance cost on one considered year was the dependent variable. Traffic density, load tonnage, QI, and maintenance cost of previous year were assigned as the independent variables. The route number 2 to 5 and year 2010 to 2015 were added into the analysis as dummy variables to reduce the impact of variables that were not statistically analyzed. The results of the analysis is presented in Table 6 and 7.

![Figure 3. Chart of track quality of 5 routes in 2009 – 2015.](chart.png)

Table 6. Results of multiple regression analysis of railway maintenance cost and related variables.

|                      | Number of obs | F (8,3) | Prob>F | R-squared | Adj R-squared | Root MSE |
|----------------------|---------------|---------|--------|-----------|---------------|----------|
| QI current year      | 12            | 28.97   | 0.0093 | 0.9872    | 0.9531        | 12231    |
| Traffic Density      |               |         |        |           |               |          |
| Load                 |               |         |        |           |               |          |
| Dummy Route 2        | Omitted       |         |        |           |               |          |
| Dummy Route 3        | Omitted       |         |        |           |               |          |
| Dummy Route 4        | Omitted       |         |        |           |               |          |
| Dummy Route 5        | Omitted       |         |        |           |               |          |
| Dummy FY 2010        | Omitted       |         |        |           |               |          |
| Dummy FY 2011        | Omitted       |         |        |           |               |          |
| Dummy FY 2012        | -126531       | -11.04  | 0.0073 | -325.44   | 4086.50       |          |
| Dummy FY 2013        | -41919.2      | -0.99   | 0.397  | -177152.5 | 93314.1       |          |
| Dummy FY 2014        | 8732.53       | 0.63    | 0.574  | -35485.5  | 52950.6       |          |
| Dummy FY 2015        | 7328.27       | 0.39    | 0.723  | -52676.6  | 67333.1       |          |
| cons                 | 300679.       | 4.04    | 0.027  | 64073.5   | 537284.7      |          |
| Maintenance cost in previous year | -0.3963 | 0.3017 | -1.31  | 0.28      | -1.3566       | 0.5639   |

Table 7. Results of multiple regression analysis of railway maintenance cost and related variables.

| Railway maintenance cost | Coef. | std. Err | t    | P>|t|  | [95% conf. Interval] |
|--------------------------|-------|----------|------|------|----------------|---------------------|
| QI current year          | 1880.52 | 693.16   | 2.71 | 0.073 | -325.44 | 4086.50            |
| Traffic Density          | 4810.33 | 1302.07  | 3.09 | 0.054 | 666.56  | 8954.11            |
| Load                     | -2.779  | 0.974    | -2.85| 0.065 | -5.878  | 0.320              |
| Dummy Route 2            | Omitted |         |      |       |         |                    |
| Dummy Route 3            | Omitted |         |      |       |         |                    |
| Dummy Route 4            | Omitted |         |      |       |         |                    |
| Dummy Route 5            | Omitted |         |      |       |         |                    |
| Dummy FY 2010            | Omitted |         |      |       |         |                    |
| Dummy FY 2011            | Omitted |         |      |       |         |                    |
| Dummy FY 2012            | -126531 | 11457.48 | -11.04| 0.002 | -162994 | -90068.3           |
| Dummy FY 2013            | -41919.2 | 42493.51 | -0.99 | 0.397 | -177152.5 | 93314.1           |
| Dummy FY 2014            | 8732.53  | 13894.36 | 0.63 | 0.574 | -35485.5 | 52950.6           |
| Dummy FY 2015            | 7328.27  | 18854.9  | 0.39 | 0.723 | -52676.6 | 67333.1           |
| _cons                    | 300679.  | 74347.07 | 4.04 | 0.027 | 64073.5 | 537284.7          |

The result showed that the dummy variables of year 2010, year 2011 and the routes did not affect the analysis. Because those relative variables were omitted from the analysis. The result showed that the traffic density, QI, load tonnage and maintenance cost in previous year had some influences to the railway maintenance cost. Amongst the four independent variables, traffic density had the highest significance to railway maintenance cost. However, these four variables did not achieve at 95% significant level. And it was found that the maintenance cost in year 2012 was a dummy variable which was significantly different from other years. The constant of the regression model showed that the average railway maintenance cost per year per track was 300,679 baht per kilometer.
4. Conclusion
This study had investigated the costs of constructing and maintaining railway infrastructure in Thailand. Five railway routes connecting regional cities in Thailand were selected for this study. The past six-year records of maintenance costs were input into the statistical analysis. It was found that traffic density, track quality index, load tonnage and maintenance cost spent in previous year had some influences to the railway maintenance cost. The results from this study had revealed the average unit costs of railway construction, signalling system maintenance, and railway maintenance that should be useful for calculating railway infrastructure usage charge or infrastructure subsidy from the government in the future.
Lastly, the authors would like to mention on some limitation of this study. The infrastructure components comprised of railway track, bridges, civil works, signalling and telecommunication system that were constructed according to SRT standard and conditions in Thailand. Therefore, the unit costs presented may be largely different for other railway authorities or other countries.

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