Unit cost analysis for road construction sustainability: A case study of national road in West Java Province, Indonesia

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Abstract. Cost estimation of road construction is required at the early stages of a project used to describe the process of predicting a project’s cost before construction through the tender process. Unit cost for road construction has a different characteristic for each area, this is caused by the component that forms unit cost is different in each area, starting from the material, equipment to human resources. The unit cost of road construction is affected by several factors, such as project location, whereas the distance to the project location can affect the transportation cost of equipment and material, other than that there is an external cost for each road project. This study describes the variants of unit cost between the estimated cost and actual (contractual) cost, based on collected data for 62 awarded road construction projects during the last 3 years especially for major items of work in West Java Province. The result describes that cost under-estimates are more implemented than cost over-estimates in national road construction projects. The variances of unit cost can be used by the government as a reference for estimating the cost item because the high accuracy of unit cost is crucial for completing the road projects.

1. Introduction

Cost, schedule, and quality are three major components for construction project performance. Among these three measures, cost and schedule are objective and quantitative, while quality is somewhat subjective and qualitative [1]. Cost estimation of the road construction as the owner estimates are required at the early stages of a project used to predict a project’s cost before project construction through the tender process. Gould defined estimate as an appraisal, an opinion, or an approximation as to the cost of a project before its construction [2].

Unit cost is a calculation of cost items in one particular quantity and quality. Unit cost for road construction has a different characteristic for each area, variations are sometimes appropriate for clearing, excavation, hauling, or other unique situations [3]. This is caused by the component that forms unit cost is different in each area, starting from the material, equipment to human resources. Unit Cost consists of salary, material, and equipment including overhead and profit. Overhead and profit are set as 10% of total unit cost components.

Road preservation is a maintenance work in certain segments, to get uniformity so that the road can fulfil the standard requirements including pavement, shoulder, drainage, and other requirements. Keeping the pavements in good condition has always been a challenge for public agencies, the cost is assigned to keep pavement, shoulders, slopes, drainage facilities, and all other road property within the road margins as near as possible to their as-constructed or renewed condition [4].

Nowadays, road pavement maintenance and rehabilitation costs are rising dramatically [5]. For the road preservation work in Indonesia, the government or public authority has established one standard to use as a reference for any authorities in estimating the cost item for the road construction. Meanwhile,
estimation of unit cost for road maintenance is affected by several factors, such as project location, whereas the distance to the project location can affect the transportation cost of equipment and material, other than that there is an external cost for each road project, as this will cause variations in cost item in a province with the different project.

In Indonesia for road construction, the parties involved are government, consultant, and contractor. The role of government is as the project owner, and the estimation of the construction cost will be assigned to a third party (consultant). The cost estimation of road construction obtained by the consultant is then established by the government as the initial project cost (owner estimate) which is then continued to be included in a tender document. After the bidding process, then the contractor will do their job based on the price agreed in a contract document (contract price).

Recent work identified that there are still many problems in cost estimation at the conceptual stage of a project. High accuracy of cost estimation of highway projects at the conceptual phase of project is more crucial [6]. This study describes the variants of cost item of the road construction project as an owner estimation with the cost item agreed in the contract of preservation road and developed based on collected data for 62 awarded road construction projects during the last 3 years especially for major items of work in West Java Province. Motivated by the lack of comparable information on costs of road work activities across countries that could ultimately improve the reliability of new cost estimates and reduce the risks generated by cost overruns. The result of this research can be used by the government as a reference for estimating the cost item.

2. Data collection
This paper relates to the recent effort in collecting data on unit costs of different road constructions across West Java regions in Indonesia. The estimating technique requires an extensive historical database was started in 2016 until 2018, and obtain average and range unit costs based on major item.

The national road preservation divided projects into four categories, based on the type of work that was undertaken, as follows:

- Periodic maintenance of paved roads
- Rehabilitation of paved road
- Construction and upgrading of paved roads

2.1. Road preservation in west java province
West Java Province lies on the western side of Java Island with an area of + 35.377.76 km². The road construction and maintenance have become one of the factors to the increase of the construction sector towards the economy in West Java. The road length in West Java in 2018 was 21.883.28 km with total length of national road + 1,483 km. In the following figure, can be seen the road sections around West Java Province.

![Figure 1. National road sections in west java province.](image_url)
National road is an arterial and collector road in one primary road section that connects the capital of provinces and the center of national and international activities. The government through the Ministry of Public Work has a task to design, construction, and maintenance of road and bridge for West Java Province.

The data collection is done in 3 (three) working regions using historic data (2016-2018) consisting of 62 work contracts for national road maintenance, such as:

- Region 1 consists of 20 maintenance works including segments: Karawang – Cikampek – Pamanukan, Pamanukan – Sewo – Lohbener, Lohbener – Jatibarang – Palimanan and Lohbener – Indramayu – Cirebon – Losari.
- Region 2 consists of 25 maintenance works including segments: Benda – Cibadak – Sukabumi – Cianjur, Nagreg – Tasikmalaya – Ciamis and Kalapagenep – Cimerak – Pangandaran – Banjar – Ciamis, Tegalbuleud – Agrabinta – Sindangbarang – Cidaun.
- Region 3 consists of 17 maintenance works including segments Cikampek – Purwakarta – Padalarang and Bandung – Cileunyi – Sumedang – Nagreg.

2.2. Major item

A work item is the smallest unit of the project that can be affected by any given constraint or dependency. The number and granularity are dependent on the size, complexity, and number of responsible parties involved in the project. They are distinct parts of the scope of work and in their sum represent the final result of the project. Major items an important element in the project represent a major expense in road construction [7].

Based on the data obtained, a weighting is then conducted to get the main work item, by calculating it based on the total percentage of every item from the total price. The major item is work items that have weights of until 80% of the total price, including:

- Asphalt for minor work
- Aggregate S class
- Binder coarse (AC-BC)
- Wearing coarse (AC-WC)
- Concrete fc’ 30 Mpa

Cost item of each major item can be seen in the following table:

| Major item                         | Owner estimate | Unit | Region 1 | Region 2 | Region 3 |
|------------------------------------|----------------|------|----------|----------|----------|
|                                    |                |      | Min      | Max      | Min      | Max      |
|                                    |                |      | 2016     |          |          |          |
| Aggregate S class                  | 428,407        | M³   | 256,300  | 352,352  | 256,828  | 359,565  |
| Hot asphalt mixture                | 2,789,000      | M³   | 2,406,290| 3,064,601| 2,520,500| 2,950,492|
| Binder coarse (AC-BC)              | 1,270,746      | Ton  | 1,266,800| 1,327,996| 1,083,028| 1,185,431|
| Concrete asphalt (AC-WC)           | 1,379,081      | Ton  | 1,295,800| 1,405,400| 1,072,297| 1,254,859|
| Concrete, fc’ 30 Mpa               | 1,748,132      | M³   | 1,436,200| 1,538,000| 1,237,900| 1,437,900|
|                                    |                |      | 2017     |          |          |          |
| Aggregate S class                  | 452,194        | M³   | 300,000  | 347,000  | 370,731  | 461,493  |
| Hot asphalt mixture                | 2,988,000      | M³   | 2,372,000| 3,344,041| 2,444,734| 2,781,375|
| Binder coarse (AC-BC)              | 1,344,807      | Ton  | 1,270,000| 1,310,188| 1,085,890| 1,368,751|

Table 1. The unit cost of major items.
Major item Owner estimate Unit Contract price

| Major item | Owner estimate | Unit | Region 1 | Region 2 | Region 3 |
|------------|----------------|------|----------|----------|----------|
|            |                |      | Min      | Max      | Min      | Max      |
| Concrete asphalt (AC-WC) | 1,381,481 | Ton | 1,280,000 | 1,379,481 | 1,124,746 | 1,228,240 |
| Concrete, fc’ 30 Mpa | 1,796,456 | M³ | 1,733,562 | 1,748,132 | 1,615,617 | 1,865,727 |

| Major item | Owner estimate | Unit | Region 1 | Region 2 | Region 3 |
|------------|----------------|------|----------|----------|----------|
|            |                |      | Min      | Max      | Min      | Max      |
| Aggregate S class | 520,400 | M³ | 325,000 | 473,966 | 288,682 | 462,400 |
| Hot asphalt mixture | 2,995,800 | M³ | 2,500,000 | 2,993,361 | 2,434,755 | 2,723,430 |
| Binder coarse (AC-BC) | 1,388,412 | Ton | 1,200,000 | 1,380,490 | 1,015,800 | 1,290,394 |
| Concrete asphalt (AC-WC) | 1,446,818 | Ton | 1,289,000 | 1,479,481 | 1,046,000 | 1,290,394 |
| Concrete, fc’ 30 Mpa | 1,968,456 | M³ | 1,743,562 | 1,798,132 | 1,710,945 | 2,097,998 |

The disparities of unit price among the region described show that cost under-estimates are more common than cost over-estimates in road construction projects implemented.

Monitoring Project time is one of the many challenges for project participants. Time monitoring seeks to assess how well the project adheres to the planned schedule over the duration project’s time [8]. For the parametric analysis, it needs duration total from major item and duration of the contract of maintenance work in West Java Province, such as seen in the following table:

### Table 2. Duration of major items.

| No. | Major item | Segment | Duration (day) | Contract's duration (day) |
|-----|------------|---------|----------------|--------------------------|
| 1   | Wearing course (AC-WC) | Lohbener - Indramayu - Cirebon - Losari | 50 | 345 |
| 2   | Binder course (AC-BC) | Lohbener - Indramayu - Cirebon - Losari | 18 | 345 |
| 3   | Binder course (AC-BC(L)) | Lohbener - Indramayu - Cirebon - Losari | 24 | 345 |
| 4   | Asphalt for Minor Work | Lohbener - Indramayu - Cirebon - Losari | 1 | 345 |
| 5   | Aggregate S Class | Lohbener - Indramayu - Cirebon - Losari | 3 | 345 |
| 7   | Concrete fc’20 MPa | Lohbener - Indramayu - Cirebon - Losari | 2 | 345 |
| 8   | Wearing course (AC-WC) | Bandung - Cileunyi - Sumedang - Nagreg | 9 | 300 |
| 9   | Binder course (AC-BC(L)) | Bandung - Cileunyi - Sumedang - Nagreg | 16 | 300 |
| 10  | Asphalt for minor Work | Bandung - Cileunyi - Sumedang - Nagreg | 2 | 300 |
| 11  | Aggregate S class | Bandung - Cileunyi - Sumedang - Nagreg | 2 | 300 |
| 13  | Wearing course (AC-WC) | Nagreg - Tasikmalaya - Ciamis | 12 | 334 |
| 14  | Binder course (AC-BC) | Nagreg - Tasikmalaya - Ciamis | 7 | 334 |
| 15  | Binder course (AC-BC(L)) | Nagreg - Tasikmalaya - Ciamis | 6 | 334 |
| 16  | Asphalt for minor work | Nagreg - Tasikmalaya - Ciamis | 2 | 334 |
| 17  | Aggregate S class | Nagreg - Tasikmalaya - Ciamis | 2 | 334 |
3. Analysis and discussion

3.1. Variations of cost item

According to table 1, it shows that the big difference is between the minimum and maximum value with 27% - 41% for asphalt for the minor work item. The difference of unit price value in contract with owner estimate is +38-45% for foundation aggregate S class and +33% for hot asphalt mixture item. There is also contract value that is bigger that the owner estimate (+12%).

The difference in a contract is identified caused by the distance of the project location that is far away from Quarry or Asphalt Mixing Plant (AMP). Other than that, it is caused by the price escalation, whereas the distance and time that takes a long process in compiling the owner estimate with the auction of the particular work (6 – 12 months).

3.2. Hypothesis on the effect of major item towards the total duration of work

Road contractor’s performance problem appears in many aspects in developing countries. Many road projects fail in time performance and others fail in cost performance [9]. On this paper, a hypothesis test is conducted to see the effect of the duration of major items towards all road maintenance work. The analysis is done in 30 road maintenance work in West Java Province. The duration of major items is obtained from the capacity of production instrumentation. There total duration of major items can be seen in the following table.

Table 3. Total duration of major item and contract.

| No. | Package name                  | Duration of major item (day) | Duration of work (day) |
|-----|-------------------------------|------------------------------|------------------------|
| 1   | Lohbener - Indramayu - Cirebon - Losari | 212                          | 345                    |
| 2   | Bandung - Cileunyi - Sumedang - Nagreg | 63                           | 300                    |
| 3   | Nagreg - Tasikmalaya - Ciamis     | 136                          | 334                    |
| 4   | Cikampek - Purwakarta – Padalarang | 71                           | 300                    |
| 5   | Lohbener - Jatibarang - Palimanan | 141                          | 180                    |

In this research, both groups’ data have an equivalent of variance so that the value of the Independent T-Test is read as Equal variance. The formula from the Independent T-test with the homogeneity variance is as follows:

\[ F = \frac{S_1^2}{S_2^2} \] (1)

Where:
- \( F \) = The calculated F value
- \( S_1 \) = The greatest variance value
- \( S_2 \) = The smallest variance value
The data is stated to have an equal variance when $F_{\text{Calculated}} < F_{\text{Table}}$, and the data variances is stated to be unequal variance when $F_{\text{Calculated}} > F_{\text{Table}}$.

T-Test for an equal variance uses the manual formula of Polled Variances:

$$t = \frac{X_1 - X_2}{\sqrt{\frac{(n_1-1)S_1^2 + (n_2-1)S_2^2}{n_1 + n_2 - 2} \left( \frac{1}{n_1} + \frac{1}{n_2} \right)}}$$

(2)

Where:
- $n_1$ = total of sample 1
- $n_2$ = total of sample 2
- $X_1$ = average value of the first sample
- $X_2$ = average value of the second sample
- $S_1$ = the first sample variance
- $S_2$ = the second sample variance

According to the data, the t-test is then taken place with condition $H_0$: no effects of duration of major item towards the total duration of work and $H_a$: there is an effect of duration of major item towards the total duration of work.

| Variable | Variable 1 | Variable 2 |
|---------|------------|------------|
| Mean    | 124.6600295 | 291.8 |
| Variance | 3666.550133 | 4311.2 |
| Observations | 5 | 5 |
| Pooled Variance | 3988.875067 | |
| Hypothesized Mean Difference | 0 | |
| Df | 8 | - |
| t Stat | 4.184322101 | |
| P(T<=t) one-tail | 0.001530726 | |
| t Critical one-tail | 1.859548038 | |
| P(T<=t) two-tail | 0.003061451 | |
| t Critical two-tail | 2.306004135 | |

The T-test shows that $t_{\text{calculated}} > t_{\text{table}}$ ($2.3060 > 4.18432$) meaning $H_0$ is rejected and $H_a$ is accepted. It means there is an effect of major items towards the total duration of work. $P$ value < 0.05 ($\alpha = 5\%$), this shows a significant effect.

4. Conclusion

This study has investigated the statistical relationship between the actual and estimated cost of road construction projects using data from West Java road construction projects awarded over the years 2016 to 2018. The study was based on a sample of 62 road construction projects, especially for major items. The results show that cost under-estimates are more common than cost over-estimates in national road construction projects.

Use the average cost for estimation whenever possible in initial stages unless there are significant variations in a region. Adjustments will be made as needed but average costs are associated with construction and reconstruction activities and is not intended for maintenance activities. Estimators should make appropriate adjustments for maintenance activities. Cost estimation of road projects with
high accuracy is crucial, especially for the project locations that is far away from the quarry or asphalt mixing plant (AMP).

Asphalt mixture and aggregate S class work item are the work item with the biggest deviation. The difference in unit price value is affected by the material price difference. The increase on the material price is affected by the distance of AMP to the project location, with additional unit price value that is constant for each 10 km, affected by the increase of fuel for the process of delivery. In other hand the cost escalation of construction projects caused by a lag time of construction period is an important area to be taken care of in the present scenario.

From the parametric comparison, it needed to ensure that major item prior to beginning for road preservation project. Duration of the major item had a significant effect to completion the work project. The accuracy of cost estimates and the duration of work estimate can affect the success or failure of a construction project.

Minimization the gap of the construction cost overrun by reducing delays of the project execution, developing good communication between construction parties and good decision making at the right time. Unit cost estimate should be considered the distance of the project site and asphalt mixing plant.

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