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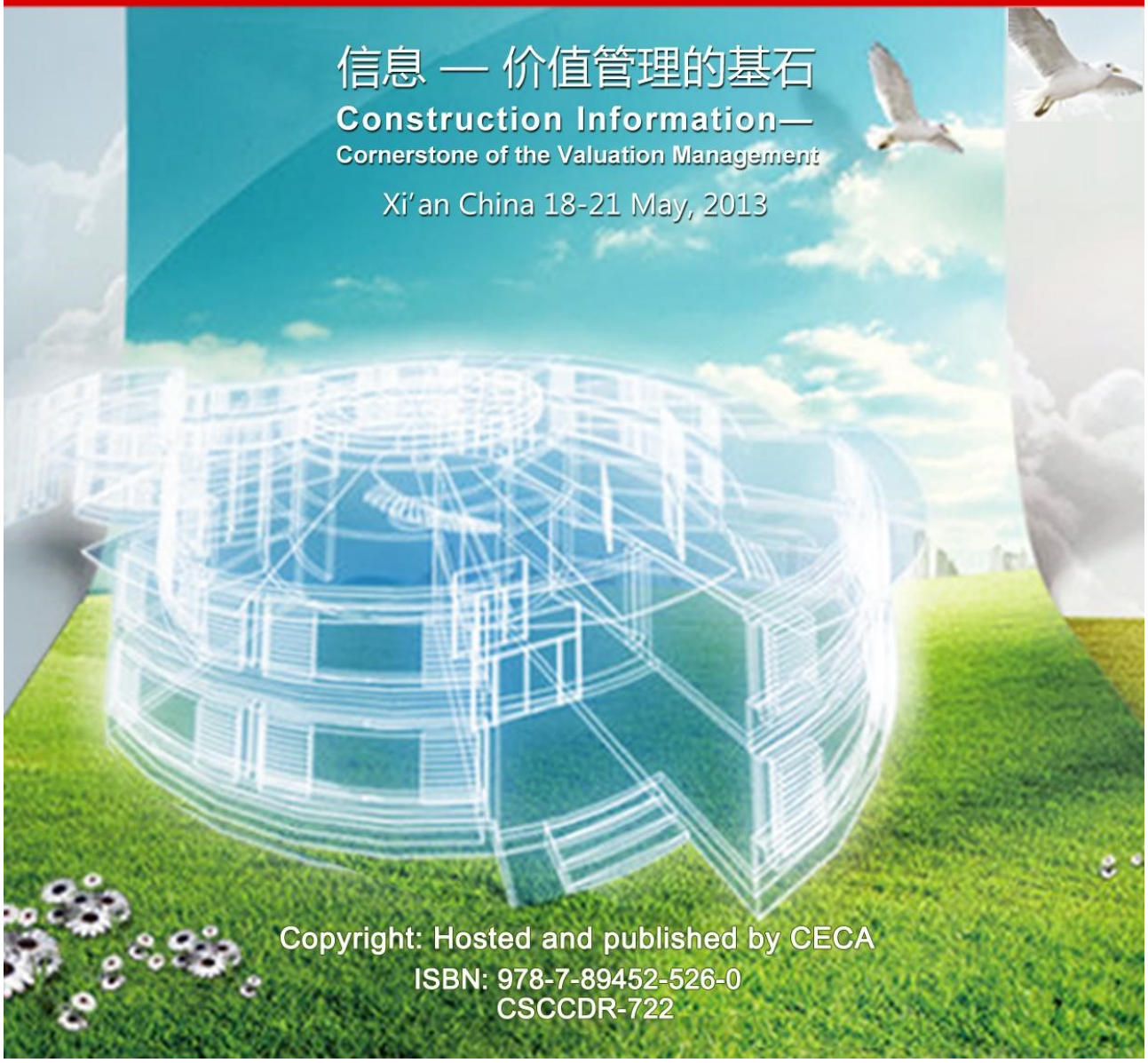

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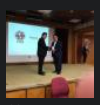
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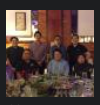
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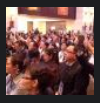
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COST INDEX MODEL FOR BRIDGE CONSTRUCTION IN INDONESIA

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ABSTRACT

In Indonesia, reliable cost estimating methods for the preliminary phase of construction project are not developed adequately; nevertheless, the one for bridge construction. However, the need to have a conceptual estimating method for bridges and other infrastructure is increasing since the Indonesian government is planning to speed up the economic development by providing infrastructures as the first important step. This research tried to develop two models of cost indices that can be used to estimate the cost of bridge construction in the preliminary phase for budgeting purposes. The first cost index model is developed based on cost per square meter of the bridge. Moreover, in the second model, the research tried to find the more accurate method in estimating the cost of bridge construction by breaking down further the bridge cost structure into bridge physical components: i.e., sub structure, upper structure, and approaches. The analysis was conducted to validate the model by comparing the estimates made by the models to the ones calculated by the use of the consumer price index and the construction cost index. The developed models in this research proposed improvement in accuracy of estimation for bridge construction cost.

Keywords: bridge construction, conceptual estimate, cost index, preliminary stage

BACKGROUND

Robust and reliable estimating methods for preliminary phase of construction project are not adequately considered in Indonesia. The practice has been considered lagging compared to the detail estimation. This is also true for estimating bridge construction. However, the need to have a conceptual estimating method for bridges and other infrastructure is increasing since the Indonesian government is planning to speed up the economic development by providing infrastructures as the first important step.

Bridges plays important role in Indonesian economic development. The development of bridge construction in Indonesia has been flourished with the use of steel truss, composite girders, and segmental pre-stressed concrete beams technologies. Most of the bridges, about 88,000 bridges all over Indonesia, are crossing small and narrow streams or rivers. Only 2% of the bridges that have length of span over 100 meters. It showed that the Indonesia government needs short span standardized type of bridges more than the longest ones for the purpose of economic development.

As the need to build bridges increases, the Indonesian government is also challenged to improve its efficiency in providing the infrastructure through a robust budgeting system. In this case, the government needs a method to estimate the cost of construction in a preliminary stage of construction project. By doing so, the government can secure the budget for construction efficiently. Yet the practices of conceptual estimating are rarely implemented by the government, nonetheless for bridges construction.

It is common practice in Indonesia, in the preliminary phase of a construction project, cost engineers use inflation value or consumer price index in estimating the cost of construction project based on the cost of similar project that were previously commented. This technique seems to be a logic approach since in the preliminary stage of a construction project the cost estimation is not expected to be a very accurate one. Nevertheless, more accurate and proper estimation in a preliminary phase of construction project is needed as important information to the owner's decision making process. Since the inflation or consumer price index reflects the average changes in prices of consumed goods and services over the time, the use of these indices for construction cost estimation will lead to inaccurate and improper estimation.

The use of cost index is a conceptual cost estimation method besides cost parameter, location index capacity factor, and component ratio methods. A cost index is a dimensionless number that is used to adjust the cost of an item in a different period of time. The adjustment is necessary because of the changing value of money in time (Black and Jelen, 1983). It is advisable not to waste the time in estimating for budgeting purposes for a known type of construction since the cost is easily developed by using cost index (Dubois, 1980).

In this research, two bridge construction cost indices were developed by using input index method. The input index measures the price change of bridge construction cost items, such as labor, material and equipment. However, this method ignores such factors as productivity, market conditions, profit levels and technological changes. Yet, it is still a robust method available for a preliminary stage of bridge construction project and it can be quickly and easily compiled and, therefore, it can be publicized more frequently (Dubois, 1980). The accuracy range of conceptual cost estimation is expected to be -30 to +50% (Black and Jelen, 1983) and for cost index, its accuracy is expected from +/- 20 – 30% (Osgood, 2005).

OBJECTIVES AND METHODS

This research was aimed to develop models of two cost indices that can be used to estimate the cost of bridge construction in the preliminary phase for budgeting purposes. The first cost index is calculated based on cost per square meter of the bridge. The second model is developed in the assumption that the estimation would be more accurate if the cost index is calculated by breaking down further the bridge structure into its components: i.e., sub-structure, upper-structure, and approaches. The comparison of the two types of bridge construction cost indices will be done and also will be compared to other estimations using the consumer price index (CPI), which is issued by the Indonesian Statistics, and the construction cost index (CCI), which is issued by local governments.

Steps of the research are started with data collection. Types of data that are needed to be collected are:

- Bridge construction contract values and their detailed cost estimations. For some projects contract data were available including drawings and specifications. The collected contract data were only limited for bridge with the length between 10 to 60 meters, in North Sumatra and East Borneo regions. Thirty seven contract documents of bridge construction projects were collected from the local governments.
- Yearly construction materials and labors prices (2006 to 2010). This data are taken from *Journal of Building Construction and Interior Material Prices* (Journal) and *Public Works Department's Unit Price Analysis* (DUPA). Both are widely used in Indonesian construction project.
- Consumer price index and construction cost index provided by the central and local governments.

The following step is to develop a bridge construction price database. This database is developed to make data processing easier. For each bridge construction project, its unit price analysis for each work item are identified and inputted into the database. The bridge construction cost structure is also broken down into its physical components, i.e., sub-structure, upper-structure, and approaches, and into its cost components, i.e., materials, labor, and equipment.

The most important step in this research is to identify the most dominant cost components that will build the cost index model. The dominant cost components are cost components that have biggest contribution of cost to the total cost. For each bridge construction cost data, each cost component is then sorted decently according to its cost percentage to the total cost. Afterward, the identification of dominant cost component could be done by accumulating the sorted cost percentage value of the cost components that contribute up to 80% of the total cost of the bridge. By knowing the dominant cost components, the following important step is to quantify the weighted quantity of each cost component. This is conducted based on the quantity of each cost component per m^2 of the bridge. The model that consists of quantity of each dominant cost component could be then used to develop the indices.

THE MODEL

The general indexing equation that is used for the model in this research is as follow (Wijiastuti and Abduh, 2006):

$$I_{t,0} = \frac{C^t}{C^0} \times 100 = \frac{\sum_{i=1}^{n} \left(c_i^t \times q_i \right)}{\sum_{i=1}^{n} \left(c_i^{\,0} \times q_i \right)} \times 100 \qquad \textit{(Eq. 1)}$$

Where: $I_{t,0}$: cost index of period t;
C^t : cost at period t;
C^0 : cost at base period;
q_i : weighted quantity of dominant cost component *i*;
c_i^t : price of dominant cost component *i* at period t; and
c_i^0 : price of dominant cost component *i* at base period.

From Eq. 1, it can be seen that to build a bridge construction cost index, the variables are:

1. Dominant cost components, i.e., materials and/or labor that represent the components of the bridge.
2. Quantity of each dominant cost component.
3. Price of each dominant cost component in a particular period and at the base period.

There are two models developed in this research; the first one is called the overall bridge construction cost index (IOBC) and the second one is called the partial bridge construction cost index (IPBC). The first model is when the Eq. 1 is used to calculate the index based on the unit cost of the bridge in square meters with the dominant cost components derived from total components of the bridge. Meanwhile, the second model used the Eq. 1 to calculate the index based on the unit cost of the bridge in square meters with the dominant cost components came from partial parts of the bridge, i.e., sub structure, upper structure, and approaches. Therefore, there are 3 indices of IPBC, i.e., IPBC1 for sub structure, IPBC2 for upper structure, and IPBC3 for approaches.

Based on 37 data collected in two locations, the developed overall cost indices for bridge construction are tabulated as follow (with year of 2006 determined as the base year):

Table 1. Overall Bridge Construction Indices (IOBC), 2006 – 2010 (Octavia, 2011)

Year	Steel Bridge	Concrete Bridge
2006	100,00	100,00
2007	106,31	102,66
2008	115,09	106,44
2009	134,83	114,05
2010	126,12	114,72

Base Year: 2006 = 100

The calculation to estimate the construction cost of a bridge in a particular period (C_2), given that there is a known construction cost of a bridge in a given period (C_2) by using IOBC, can be formulated as:

$$C_2 = C_1 \frac{IOBC_2}{IOBC_1} \qquad \textit{(Eq. 2)}$$

Whilst, based on the collected data as used in the first model, the developed partial cost indices for bridge construction are tabulated as follow (with year of 2006 determined as the base year):

Table 2. Partial Bridge Construction Indices (IPBC), 2006 – 2010 (Octavia, 2011)

Year	Steel Bridge			Concrete Bridge		
	IPBC1	IPBC2	IPBC3	IPBC1	IPBC2	IPBC3
2006	100.00	100.00	100.00	100.00	100.00	100.00
2007	102.34	102.27	100.78	102.52	102.78	102.50
2008	109.61	107.55	104.36	110.78	103.94	108.47
2009	119.61	120.57	118.43	109.25	117.00	121.79
2010	138.75	139.22	130.93	119.72	131.11	133.07

Base Year: 2006 = 100

Moreover, to calculate the construction cost estimate of a bridge in a particular period (C_2), given that there is a known construction cost of a bridge in a given period (C_2) by using IPBC, is formulated as follow:

$$C_2 = C_{2Su} + C_{2Up} + C_{2Ap} \qquad \textit{(Eq. 3)}$$

Or:

$$C_2 = C_{1Su}\frac{IPBC1_2}{IPBC1_1} + C_{1Up}\frac{IPBC2_2}{IPBC2_1} + C_{1Ap}\frac{IPBC3_2}{IPBC3_1}) \qquad \textit{(Eq. 4)}$$

Where: C_{iSu} : cost of sub structure in period of *i*;
C_{iUp} : cost of upper structure in period of *i*; and
C_{iAp} : cost of approaches in period of *i*.

MODEL VALIDATION

The developed indices are validated by measuring their accuracies in estimating given bridge construction projects' data in year of 2008 to 2010 using Eq. 2 and Eq. 4. The estimation results are then compared to the cost estimates made by the use of the consumer price indices (CPI) and the construction cost index (CCI), which are commonly used by the government. The comparison result of steel bridge is shown in Figure 1, while concrete bridge is depicted in Figure 2. The CPI and CCI values for 2006 to 2010 are depicted in Table 3.

Table 3. CPI and CCI used as Comparison (Octavia, 2011)

Year	PCI	CCI
2006	100.00	100.00
2007	106.60	100.27
2008	118.03	104.29
2009	107.32	115.84
2010	130.81	110.65

Base Year: 2006 = 100

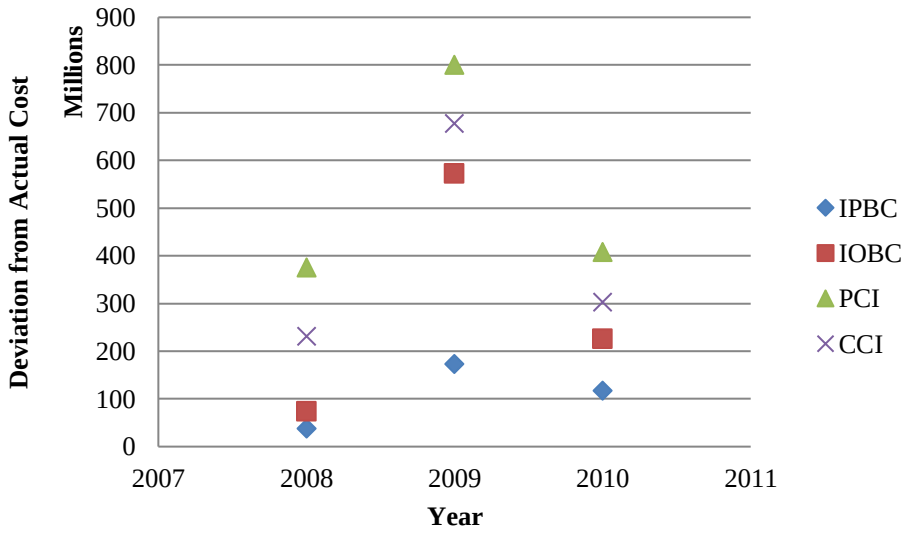

Figure 1. Comparison of Estimated Steel Bridge Construction Cost

It can be concluded from the above figure, for steel bridge, the use of IPBC in estimating the cost of bridge construction create more accurate result compared to the estimates made by the use of IOBC, CCI and PCI. The deviation made by IPBC lies between -2.52% to 0.65%.

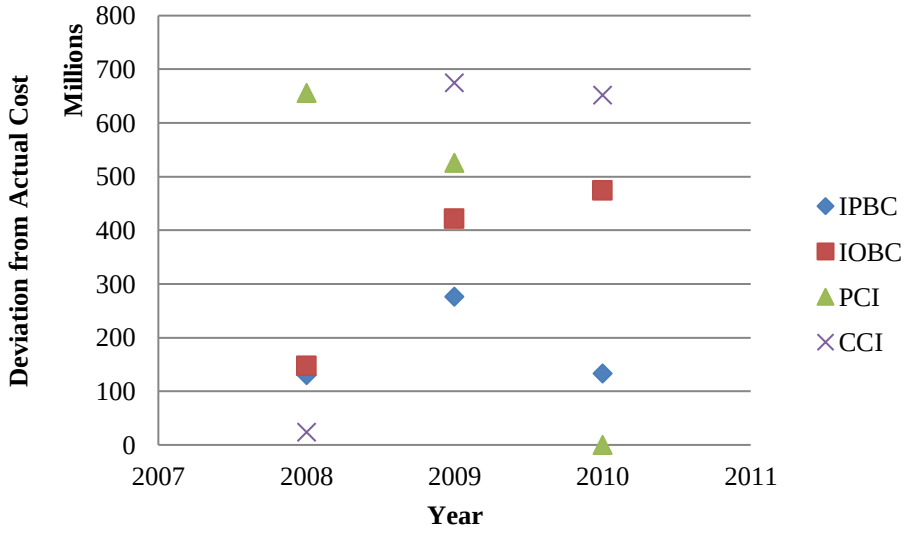

Figure 2. Comparison of Estimated Concrete Bridge Construction Cost

Again, from Figure 2, it can be concluded that, for concrete bridge, the use of IPBC in more accurate for conceptual estimate compared to the estimates made by the use of IOBC, CCI and PCI. The deviation made by IPBC lies between -4.71% to 1.55%.

DISCUSSIONS

As far as the research results found, the use of cost index is considered as one robust method available to estimate bridge construction cost in its preliminary stage. The robustness of this method comes from the use of model that depends on the quantity of dominant cost components. The more relevant the cost components to represent the type of construction, the more accurate the cost estimate.

The use of PCI as the index for estimating should not be used anymore for estimating construction cost in its preliminary stage, since the cost components associated with the CPI are not relevant to construction, neither to bridge construction. Meanwhile, the CCI, that is developed to be used for construction, seems still not really relevant either to the bridge construction. This is due to the cost components used in the model of calculating the CCI index are coming from many types of construction, not only bridge construction.

The assumption made at the beginning of the research that more detail the estimation model, more accurate the result of estimation. This is shown by comparing the accuracy of IOBC and IPBC. By breaking down further the bridge into its physical components, i.e., sub structure, upper structure, and approaches, the estimation using IPBC is more accurate compared to the one that uses IOBC. Nevertheless, the available information to estimate bridge construction cost in its preliminary stage using IOBC should be more detailed and, therefore, the current practice of estimation should be directed to accommodate the recording of more detail cost of bridge construction into its physical components.

It is advisable from this research that the Indonesian government to start developing cost indices for various types of construction for the government budgeting purposes. Alternatively, the developed models could be used widely by other Indonesian regions, for estimating cost of bridge construction, considering the models are used for preliminary stage of project which does not required very accurate estimation.

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PROFILE OF SPEAKERS

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He is an associate professor in the Faculty of Civil and Environmental Engineering, Institut Teknologi Bandung, Indonesia. He has been very active in conducting research in the field of construction engineering and management, especially in the fields of construction supply chains, construction operations, lean construction, simulation and information technology applications in construction and infrastructure management. He got his Ph.D. in the year 2000 from Purdue University, USA. He had served more than 10 years in developing procurement system in the university, and in charge as the director for several years. Now, he is serving as the head of the Construction Engineering and Management Laboratory at ITB.