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Cost Normalization Procedure for Phase-Based Performance Measurement

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***Abstract:** Capital project benchmarking requires an effective cost normalization process to compare cost performance of projects accomplished in different time and location. Existing cost normalization approaches have been established based on the assumption that all required information for cost normalization is fully identified once a project is completed. Cost normalization, however, is sometimes required to evaluate phase-level outcomes of an ongoing project where the required information is not fully available. This paper aims to provide a cost normalization procedure for phase-based performance assessment. The procedure consists of three normalization steps: currency conversion, location adjustment, and time adjustment considering various scenarios where the required information is not fully identified. This paper also presents how the cost normalization procedure has been applied to the 10-10 Performance Assessment Program, which is a phase-based performance assessment system developed by the Construction Industry Institute (CII). Both researchers and industrial professionals can apply the cost normalization procedure to studies and practices regarding to cost estimation, feasibility analysis, and performance assessment.*

***Keywords:** Cost Normalization, Phase-Based Benchmarking, Absolute Cost Metrics, and Construction Cost Index (CCI)*

I. INTRODUCTION

The Construction Industry Institute (CII) has been operating comprehensive programs to benchmark the performance of capital projects since 1995. The number of projects surpassed 2,820 projects in its database, exceeding over $ 424 billion of cumulative capital project investment as of 2014. Recently, CII worked with industry experts and academic researchers to develop a new phase-based benchmarking program, known as the 10-10 Program. It was designed to assess each of the five phases for a single project (CII 2013; Kang et al. 2014; Choi et al. 2015). The program is getting increasing attention from the industry with recognition of its diagnostic capability conducive to identify the impending problems of projects and to benefit subsequent phases of a project (Choi et al. 2015). Several phase-specific absolute metrics were adopted in the 10-10 Program.

Relative metrics (e.g., cost and schedule growth) compare actual performance to planned performance by measuring the extent at which the project is delivered as expected (Dai et al., 2012). On the other hand, absolute metrics measure actual cost to other measures such as physical dimension or capacity, duration, or team size. The absolute metrics require an appropriate data normalization process to obtain reasonable benchmarks (Hwang et al. 2008).

This paper focuses on a procedure applicable to the normalization of cost data to assess cost performance through absolute metrics. The cost normalization is necessary to allow reasonable comparisons of projects from different location and time (Dai et al. 2012; Hwang et al. 2008, 2010). The existing method applied by CII to normalize cost data in pharmaceutical / biotechnology and health care benchmarking programs is based on the assumption that all necessary information is available once the project is complete (Hwang et al. 2008). Therefore, the existing method is not applicable to the 10-10 Program which assesses project performance by phase. Since there is no previous research to date addressing a cost normalization method suitable to phase-based performance assessment, CII developed a new approach which is described in this paper.

This paper suggests a cost normalization procedure that is tailored to the 10-10 Program. To achieve this objective, a close review on existing cost normalization approaches is conducted. Additionally, case studies are used to demonstrate the procedure and critical issues associated with the developed procedure are then discussed.

II. LITERATURE REVIEW

The integral part of any cost normalization procedure is to use cost indices appropriately. Cost indices are used to predict an estimated cost at the required location and time reference based on a known cost at a certain location and time reference (Diekmann 1983; McCabe et al. 2002; Remer et al. 2008). Some indices track changes in cost over time, and some address the difference in cost with regard to location (e.g., city, state, or country) while others track both factors (Dai et al. 2012).

For cost normalization purposes, CII has been using

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three cost indices (Dai et al. 2012, Hwang et al 2008); (1) R.S. Means City Cost Index (RSMCCI), (2) Hanscomb Means International Construction Cost Index (HMICCI), and (3) R.S. Means Historical Index (RSMHI). They not only have been used in CII with success but also CII member companies have been using them for internal benchmarking and cost estimating (Hwang et al. 2008).

The RSMCCI contains over 900 cities' cost factors in the U.S. and Canada (McCabe et al. 2002), published annually (Dai et al. 2012). The index provides local multipliers representing relative construction factors for total cost for each CSI MasterFormat division (McCabe 2002). The HMICCI publishes 32 countries' cost factors by one city from one country (Dai et al. 2012), and is published biannually in the newsletter called "International Construction Intelligence" (Wiggins 2013). Considering types of locations contained in two indices, RSMCCI has been used for location adjustment for U.S. and Canada-based projects while HMICCI has been used for global projects built in the other countries (Hwang et al. 2008). The RSMHI addresses inflation and escalation, and provides the trend of construction costs with the national average reflecting 30 major cities' average in the U.S. (Dai et al. 2012).

The existing CII's method adopted in pharmaceutical / biotechnology involves three main steps using the three cost indices discussed above (Hwang et al. 2008; Dai et al. 2012); (1) currency conversion, (2) location adjustment, and (3) time adjustment. The currency conversion is to obtain project costs in the U.S. Dollars in case that local currency was used for project cost. The project location is then adjusted using HMICCI and RSMCCI. Subsequently, project costs adjusted to a reference city are converted to those in the latest index year using RSMHI for Chicago (Hwang et al. 2008; Dai et al. 2012). Finally, all project costs are normalized to the common (or reference) location and time.

III. OVERVIEW OF CII 10-10 PROGRAM

The objective of this paper is to introduce a new cost normalization procedure applicable to the 10-10 Program. 10-10 stands for 10 input measures and 10 out measures, and it assesses projects at the conclusion of each of five phases (Choi et al. 2015). There are three sets of questionnaires, one per each industry sector; industrial, building, and infrastructure totalling 15 questionnaires. The five phases of industrial and infrastructure projects are front-end planning, engineering, procurement, construction, and start-up. In building project, these phases are named differently; programming, design, procurement, construction, and commissioning.

Each questionnaire consists of three sections. The first section collects general project information (e.g., project location, nature, and delivery method). The second and third sections collect data for the input measures and output measures, respectively (Kang et al. 2014). Input measures are to generate 10 scores representing 10 leading indicators (Choi et al. 2015). On the other hand, 10 output measures are to assess whether the project is proceeding on target (Kang et al. 2014). The 10 output measures evaluate the project performance in terms of cost, schedule, team size, safety, and capacity. Examples of absolute cost metrics are project cost efficiency (total project cost per building gross square footage) and phase cost efficiency (phase cost per building gross square footage).

To measure absolute cost metrics, two types of cost data are collected in the output measure section of the questionnaires, which are phase-level costs (e.g., actual phase cost and total cost of major equipment) and project-level costs (e.g., forecasted or actual total project cost). It is noteworthy that the cost data collected varies by phase as shown in Table 1.

TABLE 1
COST DATA COLLECTED BY PHASE

Cost data	FEP	ENG	PRO	CON	STA
Actual phase cost	√	√		√	√
Total cost of major equipment			√		
Forecasted total project cost	√	√	√	√	
Actual total project cost					√

* FEP, ENG, PRO, CON, and STA stand for front-end planning, engineering, procurement, construction, and startup phases, respectively.

Critical issues were identified when the existing CII's method of cost normalization process was applied to the 10-10 cost data. The existing method is based on the assumption that all required information is fully identified at project close-out. Contrarily, the 10-10 Program measures phase specific performance of an ongoing project, which indicates the availability of cost data differs by phase as can be seen in Table 1. Accordingly, the existing method merely focuses on total project cost phase cost while phase-level costs are also accounted for in the 10-10 Program. Moreover, further investigation on attributes of five phases and their cost is required to generate a reliable normalization procedure.

IV. PHASE-BASED COST NORMALIZATION PROCEDURE

This research focuses primarily on cost normalization for phase-level and project-level costs collected by phase. They are discussed in detail next.

A. *Phase-Level Cost*

Any costs reported in a local currency in other than U.S. Dollars need to be converted into U.S. Dollars using the currency exchange rate at the midpoint of the phase. The midpoint of the phase might be a reasonable point for currency conversion based on the assumption that the majority of expense occurs around the middle of start and end dates.

After currency conversion, phase-level cost is adjusted differently with regard to the phase it relates. First, the costs in construction and start-up phases are adjusted to Chicago, IL (baseline city) using RSMCCI for U.S. or

Canada-based projects, or HMICCI for projects built in the other countries. This process adjusts costs for location, ensuring that the phase-level costs in construction and start-up phases be transformed to the equivalent cost in Chicago. It is notable that the location adjustment is not applied to phase-level costs of front-end planning, engineering, and procurement phases because the costs are not, in general, consumed locally. Thus, for these three phases, effect of location on cost difference is assumed to be negligible in a given time frame (Dai et al. 2012). As a result, location adjustment is skipped and time adjustment is carried out for phase-level costs in front-end planning, engineering, and procurement phases.

For time adjustment, phase-level costs in front-end planning, engineering, procurement phases are normalized to the most recent RSMHI year using RSMHI for National 30 cities average since the cost is not adjusted to a specific location. On the other hand, RSMHI for Chicago is used to adjust the costs in construction and start-up phases to the most recent RSMHI year as Chicago is a reference city. Importantly, the use of RSMHI requires cautions in case that a specific city is adjusted by inflation because it may distort the normalization outcome (Dai et al. 2012). For instance, the increase rate of cost factors from 2004 to 2013 of RSMHCI for National 30 cities average is 40% while those of RSMHCI for Chicago is approximately 45%.

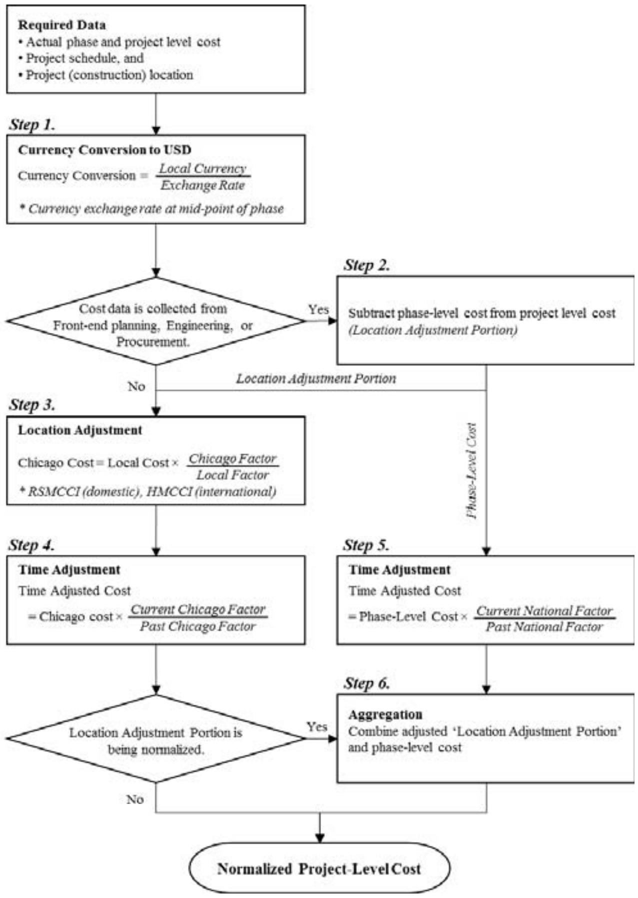
B. *Project-Level Cost*

Project-level costs gathered in all phases require to be adjusted for both of time and location. This is because the construction cost, which involves both of location time adjustments, takes majority of total project cost (Dai et al. 2012). This approach differs from the normalization process used for phase-level costs since the phase-level costs of front-end planning, engineering, procurement phases are not adjusted for location. As the phase-level cost is a part of project-level cost, a location adjustment portion is taken into account to exclude phase-level costs in front-end planning, engineering, and procurement phases. This approach allows phase-level costs and the remaining costs to be normalized differently based on whether they are adjusted for location or not. Figure 1 illustrates the process of project-level cost normalization.

As shown in step 1 of Figure 1, the project-level cost having local currency is first converted into equivalent cost in U.S. Dollars using the currency exchange rate at mid-point, similarly to the phase-level cost in other than in U.S. Dollars.

For location adjustment, the phase-level costs in front-end planning, engineering, procurement phases are first subtracted from project-level cost (step 2), and the remaining cost (location adjustment portion) is adjusted for location and time as presented in steps 3 and 4 of Figure 1. This approach is crucial since the phase-level costs of the three phases do not require a location adjustment. Yet, their normalized phase-level costs for time (step 5) will be combined with normalized portion of costs (step 6) as illustrated in Figure 1. Finally, the aggregated cost represents normalized project-level costs of the three phases.

FIGURE 1
NORMALIZATION PROCEDURE FOR PROJECT-LEVEL COST



The phase-level costs in construction and start-up phases are adjusted for location and time. Hence, segregation of these phase-level costs is unnecessary as both costs follow the same steps of location and time adjustment. Project-level costs in construction and start-up phases is first adjusted to the baseline city and then adjusted to the most recent RSMHI year as presented in steps 3 and 4 of Figure 1. As the two phases do not consider location adjustment portions, aggregation is not necessary indicating outcomes of step 4 in Figure 1 is normalized project-level costs.

V. CASE STUDIES

In this section, two hypothetical projects are presented to demonstrate the cost normalization procedure discussed in this study. It is assumed that as two 120,000 square foot commercial building projects, both provide actual design phase cost and forecasted total project cost immediately after finishing the design phase. Project A was built in Indianapolis, IN in the U.S. and project B was located in Sao Paulo, Brazil. The two projects' mid-points of design phases are identically on May 13th, 2007. Their assumed cost data of project A and B are shown in Table 2.

TABLE 2
COST DATA OF CASE PROJECTS

Cost data	Project A (Million USD)	Project B (Million BRL)
Forecasted Total Project Cost	50	100
Actual design phase cost	10	15

A. *Project A - U.S. located project*

Table 3 describes the cost normalization procedure for project A with information of the corresponding steps presented in Figure 1. For project A, 2007 RSMCCI is used to retrieve location factors for Indianapolis and Chicago as the mid-point of phase is in 2007. The values of Indianapolis and Chicago in 2007 RSMCCI are 158.5 and 191.9, respectively. A location adjustment portion is obtained by subtracting design phase cost from forecasted total project cost in order to normalize the forecasted total project cost as shown in Table 3. The design phase cost is adjusted only for time as it may not be expended locally. Once adjusted to Chicago in 2007, the location adjustment portion is computed to be $ 48.43 million as shown in Table 3. The index years of RSMHI for Chicago for 2007 and 2013 are used. Their index values are 191.9 and 234.4, respectively. Their ratio is multiplied by the location-adjusted portion to reflect the time factor.

TABLE 3
COST NORMALIZATION PROCEDURE OF PROJECT A

Cost Category	Currency Conversion[a] (Million USD)	Location Adjustment (Million USD)	Time Adjustment (Million USD)
Forecasted Total Project Cost (1)	[*Step 1*] 50	Skip	[*Step 6*] 59.16 + 11.88 = 71.04[b]
Actual Design Phase Cost (2)	[*Step 1*] 10	Skip	[*Step 5*] 10 × (201.2 / 169.4) = 11.88[c]
Location Adjustment Portion (3) = (1) - (2)	[*Step 2*] 50 – 10 = 40	[*Step 3*] 40 × (191.9 / 158.5) = 48.43	[*Step 4*] 48.43 × (234.4 / 191.9) = 59.16

[a] Currency conversion is not required since cost data of project A is provided in U.S. Dollars and thus costs are presented as they were submitted; [b] Normalized total project cost; [c] Normalized design phase cost

For the design phase cost which does not require a location adjustment, the RSMHI for National 30 city average is used. Their index values are 169.4 in 2007 and 201.2 in 2013, and their ratio is multiplied by the design phase cost.

Finally, the normalized value of forecasted total project cost is $ 71.04 million. This indicates that a total project for the same facility built in Chicago with a mid-point of design phase in 2013 is estimated to cost $ 71.04 million. Also, the normalized design phase cost is calculated to be $ 11.88 million as shown in Table 3.

B. *Project B – Brazil located project*

A currency conversion is required as cost information is provided in BRL (Brazilian Real) for project B. On May 13th, 2007, 2.04 Brazilian Real was equal to 1.00 U.S. Dollar (http://www.oanda.com). The closest date available in HMICCI for Sao Paulo is April 2007. In April 2007 HMICCI, the local cost factor for Sao Paulo, Brazil is 69.5 and that of Chicago is 100.0. Similarly to project A, the location adjustment portion is adjusted to Chicago in 2007 using the ratio of these two location factors, resulting in $ 612.44 million as presented in Table 4.

Except for the fact that project B requires the currency conversion corresponding the project location as well as different location index, the same procedure is applied. The resulting normalized forecasted total project cost and design phase cost are $ 82.14 million and $ 8.75 million, respectively.

TABLE 4
COST NORMALIZATION PROCEDURE OF PROJECT B

Cost Category	Currency Conversion (Million USD)	Location Adjustment (Million USD)	Time Adjustment (Million USD)
Forecasted Total Project Cost (1)	[*Step 1*] 100 / 2.04 = 49.13	Skip	[*Step 6*] 73.39 + 8.75 = 82.14[a]
Actual Design Phase Cost (2)	[*Step 1*] 15 / 2.04 = 7.37	Skip	[*Step 5*] 7.37 × (201.2 / 169.4) = 8.75[b]
Location Adjustment Portion (3) = (1) - (2)	[*Step 2*] 49.13 – 7.37 = 41.76	[*Step 3*] 41.76 × (100 / 69.5) = 60.08	[*Step 4*] 60.08 × (234.4 / 191.9) = 73.39

[a] Normalized total project cost; [b] Normalized design phase cost

The normalized forecasted total project and design phase costs of project A and B are then used to calculate the absolute cost metrics. For example, project cost efficiency and phase cost efficiency of project A are computed to be $ 591.93 per square foot and $ 98.98 per square foot at the conclusion of design phase. Without the cost normalization, the metrics values will be $ 416.67 per square foot and $ 83.33 per square foot, which are respectively 29.6% and 15.8% lower than the outcomes based on the normalization approach introduced in this paper.

VI. DISCUSSION

The approach to adjust cost data introduced in this paper is believed to enable the comparison of diverse projects in temporal and spatial standpoint. Some limitations of the adjustment procedure should be noted.

First, a major difference in a procedure to adjust phase-level cost lies on whether or not locational adjustment is needed by phase. For this study, phase-level costs in front-end planning, engineering, and procurement phases are determined to be consumed nationally or globally rather than determined locally. Yet, the authors believe this assumption can be corrected based on data availability in such phases. For example, if large amount of budget in engineering (design) phase is expensed at certain location and the location information is also available, the location adjustment for the design may generate more reliable normalized cost.

Next, it is notable that cost index is typically used for preliminary cost estimates known to have +/– 20% accuracy (Gould and Joyce 2009). The cost normalization procedure addressed in this study are used to measure specific absolute cost metrics such as phase cost efficiency ($/BGSF). The calculated absolute metrics using the normalized costs, however, should not be interpreted as a cost target or a substitute for detailed cost estimating (Dai et al. 2012). Instead, the metric outcomes are supposed to assist project management team to ensure whether phase of a project are efficient in their use of financial or human resources from cost perspective (Dai et al. 2012).

In addition, selected indices for location adjustment do not include all cities in the U.S. although location factors for many cities were included (Migliaccio et al. 2011). To address the missing location cost factor, a ‘closest city’ (Hwang et al. 2008) and a proximity-based interpolation method (Migliaccio et al. 2011) can be used. Both methods have the pros and cons to each other. The procedure proposed in this study is designed to select a cost index adopting a ‘close city’ method. Although the interpolation method is straightforward and easy to apply, it has a limitation that geographical distance is merely accounted for to obtain location factors (Dai et al. 2012).

Finally, scale-up factors are typically used for early estimating project costs at different size along with location and time adjustments (Remer et al. 2008). The suggested cost normalized method did not take the size factors into consideration since there is no change in capacity of projects required to be adjusted. However, scale-up factors need to be accounted for if the procedure is used for the other purposes other than benchmarking such as cost estimating.

VII. CONCLUSION

A cost normalization procedure applicable to phase-based performance assessment program is introduced in this study. Case studies are also presented to illustrate how the proposed procedure can be used to the phase-based performance assessment. Through the results from case studies, it became clear that the procedure enables the cost data to be maintained in current dollars at a reference location, allowing reasonable comparisons from location to location, and from a particular time to a reference year via absolute cost metrics (Dai et al. 2012; Hwang et al. 2008, 2010). Accordingly, it should be of significant value for assessing cost performances. It is expected that the new procedure can be used by both researchers and industrial professionals in studies and practices regarding cost estimation, feasibility analysis, and performance assessment.

Several limitations and challenges related to the cost adjustment procedure are also discussed. Considering the issues identified, further investigation on the procedure is required to validate its accuracy and reliability as a path forward. The authors believe that it could be accomplished as data accumulates and more project data are available with time.

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