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Developing a cost normalization framework for phase-based performance assessment of construction projects

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Abstract

Capital project benchmarking requires an effective cost normalization process to achieve reasonable comparisons of cost-related performance for projects which are executed at different times and locations. Traditionally, cost normalization approaches were developed for *ex post facto* analysis of project performance and assume that all required information is fully available from a completed project. However, practitioners have expressed the need for cost normalization techniques to evaluate phase-level outcomes during ongoing projects. This paper aims to provide a cost normalization framework tailored to phase-based performance assessment. The framework involves three main steps: currency conversion, location adjustment, and time adjustment with considerations for various scenarios where the required information is not fully available. Case studies are conducted to demonstrate how the proposed cost normalization framework has been applied to phase-based performance assessment for capital projects. The proposed framework can benefit both researchers and industrial professionals interested in cost estimation, feasibility analysis, and performance assessment.

Keywords: Cost normalization; Phase-based benchmarking; Absolute performance metric; Construction cost index (CCI); 10-10 program

1. Introduction

Benchmarking plays a critical role in a mature capital project delivery process as it enables a project organization to evaluate project performance and to seek appropriate best practices for improvement, (Hwang et al., 2008; Luu et al., 2008). There is no doubt that the success of capital project benchmarking is determined by what performance metrics are used and how appropriately they assess project performance and outcomes. Many researchers and industry practitioners have endeavored to produce effective measurements and numerous performance metrics have been developed to address the diverse perspectives of a capital project (Beatham et al. 2004; Chan and Chan 2004; Costa et al. 2006; Hwang et al. 2008; Li et al. 2001; McCabe 2001; Remer et al. 2008; Suk et al. 2012; Yeung et al. 2013a). A multitude of absolute performance metrics have been established from these efforts, and employed to assess the project efficiency of capital projects (Hwang et al. 2010; Suk et al. 2012). Some common absolute metric measures are, for example, \$TIC/BGSF (Total Installed Cost per Building Gross Square Footage) and Days/BGSF (Project duration per Building Gross Square Footage).

Absolute performance metrics require an appropriate data normalization process to obtain reasonable benchmarks, unlike relative performance metrics which measure relative difference between planned and actual performance (e.g., project cost growth and project schedule growth) (Hwang et al., 2008). In particular, cost data used in absolute performance metrics needs to be properly normalized depending on the time and location that a facility was built (Dai et al. 2012). The cost normalization method was developed by employing a similar approach for cost adjustment as is used in conceptual cost estimation (Dai et al. 2012; Hwang et al. 2010). This

cost normalization method is essentially based on the assumption that project information is fully available after project completion.

A new benchmarking program called the 10-10 Program, recently initiated by the Construction Industry Institute (CII), adopts a phase-based benchmarking approach. The program assesses organizational performance at each phase of on-going capital projects so as to support the establishment of proactive strategies to improve outcomes of subsequent phases and overall project performance. In this program, various phase-specific and cost-related absolute metrics were used to measure phase-based project outcomes. It was not feasible to apply the existing cost normalization method due to insufficient information collected by phase, however. As a project progresses, more data are available; there are more knowns during the construction or start-up / commissioning phase than front end planning / programming. As the necessary data for cost normalization is not fully available at the conclusion of each phase, an alternative cost normalization procedure was required to compare cost performance through absolute metrics in the phase-based benchmarking program.

This study aims to establish an adjusted cost normalization framework tailored to phase-based benchmarking which collects limited, but critical project information so that absolute cost metrics can be reliably compared by phase. A thorough review of existing cost normalization methods and cost indices was conducted, and both available and required information for cost normalization was identified with reference to phases of capital projects. Based on the background research and documented requirements, this paper presents a cost normalization framework applicable to phase-based benchmarking. A case study was also conducted to

demonstrate how the suggested normalization framework is applied to real projects. The limitations and future improvement of the framework are then discussed.

2. Research background

2.1. Concept of cost normalization

The cost normalization approach used by existing benchmarking programs was derived from early cost estimation techniques employed in the preliminary stages of project development, such as programming or conceptual design. One approach to making such estimates is to obtain costs of similar projects completed at an earlier date and update these costs to the present time by adjusting variables such as time and location (Humphreys 2005; McCabe et al. 2002; Remer et al. 2008). Cost indices are established based on these variances in costs at different times and locations (Humphreys 2005; Hwang et al. 2008). A cost index is defined as the ratio of cost or price for a given commodity or service at a given time and location, compared to the cost or price at a time and location reference (Dai et al. 2012; Humphreys 2005). The indices are used to predict an estimated cost at the desired location and time, based on a known cost at a certain location and time reference (Diekmann 1983). The project cost can be adjusted with consideration for location and inflation factors, as can be seen Equation 1 (Remer et al. 2008, 1998). To estimate the cost of Project 2, the index values for Projects 1 and 2, and the cost of Project 1 (the known cost) are used. The ratio of the two selected index values indicates the proportion of the two projects' costs. The location indices are used to distinguish location and to predict cost implications (Remer et al. 2008; Migliaccio et al. 2015), while inflation indices are

used to track fluctuations of price and cost at different time points (Humphreys, 2005; Remer et al., 2008).

$$Cost_2 = Cost_1 \times \left(\frac{Inflation\ Index_2}{Inflation\ Index_1} \right) \left(\frac{Location\ Index_2}{Location\ Index_1} \right) \quad (1)$$

Where, $cost_1$ is the cost of Project 1 (with known cost); $Inflation\ Index_1$ and $Location\ index_1$ is for Project 1; $Inflation\ Index_2$ and $Location\ index_2$ is for Project 2

2.2. Cost normalization for capital project benchmarking

Cost-related absolute metrics measure actual or planned costs to other measures (e.g., physical dimension, capacity, or duration), while relative cost metrics measure the relative difference between planned and actual costs (Dai et al. 2012). In order to reasonably evaluate cost performance through absolute metrics, cost data needs to be normalized from the project location and time to the reference location and time (Hwang et al. 2008). The normalization process enables the costs to be maintained in current dollars at a common location, thereby allowing reasonable comparisons from location to location, and from a particular time to the current year via absolute metrics (Dai et al. 2012; Hwang et al. 2008, 2010). The existing cost normalization method, which was adapted by the CII pharmaceutical / biotech project benchmarking program, was designed with three main steps; 1) currency conversion, 2) localization, and 3) time adjustment. This sequence of the three steps was tested and identified to be an optimal way to minimize cost variations resulting from different sequential combinations (Dai et al. 2012).

2.2.1. Currency conversion

The international construction marketplace continues to grow and become more diverse and interconnected (Jaafari 2000; Kapila and Hendrickson 2001). Nowadays, multinational owners and contractors are engaged in capital projects in various places around the world. Numerous engineering and construction companies have adopted business strategies such as high value engineering centers, offshore design offices, and global purchasing across borders (Dai et al. 2012; Walsh et al. 2005). As a result, project costs are often paid in local currencies or other reference currencies, instead of U.S. dollars. In general, businesses agree upon a currency exchange rate valued at a specific point in time for converting one currency to another (Dai et al. 2012; Walsh et al. 2005), thus enabling cost data to be managed in a single currency unit (U.S. dollars).

2.2.2. Location adjustment

Location adjustment converts costs in U.S. dollars from its original location to those at a reference location (Hwang et al. 2008). Location factors are used to translate the total cost of a project from one geographical location to another in order to account for differences in, for instance, productivity and costs for labor, weather, and climate by project location. For the pharmaceutical / biotech project benchmarking program, Dai et al. (2012) and Hwang et al. (2008) two indices were used to select the proper location factors; 1) the International Construction Intelligence Index (ICII), previously Hanscomb Means City Cost Index (HMCCI)

for international projects, and 2) the RS Means City Cost Index (RSMCCI) for U.S. and Canadian projects. Chicago, IL was chosen as a reference city. Thus, using the ICII and the RSMCCI project costs are converted from the original location to those at Chicago, IL.

2.2.3. Time adjustment

To accommodate inflation and escalation, time adjustments are the third and final step and are carried out using the RS Means Historical Index (RSMHI). The time adjustment converts the costs in Chicago, IL to current dollars (Dai et al. 2012; Hwang et al. 2008). The RSMHI for Chicago is used to adjust the project cost to the latest index date, and this time adjustment generates a Chicago-equivalent project cost in the most recent year available.

2.3. Cost normalization for phase-based benchmarking

The traditional benchmarking process, as an *ex post* evaluation, focuses on assessing project-level outcomes rather than phase-level outcomes by collecting project data after the projects are complete (Yeung et al. 2013b). Due to this inherent characteristic, it has been impossible to fully assess phase-specific performance in a timely manner for on-going projects. In response to this issue, CII launched a phase-based benchmarking system called the 10-10 Program, which collects project data at the end of project phases so as to evaluate performance at the phase-level (CII 2013). This new benchmarking approach enables a project manager and project team of an in-progress project to identify impending problems and then to take proactive strategies for subsequent phases (Choi et al. 2015; Kang et al. 2014).

The performance metrics employed in the 10-10 Program evaluate phase-wide and phase-specific performance outcomes in terms of cost, schedule, capacity, staffing, and safety through absolute and relative performance metrics (Yun et al. 2016). A prerequisite to cost-related absolute metric comparison is cost normalization, which adjusts cost data in different currencies collected from projects executed in various locations and time. It is not difficult to collect information for cost normalization in capital project benchmarking after project completion, but the 10-10 phase-based benchmarking program utilizes project data from one specific phase at a time during an on-going project. Consequently, the available data is different in each phase. For example, actual cost expended during the construction phase is not known at the end of engineering or design and neither is actual schedule. Therefore, the cost normalization process for phase-based benchmarking needed to be established considering what information is known and unknown in each project phase. No previous attempt has made thus far to address the need for a formalized cost normalization approach applicable to phase-based benchmarking.

3. Research methods

This study presents a cost normalization framework and its procedures so that cost data of each project phase can be properly normalized to evaluate cost-related absolute performance metrics adopted in the phase-based benchmarking program. To accomplish this, the CII Performance Assessment (PA) team reviewed key elements for cost normalization such as cost types and indices applicable to each project phase. Then, the proposed cost normalization framework was established with considerations for possible normalization scenarios based on the characteristics

of the individual project phases. The initial framework was validated by industry experts for its practical applicability, and was refined according to their recommendations. A case study was conducted to demonstrate a detailed cost normalization procedure and its application toward the phase-based benchmarking framework. Then, industry experts were again consulted and framework limitations and recommendations for future improvements to obtain more accurate normalization outcomes by project phase were discussed.

3.1. Definition of framework requirements

There are three key elements that critically influence cost normalization for project benchmarking: 1) which currency was used on the project; 2) where a project was located; and 3) which point in time was selected for cost normalization. In the CII capital project benchmarking framework, local currency is converted by market exchange rate to U.S. dollars at the given time point. It is important to note that construction location and the date at the midpoint of the construction schedule are used as the location and point in time for normalization, respectively. The midpoint of construction was selected because it is generally agreed that the construction phase is the most expensive project phase compared to other phases, and also construction costs are significantly affected by local conditions such as construction labor, equipment, suppliers, and material costs (Dai et al. 2012; Hwang et al. 2008). This approach had to be altered to suit phase-based benchmarking, however. To normalize the engineering phase cost of an on-going project, for instance, the construction location and midpoint of construction schedule are not applicable because the engineering office is usually located in a different place and the

construction schedule is not determined fully by the completion of the engineering phase. To establish the framework, it was important to identify what information is known or unknown during each project phase so that phase-specific project data can be exploited to produce reliable cost normalization. The next subsection documents the cost elements and other information for each project phase. Then, the cost indices which could be applied to cost normalization are reviewed and analyzed.

3.1.1. Project phases and their cost elements

A capital project consists of several project phases that are divisions within the project, and are where additional control is necessary to effectively manage the completion of major deliverables (Kerzner 2013). The concept of the project phase allows for the project to be divided into logical subsets for management, planning, and control (PMI 2013). The definitions or types of project phases can vary among industries, or even among organizations due to complexity and diversity of projects. Therefore, it was necessary to clearly define phase scopes and their cost elements for appropriate performance comparison of phase-level outcomes. CII Performance Assessment (PA) defines five project phases, and their cost elements as shown in Table 1. The five project phases are front end planning (programming in the building sector), engineering (design in building), procurement, construction, and start-up (commissioning in building and infrastructure). From an owner's standpoint, the total project cost represents the total amount of all project costs from front end planning through the start-up phase, excluding land costs, but including in-house salaries, overhead, travel, etc. (CII 2012). Phase cost essentially means all cost elements

associated with the project phase, as listed in Table 1. The 10-10 Program collects different cost items by the defined five phases; for example, 1) the construction phase cost is confirmed and submitted at the end of the construction phase although costs consumed during other phases (e.g., procurement, or start-up) are unknown at the time, and 2) the start-up phase questionnaire asks for actual total project cost, unlike other phases which request forecasted total project cost, because actual total project cost is confirmed at the completion of the start-up phase.

The cost data collected from the 10-10 Program are mainly categorized into two types; 1) phase-level cost (e.g., phase cost and total cost of major equipment), and 2) project-level cost (e.g., forecasted and actual total project cost). Both phase-level and project-level costs are normalized to measure cost-related absolute metrics by phase. The two types of costs collected from the five phases, however, have different characteristics when a normalization approach is taken into consideration. Most cost elements in front end planning and engineering phases are related to expenses of management or engineering personnel, and permit or licence costs. The tasks in these phases are typically executed in different places that are not the construction site. In addition, major equipment is purchased from various locations, nationally or globally. Consequently, phase costs in the front end planning, engineering, and procurement phase are not applicable to location adjustment. Therefore, cost normalization process needs to be different for these project phases.

Table 1: Definition of project phases and their typical cost elements and cost data

3.1.2. Cost indices as adjustment factor

Selection of appropriate cost indices are crucial to producing reliable benchmarks in which cost data is normalized to compute cost-related absolute metrics. In the construction industry, a large number of cost indices have been introduced to provide a resource for cost estimators and engineers to adjust costs for different time periods and locations, as shown in Table 2 (McCabe et al. 2002; Remer et al. 2008, 1998). Due to the variety of cost indices, one of the challenges has been to determine the most appropriate index to use. Cost indices have been created to suit different industries or locations, public or private intents, or to ascertain cost for general or special purposes such as contractor pricing and valuation, as well as estimation (Remer et al. 2008).

To establish proper cost normalization tailored to phase-based benchmarking, the CII PA team thoroughly reviewed cost indices which have been widely adopted in the construction industry. The authors established selection criteria to select the most appropriate cost index for cost normalization applicable to phase-based benchmarking. First, the benchmarking program was designed to cover all industry sectors including industrial, building, and infrastructure projects so the cost index for normalization needs to be applicable across all industry sectors. Second, the cost index should be able to adjust costs of the projects built in the various locations in the United States, as well as foreign countries. Third, the cost index needs to reflect inflation and other economic changes in order to track project costs at different times. Lastly, the cost index should represent various cost elements including labor, material, and equipment, which are major cost components in both phase and overall project costs.

Table 2: Summary of cost indices in the construction industry**3.2. Initial framework formulation**

Following the analysis of published cost indices and cost characteristics, the CII PA team developed an initial framework for cost normalization applicable to phase-based benchmarking. The framework grouped each of the phases into one of two different categories for cost normalization, to account for the characteristics and availability of cost data obtained at the end of each phase. In particular, the project phases were categorized by the adjustment process for major cost elements, as aforementioned in Table 1.

One group, the preconstruction phases, is comprised of front end planning (programming), engineering (design), and procurement. The main cost elements in this group are expenses from the management, consulting, and design personnel or administrative fees for permit and license. The cost data collected in the preconstruction phases are not adjusted by location due to: (1) difficulty on determining a specific location where the phase was executed; and (2) lack of appropriate location indices applicable to adjustment of the phase cost. Therefore, cost normalization methods for the preconstruction phases include currency conversion and inflation adjustment only.

The second group of project phases is construction and start-up (commissioning) where the location of the phase is specified, and when a large amount of project information, relative to the preconstruction phases, is available as a project is considerably progressed. In these phases,

the main cost elements including labor and material cost and these are strongly influenced by the region where the project is executed. Therefore, location adjustment is required for the cost in these phases because it aims to adjust price difference of labor and material by region. Thus, the cost normalization methods for construction and start-up phases include currency conversion, location adjustment, and time adjustment.

Figure 1. Initial framework for phase-based cost normalization

As shown in Figure 1, phase costs are normalized according to the characteristics and availability of information by phase. The phase costs in the preconstruction phases are normalized through currency conversion and time adjustment using inflation indices while the phase costs in construction and start-up phases are normalized through currency conversion, and location and time adjustment using both location and inflation indices. In addition to phase costs, project costs are normalized through currency conversion, location and time adjustment, in line with the existing cost normalization method for project-level benchmarking (i.e., *ex post* evaluation).

The primary step of cost normalization was to ascertain the local currency used for costs and to convert them to U.S. dollars. Any costs reported in a currency other than U.S. dollars needs to be converted into U.S. dollars. In order to select the appropriate exchange rate, the timing of phase execution must be taken into consideration (Hwang et al. 2008). The mid-point of a phase is a reasonable point for currency conversion, based on the assumption that the

majority of expenditure occurs at mid-phase. While more accurate results could be produced by converting individual project transactions to U.S. dollars, this would require an extensive effort (Dai et al. 2012). Using the exchange rate at the mid-point of the phase is anticipated to produce reasonably accurate results. The cost converted into U.S. dollars is then adjusted for location and/or time considering the type of cost and phase in which it was collected, as shown in Figure 1. Details are discussed next with regard to the types of cost.

The next steps of cost normalization is to adjust costs by where and when a project was executed to Chicago in the U.S., at the latest time, in order to make an equivalent comparison between projects. Considering the selection criteria for cost indices, the team chose RS Means City Cost Index (RSMCCI) for U.S. and Canada projects, and the International Construction Intelligence Index (ICII) for international projects as the location adjustment index. For time adjustment as the inflation index, the RS Means Historical Cost Index (RSMHCI) was selected because of several advantages it has compared to others in its cost normalization procedure. First and foremost, the RSMHI is produced by collecting actual material, labor, and equipment quantities from nine building types including office buildings, hospitals, parking garages, and apartments, which are similar to project types in the database of the phase-based benchmarking program. In addition, RSMHI can be used in conjunction with RSMCCI that has location factors of more than 900 cities in the U.S. and Canada. Therefore, any cost from one city and time can be moved to another city and time using the two indices, (RS Means 2012). RSMHI and RSCCI are published annually by Reed Construction Data (Dai et al. 2012; McCabe et al. 2002). The

index provides relative location factors (or multipliers) representing the weighted average for total cost for each CSI Master Format division (RS Means, 2012).

For location adjustment of international projects, the ICII has been used in past research studying cost normalization methods for capital project benchmarking. It has been confirmed that the index reliably accounts for global project variation in costs by employing a parity index (Dai et al. 2012; Hwang et al. 2008). CII has successfully applied the ICII on CII Pharmaceutical / Biotech benchmarking as well as general project benchmarking programs. The ICII is published biannually (April and October) in a “International Construction Intelligence” report and covers 32 location factors with one city from each country (Wiggins 2013). As an output index, ICII compares construction costs based on a 150,000 square foot single story manufacturing facility and it roughly approximates the characteristics of projects in the building sector (Dai et al. 2012).

3.3. Framework validation

The CII 10-10 Program distributed online questionnaires to CII member companies in early August 2013. A total of 69 owner and contractor companies participated in the 10-10 Program and submitted 578 phase-based project data from August 2013 to July 2014. The submitted data were validated to ensure data quality in compliance with the CII benchmarking validation process, and confirmed that the normalization requirements are sufficient for cost normalization such as currency, time, and location information.

Figure 2. Geographical distribution of project data submitted

The locations of the submitted projects were from 35 countries across the world, as shown in Figure 2. Among them, 75% of projects were executed in the US. In addition, the midpoints of the phase of the submitted projects were distributed from 1997 to 2014, including complete or ongoing projects. The U.S. Dollar was mainly used as a currency in the submitted projects; a few international projects used the local currency such as Canadian Dollar (CAD\$), Columbian Peso (COP), Malaysian Ringgit (MYR), and Brazilian Real (BRL).

The initial framework was validated through the reviews and feedback from CII's industry experts on the Performance Assessment Committee (PAC) and the Performance Assessment Community of Practice (PACOP). The PAC is a group representative of CII member organizations and academic researchers with benchmarking experience and expertise. The PACOP is an industry experts' group consisting of more than 50 industry participants with more than 20 years' experience, and was launched to allow the members to share and learn about enhanced project performance through benchmarking and performance assessment.

3.4. Framework refinement

During the experts' review on the initial framework, the CII PA and PACOP made some suggestions to modify the initial framework based on their practical or academic knowledge, and relevant experience.

Initially the framework was formulated to use the midpoint of the phase schedule in order to determine the currency exchange rate and inflation index for time adjustment. However,

industry experts and researchers claimed that when converting local currency to reference currency which is usually U.S. Dollars, specific date(s) are selected for the international project from an accounting standpoint. Thus, it was recommended that the currency conversion use a given value of the exchange rate provided by benchmarking users instead of using the mid-point of a phase. Ultimately, the midpoint of the phase was adopted as an alternative date to obtain currency exchange rate, when an actual conversion date was not provided.

Another key issue regarding currency conversion from some experts was that the exchange rate might be not appropriate due to its volatility. Exchange rates are determined in an international market with reflection of various economic influences; for example, economic conditions in a given country where a capital project is executed, or worldwide and regional economic conditions. To overcome the limitations of the currency exchange rate process, some experts suggested use of the Purchasing Power Parity (PPP), which is the amount of currency in a given country required to purchase a set of goods and services over the amount of currency in another country required to purchase the same set (Walsh et al. 2005). In construction research, significant attempts have been made to utilize the PPP to compare construction project costs internationally (Gruneberg and Fraser 2012; Sawhney et al. 2004; Walsh et al. 2005). The PPP has been introduced as an alternative conversion factor for international comparison of construction costs. It helps minimize discrepancies due to volatility in the currency exchange rate, tariff and taxation policies, and transportation difficulties (Gruneberg and Fraser 2012; Sawhney et al. 2004; Walsh et al. 2005). However, a company commonly uses the market exchange rate at a given date to estimate the converted value of project costs, for business

purposes. Although the PPP could be worth utilizing as a conversion factor, the CII PAC recommended the market exchange rate for currency conversion because business entities use common exchange rates to convert capital earned or spent in local currency to the US dollar. Moreover, project cost is commonly determined considering risk and uncertainty of economic conditions in a given country for the project location during the project life cycle.

Furthermore, there was a recommendation on the selection of cost indices for location adjustment. Some industry experts recommended using industry-specific or facility-specific cost indices such as the Nelson-Farrar Refinery Construction Cost Index (NFRCCI) or the Chemical Engineering Plant Cost Index (CEPCI). After an extensive review of alternative cost indices, there was a general consensus among the CII PA team, the PAC and the PACOP that the RSMCCI for U.S. and Canada projects and the ICII for international projects were appropriate as a location adjustment index. This consensus is essentially from three findings from the analysis on the commercialized cost indices. First or foremost, cost normalization for benchmarking should be done by comparing various industries and project types based on the same comparison criteria. Second, the RSMCCI covers more locations within the US and Canada than other indices. Lastly, both the RSMCCI and ICII can use the Chicago-based historical cost index for the time adjustment because the ICII for U.S. is based on Chicago. Therefore, the RSMCCI and ICII were determined to be the best cost indices to accommodate all types of facilities regardless of industry sectors. However, it was noted that industry-specific or facility-specific cost indices should be applied to industry-specific benchmarking once project data sufficiently accumulate.

The refined framework for cost normalization is demonstrated in Figure 3. Detailed procedures for cost normalization by project phase, location, and cost type are described in the next section through a case study.

Figure 3: Phase-based cost normalization framework

4. Case study

In order to demonstrate cost normalization practices, a case study was carried out for four building projects executed in different locations and at different times. As discussed, the cost normalization procedure differs by phase, location, and types of cost. To illustrate the procedure, four building projects were selected from the database of the 10-10 Program. They included 1) the design phase of a U.S.-based project, 2) the construction phase of a U.S.-based project, 3) the design phase of an international project, and 4) the construction phase of an international project. The selected cases cover all distinctive procedures discussed in this study, and are expected to help to demonstrate how cost data collected in the phase-based benchmarking program can be adjusted for measure absolute cost performance. Descriptions of the four case study projects are summarized in Table 3.

Table 3: Case project information for cost normalization

4.1 Identification of required information

Identification of required information is imperative when the cost normalization framework is employed. Table 3 specifies the required information for cost normalization, as applied by the case study projects. The mid-point of a phase is defined as the middle date of an actual phase start and stop. When a given date is not available on the phase, the mid-point date can be used for the selection of the currency exchange rate for cost conversion as well as for location and time adjustment factors from the indices. As cost data from Malaysia and Brazil (projects C and D, respectively) are in their local currencies, MYR (Malaysian Ringgit) and BRL (Brazilian Real), their costs are first converted to U.S. dollars by obtaining the average currency exchange rates at the date of their mid-points. 3.181 MYR on Sep. 27th, 2011 is equal to 1.00 USD for project C and 1.757 BRL on Jan. 26th, 2012 are equal to 1.00 USD for project D, respectively.

Time adjustments were made for design phase costs on projects A and C, RSMHI using the national average index for their year mid-points and for 2013 (the most current index year). The RSMHI national average in 2010 is 183.5 and 201.2 in 2013 for project A, for example. The forecasted total project costs in the design phase require both location and time adjustments. For location adjustment, the 2010 RSMCCI for Ann Arbor, MI and Chicago were obtained for project A, and the Oct. 2011 ICII for Malaysia and Chicago were obtained for project C. For time adjustment of the forecasted total project cost for project A, the RSMHI for Chicago in 2010 and 2013 were chosen, which are 212.8 and 234.4, respectively. Likewise, 2011 and 2013 were selected for time adjustment of the forecasted total project cost for project C.

The costs for projects B and D are collected at the end of the construction phase, and so both the construction phase cost and the forecasted total project costs were adjusted for location and time. The phase and project costs for project B were adjusted for location using the 2013 RSMCCI for Flint, MI and Chicago. Project D was adjusted using Apr. 2012 ICII for Brazil and Chicago. For time adjustment of the phase and total project costs for project D, the RSMHI for Chicago in 2012 and 2013 were used. Both the mid-point of the phase year and the most current RSMHI year were 2013 for project B, implying that no change in costs for time adjustment were necessary.

4.2. Procedure of cost normalization

Table 4 describes the normalization procedure for the design phase and forecasted total project costs for projects A and C. The procedure for the construction phase and forecasted total project costs for projects B and D are specified in Table 5. Both tables include information for the corresponding steps illustrated in Figure 3: the formulas with relevant location and time factors identified in Table 3, and the outcomes acquired from the formulas. The design phase costs used for measuring cost-related absolute metrics for projects A and C were determined to cost \$4,934,608, and \$4,223,000, respectively. The forecasted total project costs for these two projects were estimated to cost \$53,016,295 and \$61,846,293. Moreover, the construction phase costs of projects B and D were normalized to \$7,059,100 and \$20,387,762, with forecasted total project costs normalized to \$9,134,521 and \$28,090,819, respectively.

Table 4: Cost normalizations for project A and C (Design Phases) (US Dollars)**Table 5: Cost normalizations for project B and D (construction phases) (US Dollars)**

4.3. Application of normalized costs

The normalized costs were used to compute absolute metrics in the design and construction phase. For illustration, project cost and phase cost efficiencies are evaluated using capacities or dimension as forecasted at the conclusion of the phase and the normalized costs obtained from Tables 4 and 5. In building projects, cost efficiency is measured as the ratio of relevant costs to BGSF (Building Gross Square Footage), which means how much cost was spent per 1 BGSF (Kang et al. 2014). The outcomes essentially imply the efficacy in performance for phase-level and project-level costs by the floor area of the building being designed or constructed. In this regard, lower efficiency is indicative of better performance in terms of cost.

In order to derive meaningful benchmarking results, it is crucial to compare projects having similar attributes such as phase, project type, or nature, (Hwang et al. 2008). As the four case studies with the two different phases demonstrated in this paper, comparison of their metric values do not show the relative successfulness in cost performance in comparison to other similar projects' outcomes. Nevertheless, the outcomes are still useful to examine the case projects' cost performance by phase and to understand why the cost normalization process is paramount for absolute metrics.

Table 6 presents the phase cost and forecasted total project cost efficiencies calculated using both raw costs and normalized costs. When normalized costs are used, the metrics outcomes of all four case projects are increased compared to when raw costs were used for metric calculation. In particular, the total project cost efficiency of project C is estimated to increase 102.8% from \$235.9/BGSF when the normalized cost is used instead of the raw cost. Accordingly, it is concluded that the total cost efficiency of project C is larger than that of project A, which is compared at the same phase of design, indicating that project A shows better total cost efficiency than project C. However, this result is reversed when raw costs were used for the calculation since the metric values of projects A and C are 258.7 and 235.9 respectively, when raw costs are used. A similar phenomenon occurred for construction phase cost efficiencies for projects B and D which both provided construction phase data. Project D is estimated to show better phase cost efficiency compared to project B when normalized phase cost is used. However, a better performed project is suggested when raw phase cost is considered. Without cost normalization, the increase rates presented in Table 6 are disregarded and thus reliable comparison of performance could be hindered.

Moreover, design phase efficiencies for projects A and C were much lower than construction phase efficiencies in projects B and D. The results make sense considering the fact that a larger expense occurs in the construction phase in comparison to the design phase. On the other hand, the total project cost efficiencies of the four case projects ranged from \$325.9/BGSF

to \$478.4/BGSF. As total project cost efficiency uses project-level costs for the metric, a large difference between the two phases were not found among case study projects.

Table 6: Comparison of absolute cost performance

5. Discussions

It is strongly believed that the cost normalization framework suggested in this paper enables projects executed at diverse times and locations to be compared, while ensuring that cost-related absolute metrics are properly measured with an appropriate level of effort. The authors believe that the research outcomes can also be applied to cost estimation or feasibility analysis. However, there are some limitations which warrant attention when the adjustment procedure is applied. A number of issues and challenges associated with the suggested procedure are worthy of discussion, and are listed below.

First, it should be noted that the cost index is generally used in early-stage cost estimation, which is known to have a +/- 20% accuracy, (Gould and Joyce 2009). In this regard, the outcomes of adjusted costs are used to measure specific metrics such as phase burn rate (\$/day), phase cost efficiency (\$/BGSF), and forecasted total project cost efficiency (\$/BGSF); however, they should not be interpreted as a cost target or a substitute for detailed cost estimating. Rather, the metric outcomes are expected to assist a project management team to ensure whether the estimated budget is either within a reasonable range, or needs additional justification (Dai et al. 2012).

Second, scale-up factors are used in the process of adjusting project costs of different size, along with location and time adjustments (Remer et al. 2008). The adjustment procedures discussed in this study did not take size factors into account since there is no change in capacity of projects that must be adjusted. For performance assessment purposes, the costs of a project carried out at a certain time and location are adjusted to Chicago equivalent values at the reference year. However, scale-up factors do need to be accounted for if the procedure is to be used for other purposes, such as early cost estimating.

Site-specific conditions such as location, regulatory requirements, weather conditions, geological, and design style considerations are not reflected in location factors (Humphreys and Hamilton 1999; Wiggins 2013). In this regard, if a group of projects with a different design are compared, the total variance in cost-related performance is not accounted for when location factors are solely considered (Dai et al. 2012). To overcome this challenge, the 10-10 program limits comparison of project performance to matching project and respondent types, industry sector and the same project phase. This approach might not be a perfect solution, but it leverages the impact derived from unique design of facilities. It is also believed that this issue will diminish over time as data accumulates and more project comparison data are available.

One critical limitation in the application of location indices is that not all cities in the U.S. are included in the indices, (Migliaccio et al. 2015). When a project is executed in a city where there is no location cost factor, the 'closest city' (Hwang et al. 2008) or a proximity-based interpolation method (Migliaccio et al. 2011) can be used. The procedure proposed in this study

is to select a cost index adopting the ‘closest city’ method. Although the interpolation method is straightforward and easy to apply, it has the limitation that geographical distance is merely accounted for to obtain location factors (Dai et al. 2012). Another critical issue pertaining to the location index is that the selection of certain location factors can be challenging in the case of some types of infrastructure projects (e.g., pipeline and highway) and industrial projects (e.g., offshore). As a result, one location cost factor may not be applicable for the whole project. To overcome this issue, it is recommended that the most representative location be selected based on relevant industry experience and knowledge from experts.

A limitation of the time factors is that one single representative factor is selected and used for time adjustment in the method discussed in the paper. As discussed earlier, RSMHI is index used for time adjustment and the index is published once per year. This means that the continuous fluctuation of exchange rates within a year is represented in a single composite value (Hwang et al. 2008). Given this limitation, absolute cost metrics need to be interpreted with caution. In addition, the mid-point of a phase is vital for cost normalization since it is the first step in enabling the selection of the exchange rate and indices for cost and time factors. This study defines the mid-point of a phase as the actual mid-date between the start and end dates of the selected phase. This date is based on the assumption that the largest expense for the phase execution usually occurs around that date. However, project personnel such as the project manager or cost engineer have more knowledge about the project itself and their input on the selection of the mid-point of the phase is critical to generating reliable metric values. In fact, this

is the reason why the survey instrument in the phase-based benchmarking system allows respondents to adjust the mid-point date used for calculation.

Lastly, a major difference in the way phase-level cost data are adjusted depends on whether the locational adjustment needs to be conducted. In this study, phase-level costs in programming, design, and procurement are not considered to be influenced by geographical factors because they were assumed to be bid nationally or globally and are not tied to a certain project location. However, the authors believe this idea could be refined if data are available. For example, if a large amount of budget for the design phase is expensed at a certain location and the location information is known, then location adjustment may be considered to generate a more reliably adjusted cost.

6. Conclusions

Benchmarking requires an effective cost normalization process for reasonable comparison of cost-related performance for capital projects executed at different times and locations. Cost normalization is often required to evaluate phase-level outcomes for an ongoing project, even when the required information is not fully available. While the cost normalization processes for performance assessment were developed based on methods for early cost estimating, it was established based on the assumption that all the required information for cost normalization is only fully identified once a project is completed.

This paper introduces a cost normalization framework tailored to phase-based benchmarking, it allows for appropriate comparisons of cost-related absolute measurements. Through a literature review of early cost estimating methods and by gathering feedback from industry experts, the cost normalization procedure was designed to adjust phase cost data associated with ongoing capital projects for the first time. Cost normalization allows similar projects to be compared, even though they differ in terms of time and location by adjusting costs to a selected reference city and year. Given the fact that sufficient data is crucial for reliable benchmarking, the proposed cost normalization provides essential controls to produce meaningful comparison of cost performance. Following the development of the framework and the building project case studies, it became clear that meaningful phase-specific absolute cost metrics can be measured for building projects and should be of significant value for phase-based performance assessment. In addition to that, the results may enable industry practitioners to assess whether the proposed total or phase specific budget is either within a reasonable range, or needs additional justification.

Several issues and limitations associated with the proposed cost normalization procedure were also discussed in detail. One of challenges is derived from the inherent nature of published indices which have limited accuracy and are not able to capture cost variations due to regulatory environment, site conditions, change in code requirements, and so forth (RS Means 2012). Additionally, the selection of appropriate index factors and the application of them are critical in cases when the adjustment procedure is applied. Further investigation of the procedure is

required to validate its accuracy and reliability. This can be accomplished as data accumulates and more project data are available with time.

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Table 1: Definition of project phases and their typical cost elements and cost data

Project Phase	Phase Definition	Typical Cost Elements	Cost Data to be Collected
Front End Planning /Programming	<ul style="list-style-type: none"> • Start: Defined business need that requires facilities • End: Total project budget authorized 	<ul style="list-style-type: none"> • Owner Planning Team Personnel Expenses • Consultant Fees & Expenses • Environmental Permitting Costs • Project Manager/Construction Manager Fees • Licensor Costs 	<ul style="list-style-type: none"> • FEP Phase Budget • Actual FEP Phase Cost • Forecasted Total Project Cost
Engineering /Design	<ul style="list-style-type: none"> • Start: Design basis • End: Release of all approved drawings and specs for construction 	<ul style="list-style-type: none"> • Owner Project Management Personnel • Project Manager/Construction Manager Fees • Designer Fees 	<ul style="list-style-type: none"> • Engineering Phase Budget • Actual Engineering Phase Cost • Forecasted Total Project Cost
Procurement	<ul style="list-style-type: none"> • Start: Procurement plan for engineered equipment • End: All engineered equipment has been delivered to site 	<ul style="list-style-type: none"> • Owner Project Management Personnel • Project/Construction Manager Fees • Procurement & Expediting Personnel • Engineered Equipment • Transportation • Shop QA/QC 	<ul style="list-style-type: none"> • Total Cost of Major Equipment • Forecasted Total Project Cost
Construction	<ul style="list-style-type: none"> • Start: Commencement of foundations or driving piles • End: Mechanical completion 	<ul style="list-style-type: none"> • Owner Project Management Personnel • Project Manager / Construction Manager Fees • Bulk Material • Construction Labor, Equipment & Supplies • Construction Equipment • Building Permits • Inspection QA/QC • Contract Management Personnel • Warrants 	<ul style="list-style-type: none"> • Construction Phase Budget • Actual Construction Phase Cost • Forecasted Total Project Cost
Start-up /Commissioning	<ul style="list-style-type: none"> • Start: Mechanical completion • End: Custody transfer to user/operator (steady state operation) 	<ul style="list-style-type: none"> • Owner Project Management Personnel • Project Manager/Construction Manager Fees • Operator Training Expenses • Consultant Fees and Expenses • Wasted Feedstocks • Supplier Fees 	<ul style="list-style-type: none"> • Start-up Phase Budget • Actual Start-up Phase Cost • Actual Total Project Cost

Table 2: Summary of cost indices in the construction industry

Index name	Industry	Cost Elements			
		Labor	Material	Equipment	Others
Associated equipment distributor (AED) compilation of averaged rental rates for construction equipment	Construction			X	
Association of American Railroads Railroad Cost Index	Infrastructure (Railroad)	X	X		<ul style="list-style-type: none"> • Fuel • Supplies • Operating expenses
Austin BCI	Industrial/Building	X	X		
Boeckh Building Cost Index	Building	X	X		<ul style="list-style-type: none"> • Tax • Insurance
Chemical Engineering Plant Cost Index (CEPCI)	Industrial (Process plant)	X	X	X	<ul style="list-style-type: none"> • Machinery • Engineering cost • Supervision costs
Dodge Building Cost Index	Building	X	X	X	
Engineering News-Record Building Cost Index	Building	X	X	X	
Engineering News-Record Common Labor Index	Building	X			
Engineering News-Record Materials Cost Index	Construction		X		
Fru-Con BCI	Building	X	X		
Handy-Whitman of Public Utility Construction Cost Index	Infrastructure (Utility)	X	X	X	
Lee Saylor BCI	Building	X	X		
Marshall and Swift Industrial Equipment Cost Index	Construction			X	
Marshall and Swift Building Cost Index	Building	X	X	X	
RS Means Building Construction Cost	Building	X	X	X	
RS Means Concrete & Masonry Cost	Building		X		
Nelson-Farrar Refinery Construction Cost Index	Industrial (Oil/Gas)	X	X	X	<ul style="list-style-type: none"> • Machinery • Instrumentation • Heat exchanger
Richardson Construction Cost Trend Reporter	Construction	X			
Richardson International Construction Factors	Industrial (Process plant)	X			
International Construction Intelligence Index	Building	X			

*Adopted from McCabe et al., 2002; Remer et al., 2008

Table 3: Case project information for cost normalization

Category	Project A	Project B	Project C	Project D
Phase participated in	Design	Construction	Design	Construction
Building Gross Square Footage	162,700	24,500	129,280	143,600
Project Location	Ann Arbor, MI, U.S.	Flint, MI, U.S.	Kuala Lumpur, Malaysia	Sao Paulo, Brazil
Actual Phase Cost	USD 4,500,500	USD 5,823,000	MYR 12,765,700 ^a	BRL 31,242,300 ^b
Forecasted Total Project Cost	USD 42,093,000	USD 7,535,000	MYR 97,021,000 ^a	BRL 43,046,500 ^b
Actual phase start date	5/1/2010	10/15/2012	9/24/2010	7/9/2011
Actual phase stop date	2/28/2011	7/29/2013	9/30/2012	8/15/2012
Mid-Point of Phase (mm/dd/yyyy)	9/29/2010	3/7/2013	9/27/2011	1/26/2012
Currency Exchange Rate	N/A	N/A	1USD = 3.181 MYR ^c	1USD = 1.757 BRL ^c
Required Cost Index Information				
ICII				
Index for project location	N/A	N/A	48.1	90.1
Index for Chicago, IL	N/A	N/A	100	100
RSMCCI ^d				
Index for project location	99.9	96.1	N/A	N/A
Index for Chicago, IL	116	116.5	N/A	N/A
RSMHI				
Index for Chicago (in year of mid-point)	212.8	234.4	224.0	226.9
Index for Chicago (in 2013)	234.4	234.4	234.4	234.4
Index for Nat'l 30 City Average (in year of mid-point)	183.5	N/A	191.2	N/A
Index for Nat'l 30 City Average (in 2013)	201.2	N/A	201.2	N/A

Notes: ^a Malaysian Ringgit; ^b Brazilian Real; ^c Currency exchange rates are adapted from OANDA (<http://www.oanda.com>); ^d RSMCCI in the year of mid-point of phase were selected for both of project location and Chicago.

Table 4: Cost normalizations for project A and C (Design Phases) (US Dollars)

		Project A		Project C	
Cost type	Step	Formula	Outcome	Formula	Outcome
<i>Actual phase cost</i>					
Currency conversion	1	N/A	4,500,500	MYR 12,765,700 / 3.181	4,013,109
Time adjustment	8	$4,500,500 \times (201.2 / 183.5)$	4,934,608	$4,013,109 \times (201.2/191.2)$	4,223,000
<i>Forecasted total project cost</i>					
Currency conversion	1	N/A	42,093,000	MYR 970,205,000 / 3.181	30,500,157
Location adjustment portion	2	$42,093,000 - 4,500,500$	37,592,500	$305,000,157 - 4,013,109$	26,487,048
Location adjustment	3	$37,592,500 \times (116 / 99.9)$	43,650,951	$274,300,000 \times (100 / 48.1)$	55,066,628
Time adjustment	6, 7	$98,349,427 \times (234.4 / 212.8)$	48,081,687	$570,270,270 \times (234.4 / 224)$	57,623,293
Aggregation	10	$108,332,264 + 274,173$	53,016,295	$596,747,104 + 32,305,649$	61,846,293

Notes: Bold indicates adjusted phase and total project costs

Table 5: Cost normalizations for project B and D (construction phases) (US Dollars)

Cost type	Step	Project B		Project D	
		Formula	Outcome	Formula	Outcome
<i>Actual phase cost</i>					
Currency conversion	1	N/A	5,823,000	BRL 31,242,300 / 1.757	17,781,616
Location adjustment	3, 4, 5	$5,823,000 \times (116.5 / 96.1)$	7,059,100	$17,781,614 \times (100 / 90.1)$	19,735,423
Time adjustment	6, 7	$7,059,100 \times (116.5 / 116.5)$	7,059,100	$19,735,421 \times (234.4 / 226.9)$	20,387,762
<i>Forecasted total project cost</i>					
Currency conversion	1	N/A	7,535,000	BRL 43,046,500 / 1.757	24,500,000
Location adjustment	3, 4, 5	$7,535,000 \times (116.5 / 96.1)$	9,134,521	$24,500,000 \times (100 / 90.1)$	27,192,009
Time adjustment	6, 7	$9,134,521 \times (234.4 / 234.4)$	9,134,521	$27,192,009 \times (234.4 / 226.9)$	28,090,819

Notes: Bold indicates adjusted phase and total project costs

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Table 6: Comparison of absolute cost performance

Category	Project A	Project B	Project C	Project D
<i>Phase participated in</i>	Design	Construction	Design	Construction
<i>Actual phase cost</i>				
Raw Cost (USD)	4,500,500	5,823,000	4,013,109 ^a	17,781,616 ^a
Normalized Cost (USD)	4,934,608	7,059,100	4,223,000	20,387,762
<i>Forecasted total project cost</i>				
Raw Cost (USD)	42,093,000	7,535,000	30,500,157 ^a	24,500,000 ^a
Normalized Cost (USD)	53,016,295	9,134,521	61,846,293	28,090,819
<i>Phase cost efficiency</i>				
Raw Cost used (\$/BGSF)	27.7	237.7	31.0	241.6
Normalized Cost used (\$/BGSF)	30.3	288.1	32.7	277.0
Increase Rate (%)	9.6%	21.2%	5.2%	14.7%
<i>Total project cost efficiency</i>				
Raw Cost used (\$/BGSF)	258.7	307.6	235.9	332.9
Normalized Cost used (\$/BGSF)	325.9	372.8	478.4	381.7
Increase Rate (%)	26.0%	21.2%	102.8%	14.7%

Notes: ^a Raw costs of projects C and D submitted using local currency other than USD were converted into USD using currency exchange rate at the mid-point of phase.

List of Figures

Figure 1. Initial framework for phase-based cost normalization

Figure 2. Geographical distribution of project data submitted

Figure 3: Phase-based cost normalization framework

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