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Cost Normalization Framework for a Benchmarking System: A Case for Downstream and Chemical Construction Projects

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Abstract: Benchmarking is an important tool to assess the performance of capital projects in the construction industry. Incorporating cost-related metrics into a benchmarking system requires an effective cost normalization process to enable meaningful comparisons among projects that were executed at different locations and times. Projects in the downstream and chemicals sector have unique characteristics compared to other types of construction projects, they require a distinctive cost normalization framework to be developed to benchmark their absolute cost performance. The purpose of this study is to develop such a framework to be used for the case of benchmarking the downstream and chemical projects for their performance assessment. The research team started with a review of existing cost normalization methodologies adopted in benchmarking systems and conducted 7 interviews to identify the current cost normalization practices used by industrial professionals. A panel of 12 experts was then convened and it held 6 review sessions to accomplish the framework development. The cost normalization framework for benchmarking downstream and chemical projects was established as a three-step procedure and it adopts a 4-element cost breakdown structure to accommodate projects submitted by both owners and contractors. It also incorporated 5 published cost indexes that are compatible with downstream and chemical projects and they were embedded into 2 options to complete the normalization process. The framework was then pilot-tested on 4 completed projects to validate its functional practicality and the downstream and chemical use case in the benchmarking system.

Keywords: Cost Normalization, Cost Index, Downstream and Chemical Project, Benchmarking, Performance Assessment

1. INTRODUCTION

Benchmarking is an important tool to assess project performance [1]. For companies that put their projects under constant pressure for improvement [2], incorporating benchmarking into their holistic project management programs can help improve the project delivery efficiency as well as the satisfaction of key project stakeholders [3].

Cost metrics used in benchmarking programs are considered key indicators of construction project performance [4], they are tangible results of project execution [5]. In fact, many of them are absolute cost metrics (e.g., Total Installed Cost per Square Foot), which require an effective cost normalization process for reasonable comparison (benchmarking) among projects that have been executed at different locations and times [6]. Compared to relative cost metrics that can be used directly without normalization, absolute cost metrics are preferred by industrial practitioners because they convey more direct and valuable information [7].

Downstream and chemical projects can be large and complex [8]. They are considered business ventures of the owner companies [9] and their development costs and profitability are closely tied to the feedstock price and market demands [10]. Due to the evolution in technology, downstream and chemical projects have also undergone important structural changes in recent years [11]. Furthermore, because they are also competing with renewable and sustainability projects, maintaining a competitive cost performance is vital for the owner companies [12]. These unique characteristics require a distinct cost normalization framework to be developed in this research effort to enable benchmarking of the absolute cost performance of the construction projects in the downstream and chemical sector.

2. BACKGROUND

Cost normalization for benchmarking purposes is to enable a direct comparison among projects that have been built in different locations and times. The fundamental process contains adjustments in location and time that bring projects to a selected base location at a referenced time [13]. Whereas, these adjustments require different types of indexes to account for the impact of inflation (time) and location variances [14]. Besides location and time, other factors are also suggested for consideration in normalizing the project cost [15]. These factors (most are only suggested) include project capacity factor [16] with different units for different project types [17], productivity and managerial efficiency [7], site-specific and local factors [18], and size [6] or scale-up factors [19].

2.1 Cost Indexes

A cost index (also referred to as price index), is defined as the ratio or percent of cost or price of a certain commodity, product, or service at a given time and location, compared to the same cost or price of the referenced time and location [20]. The location index compares the cost of a project relative to the base location; whereas the inflation index, a specific type of cost index, reflects the cost changes by referencing a base year [16]. The index number is a normalized average of the price that relates to a certain category of goods or services in a given region, during a given period. The *Engineering News-Record* (*ENR*) index started in the year 1909 is the earliest inflation index used by engineers to adjust project costs [21].

2.2 Location and Time Adjustments

For different purposes, time and location can be adjusted individually or at the same time. Kaiser and Gary suggested using a one-step formula to adjust the project cost from Time 1 to Time 2 for refinery projects [22]. A similar step was adopted and used on projects in the petrochemical and chemical industries by incorporating with Nelson-Farrar Cost Indexes [23]. Using multiple indexes, a project cost can be brought to a certain time and location. This is particularly helpful in benchmarking the remotely located or international projects that are completed in different years. Remer et al. used both inflation and location indexes in **Equation 1.** to normalize a project cost to the base location and time [16].

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

3. RESEARCH METHOD

This research started with a review of cost normalization frameworks used in existing benchmarking programs and it continued with interviews with subject matter experts (SMEs) to identify the existing methodologies used for cost normalization. It then established an expert review panel for decision-making towards the final framework development via review sessions. **Table 1** presents the information of SMEs who participated in this research from member companies in the Construction Industry Institute (CII) at The University of Texas at Austin.

Table 1. Summary of SME Information

Company	Designation	Years of Experience	Interview	Review Panel
Owner 1	Senior Project Engineer	11		Yes
Owner 2	Manager of Metrics Department	15	Yes	
Owner 3	Project Control Site Owner	33		Yes
Owner 4	Lead in Estimating & Benchmarking	33		Yes
Owner 5	Project Director	27		Yes
Owner 6	Competitive Intelligence Advisor	25	Yes	Yes
Owner 7	Benchmarking Advisor	12	Yes	Yes
Contractor 1	Senior Estimator	13	Yes	Yes
Contractor 2	Manager of Estimating	23	Yes	Yes
Contractor 3	Construction Engineer	15	Yes	
Consultant 1	Project Director	18		Yes
Consultant 2	Manager in Business Development	35		Yes
Consultant 3	Construction Manager	9		Yes
Consultant 4	Senior Cost Manager	15	Yes	Yes

3.1. SME Interviews

Interviews were designed to ascertain how industrial leading organizations do internal cost normalization and to obtain direct information regarding which cost indexes they use. Each interview was standardized with the same core questions [24] and it was limited to between 20 and 30 minutes. The interviewee was asked three questions to learn: (1) the purpose of normalizing the project cost, (2) the process (steps) used to normalize, and (3) the cost indexes he considers relevant and would recommend using to normalize the cost of downstream and chemical projects. A total of 7 SMEs from owner, contractor, and consultant organizations participated. Their specialties and roles cover cost normalization practices in their respective organizations.

3.2. SME Review Panel

An SME review panel consisting of 12 SMEs was convened to develop the cost normalization framework. A total of 6 review sessions were held. Each session was 2 to 3-hour long and was comprised of reviews and discussions to gain feedback as to whether to keep or eliminate the suggestions. The panel adopted a non-objection rule, from any member, to enable a thorough discussion with full consideration of all relative elements and factors; so, it would progress the development based on consensus in each session towards the end.

4. COST NORMALIZATION: THE STATE-OF-THE-ART

As a construction research organization, CII started global capital project benchmarking in the mid-1990s. Five independent benchmarking programs have been developed and they all have cost normalization processes embedded. These programs include Performance Assessment System (PAS), Construction Owners Association of Alberta Benchmarking (COAA), 10-10 Program, Pharmaceutical Benchmarking (Pharma), and National Health Care Facility Benchmarking (Health Care). More than 3,000 construction projects have been submitted by CII member companies for benchmarking. **Table 2** presents the three-step framework and indexes used. Although the steps are similar, certain cost items are excluded in the step of Location Adjustment (Step 2) when they are considered not subject to the location variance by the researchers. Excluded items include Capital Medical Equipment Cost and Total A/E and Construction Management Cost in Health Care [19], Equipment Cost in Pharma [25], Engineering, Construction Management, and Process Equipment Costs in the PAS [6], and Front-End Planning (FEP) Phase Cost, Engineering Phase Cost, and Major Equipment Cost in 10-10 Program [18].

Table 2. Cost Normalization Process Used in CII Benchmarking Programs

#	Program	**Cost Normalization Process**		
		Step 1 Currency Conversion	Step 2 Location Adjustment	Step 3 Time Adjustment
		Conversion Date	Location Indexes	Inflation Indexes
1	Health Care	Mid-point of Construction	U.S. Projects: RS Means City Cost Index	RLB* & PPI**
2	Pharma			RS Means Historical Index
3	PAS		International Projects: Faithful+Gould Global Location Index	
4	10-10 Program	Project Phase Mid-point		
5	COAA	N/A	N/A	

*National Construction Cost Index by Rider Levett Bucknall (RLB) for projects before 2002.
**Producer Price Index (PPI) for Direct Health and Medical Insurance Carriers after 2002.

Cost normalizing practices reported from 7 interviews are presented in **Table 3** and procedures used varied among organizations. Similar to CII's existing process, Owner C and Contractor C skipped the major equipment cost in location adjustment. Owner A used the Project Size factor (the floor area as the unit) to normalize building projects. Also, Contractor B used its internal data to adjust the productivities of different trades working on the projects. The interviewees also identified 12 cost indexes that are considered applicable in downstream and chemical projects.

Table 3. Cost Normalization Practices Reported by Industrial Experts

Organization	**Business Sector**	**Cost Normalization Process**			
		Step 1	Step 2	Step 3	Step 4
Owner A	Health Care	Currency	Location	Time	Project Size
Owner B	Oil and Gas	Currency	Location	Time	
Owner C	Oil and Gas	Time	Currency	Location	
Contractor A	Heavy Industrial	Location	Time	Currency	
Contractor B		Currency	Location	Productivity	Time
Contractor C		Currency	Location	Time	

Consultant A	Industrial	Currency	Location	Time

5. FRAMEWORK FOR THE CASE OF DOWNSTREAM AND CHEMICAL PROJECTS

The cost normalization framework (process illustrated in **Figure 1**) has embedded the following features as outcome decisions of the non-objection procedure of the SME review panel:

- Re-affirmed the Currency-Location-Time sequence in the normalization process
- New and simplified cost breakdown structure for both owner and contractor projects
- Determined the FEP cost is location-sensitive and tied to the owner company's location
- Adopted 5 new cost indexes (built into 2 options) are considered compatible:
  - Location Index: Compass - City Location Factors (CLF) for U.S. projects [26]
  - Location Index: Compass - Global Location Factors (GLF) for international projects [27]
  - Time Index: Option 1 - Chemical Engineering - Plant Cost Index (PCI) [28]
  - Time Index: Option 2 - IHS Markit - Downstream Capital Cost Index (DCCI) [29]
  - Time Index: Option 2 - BLS - PPI for Engineering Service (PPI-ES) [30]

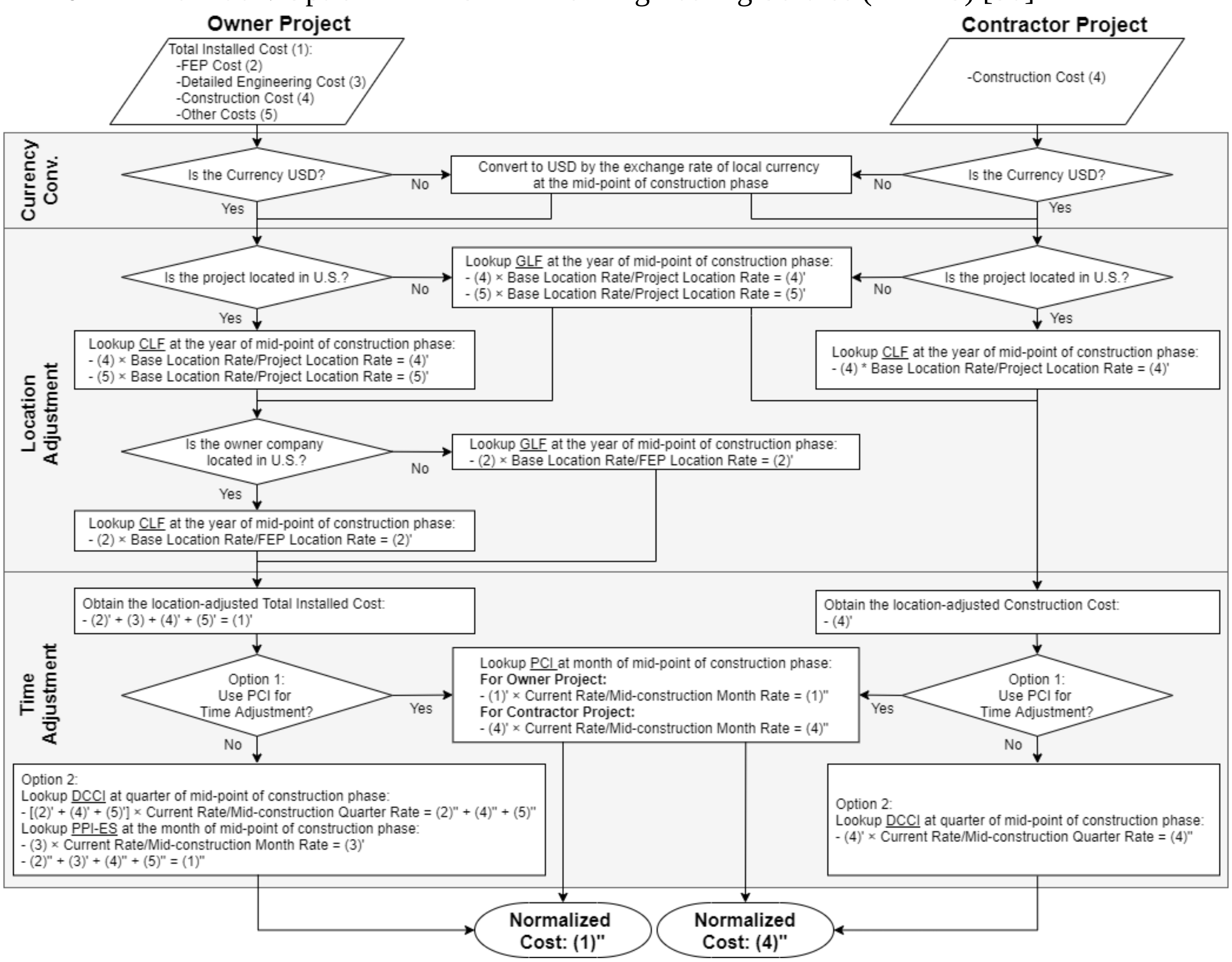

Figure 1. Cost Normalization Framework for Downstream and Chemical Projects Benchmarking

Regarding Time Adjustment in the framework, the PCI in Option 1 is a composite index to adjust process plant construction costs and it includes engineering and supervision considerations. The DCCI in Option 2 was specifically developed from refining and photochemical construction projects, it requires another index (PPI-ES) to adjust the engineering part of the work. Choosing between the options should be based on how close are the project characteristics to the index.

Researchers selected 4 case projects (2 from owners and 2 from contractors) in the existing benchmarking program database and tested the framework. **Table 4** presents a detailed calculation of two case projects.

Table 4. Cost Normalization of Case Projects

	Steps	Project A		Project B	
Project Information	Project Submitted by	Owner		Contractor	
	Project Type	Oil Refining		Oil Refining	
	Project Location	Shreveport, LA, U.S.		Calgary, AB, Canada	
	FEP Location	Houston, TX, U.S.		N/A	
	Construction Start Date	8/25/2014		6/15/2014	
	Construction End Date	5/30/2016		6/14/2017	
	Currency	U.S. Dollar		Canadian Dollar	
	Total Installed Cost (1):	247,425,000			
	-FEP Cost (2)	5,962,000			
	-Detailed Eng. Cost (3)	21,848,000			
	-Construction Cost (4)	136,320,000		85,777,200	
	-Other Costs (5)	83,295,000			
Currency Conv.	Construction Mid-point	**7/13/2015**		**12/14/2015**	
	Currency Conv. Rate	1.0000		0.7281	
	Total Installed Cost (1):	**$247,425,000**			
	-FEP Cost (2)	$5,962,000			
	-Detailed Eng. Cost (3)	$21,848,000			
	-Construction Cost (4)	$136,320,000		**$62,454,379**	
	-Other Costs (5)	$83,295,000			
Location Adjustment	Index Name and Year	CLF 2015		GLF 2015	
	Project Location Factor	0.81		1.06	
	FEP Location Factor	0.92		N/A	
	Base Factor	1.00		1.00	
	Total Installed Cost (1)':	**$299,458,064**			
	-FEP Cost (2)'	$6,480,435			
	-Detailed Eng. Cost (3)	$21,848,000			
	-Construction Cost (4)'	$168,296,296		**$58,919,226**	
	-Other Costs (5)'	$102,833,333			
Time Adjustment	Selection	Option 1	Option 2	Option 1	Option 2
	Index 1 Name	PCI	DCCI	PCI	DCCI
	Project Time 1	2015-Jul	2015-Q3	2015-Dec	2015-Q4
	Project Rate 1	556.2	186.46	537.1	183.29
	Current Year Time 1	2020-Dec	2020-Q4	2020-Dec	2020-Q4
	Current Year Rate 1	592.0	196.00	592.0	196.00
	Index 2 Name		PPI-ES		
	Project Time 2		2015-Jul		
	Project Rate 2		159.7		
	Current Year Time 2		2020-Dec		
	Current Year Rate 2		177.0		

Total Installed Cost (1)":	**$318,732,783**	**$316,028,400**		
-FEP Cost (2)"		$6,811,998		
-Detailed Eng. Cost (3)'		$24,214,753		
-Construction Cost (4)"		$176,906,972	**$64,941,690**	**$63,004,901**
-Other Costs (5)"		$108,094,676		

6. DISCUSSION AND FUTURE RESEARCH

All 4 projects and their normalization results were reviewed by the SME panel. It was observed that owner projects have a 4 to 6% annual increase from their nominal cost and the contractors have a 2 to 4% increase, yearly. According to the indexes, not every year has an absolute increase, especially in the time adjustment indexes. The SME panelists reviewed the results and considered them satisfactory according to their professional expectations and expert judgment.

The SMEs affirmed that the three-step process achieves an ideal balance between accurate cost normalization results and a manageable number of cost indexes in the benchmarking program. Also, due to the design of the adopted cost indexes, the panel was able to simplify the cost breakdown structure. This is significantly important to a benchmarking program since it takes projects with different levels of cost information from numerous companies. The panel further validated the framework and confirmed that it provides reasonable accuracy and reliability in the context of downstream and chemical construction.

The methodology used in this research, including interviews and SME reviews, is duplicable in developing of cost normalization framework for other industrial sectors. The scale-up factor is worth further exploration as Size Adjustment could be an added step that follows Time Adjustment if meaningful units can be determined for a specific type of project.

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