

Construction Performance Mapping Model for Outsourcing Organizations

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Performance mapping and determination of the key drivers for outsourcing organizations is important to determining the performance of the organization as well as ways to improve overall construction efficiency. A large private Utility Company (UC) partnered with a research group to measure the performance of their construction contracting environment and to identify solutions to the perception that construction costs were rising dramatically over the last few years. The research objectives were as follows: to determine and measure the performance of the UC's current contracting environment based on completed projects, then to analyze the costs of those projects, plot the costs out over time, and finally determine if increases in construction costs were realized. If these cost increases were effectual, a course of action(s) to mitigate this issue would have to be developed. A performance mapping model is also developed, along with a listing of best practices derived from the research effort. Outsourcing organizations looking to measure the performance of their contracting environment or to modify their existing measurement systems can use this research to improve their understanding of their current environment and better establish performance measurement initiatives to improve overall construction efficiency.

Key Words: performance, metrics, mapping, outsourcing, utility

Introduction

Utility construction represents a large majority of the key infrastructure in the built environment and is a critical component to the success of construction projects that are built upon its foundation (Sweeney, 2010). In the USA alone, there are more than 35 million miles of underground utilities (Anspach, 2013). As a key component of infrastructure, utilities are commonly present in the many infrastructure construction projects. Further, utility projects themselves are also highly complex (Anspach, 2013; Sweeney, 2010). Efforts to measure the outcomes of utility construction projects would have beneficial results for a wide range of construction projects as well as stakeholders.

Literature Review

The idea of performance measurement is not new to the construction industry; however, the exploration of how utility organizations that outsource their construction work by selecting contractors may gather and use this information in order to understand and improve their contracting environment is less explored. Further, these type of measurements have typically been generated from the perspective of the contractor (Perera and Imriyas 2002) or related to job-specific items during the management of the project (Skibniewski and Nitithamyong, 2004; Tseng et al., 2011). The benefit of performance measurement has potential impacts on all project stakeholders, both outsourcing organization as well as contractors (Skibniewski and Nitithamyong, 2004).

Performance measurement, specifically financial measurement, is a key driver for public utilities a basis for future planning, budgeting, and forecasting of potential rate changes. By law, the major four electric and gas companies in the state of California are regulated by the California Public Utilities Commission (CPUC). The CPUC is required to annually report on the costs of their programs and activities in the state for the main purpose of identifying the costs to ratepayers (CPUC, 2013). The key variables that have the potential to impact electrical utility rates are: generation costs, distribution costs, transmission costs (including other capital costs), and inflation rates (CPUC, 2013). Further sub factors include: labor escalation, material escalation, healthcare costs, and other non-labor escalations (SCE, 2013). Recently, California has taken on various renewable energy and energy conservation efforts as a way to reduce consumption and increase monitoring (CPUC, 2013). The impacts of the costs of utility construction are far reaching and a performance measurement system will aid in the effort to properly forecast and plan for any potential impacts.

Research Scope

A large public utility company (UC) partnered with a research group to measure the performance of their current construction contracting environment and to address the perception that construction costs were rising dramatically over the last few years. While the initial questions involved in the research were simply to determine solutions to rapidly rising costs, the researchers had to first extract the necessary research objectives. The research objectives were as follows: to determine and measure the performance of the UC's current contracting environment based on completed projects, then to analyze the costs of those projects, plot the costs out over time, and finally determine if increases in construction costs were realized. If these cost increases were effectual, a course of action(s) to mitigate this issue would have to be developed. Further a review of industry factors that could lead to increases is provided.

Method

The research was conducted in close collaboration with the UC and their internal personnel, especially during the data collection phase. The UC is a large public utility company, servicing over 2 million customers in the southwestern USA with electricity and water. In the electrical area, the UC has an annual construction utility construction volume of 300 projects ($30M). The UC has a small internal construction workforce, consisting mostly of utility maintenance crews and managerial personnel. For utility construction over $10,000 in value, the UC outsources their construction to general and utility specific contractors, with contracts primarily awarded based on costing. The characteristics of these construction jobs were: utility related, earthwork (boring and trenching), and electrical (underground only).

The goal was to gather data on all construction jobs that were contracted in fiscal years 2011-2013 and to then analyze the data for trends pertaining to performance (cost, time, and quality). The initial performance mapping model, based on the UC's organization, contained three main phases (Figure 1).

Figure 1 – Initial Performance Mapping Model

Data Collection

Identification

The structure of an organization's databases/resource systems closely follows their core business drivers. For some companies, construction is not their core business, leading databases/records containing construction performance information to be isolated or unestablished due to the sense of disparity. A common solution is to develop separate databases of information, dependent on the users' needs and a computer communication network to connect these separate units (Frank, 1985). The mapping of existing utilities and use of mapping data has become highly specialized based upon a particular group's needs, making general standards challenging (Anspach, 2013).

Following the initial performance mapping model, the source(s) of project performance data (cost, time, and quality) needed to be identified at the UC (Phase 1). As a large public utility with external reporting requirements, the UC kept various records in a variety of sources within the organization. Two separate databases housed the majority of the data needed and had to be mined for the projects' information through reports. The UC stored the financial-related data in one database and the construction-related data in a separate database, with some of this information needing interpretation from key personnel involved in projects (Figure 2).

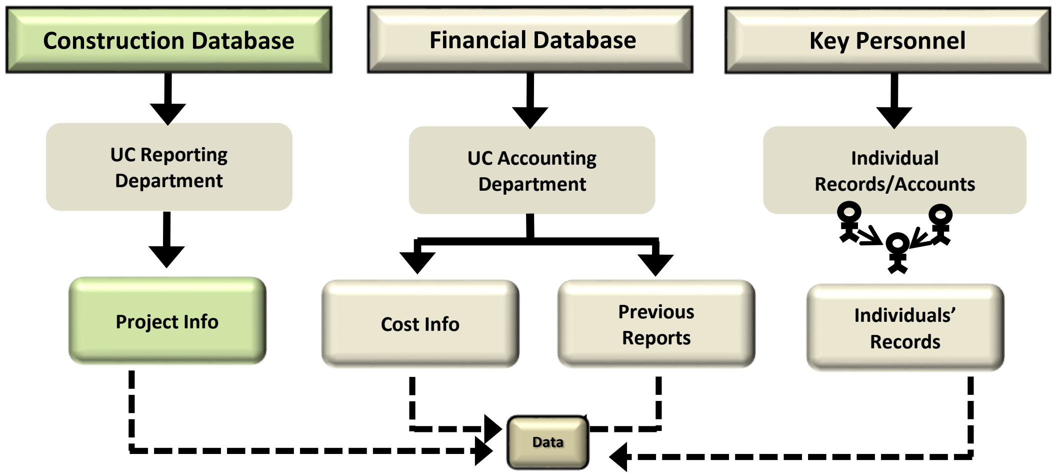

Figure 2 – Database Process Workflow

The data mining of the databases proved challenging and involved mapping of the key performance data points needed. The databases were all programmed using C++ language and the reports could only be created by one computer programmer that had designed the systems. This programmer was overwhelmed with internal requests for reports and it became necessary to consult with internal managers to make this research a priority for the programmer. The UC invested the programmer's time in this effort as well as the efforts of two other internal personnel in the contracts management department that could assist with interpreting the data.

In consultation with the UC computer programmer, it was uncovered that the source fields were not named in line with construction vernacular, thus the researchers had to map out each necessary data point and the potential original UC entry source of information for the database programmer (Table 1). For information that had multiple database sources (final cost and actual completion date), the data needed to be compared across both systems and checked for inconsistencies.

Table 1

Data Points' Mapping

No.	Data Point	Database Source	Typical Documentation
1	Awarded cost	Financial database	Purchase order
2	Final cost	Construction database and/or Financial database	Closeout report or paid invoice
3	Proposed completion date	Construction database	Contractual date
4	Actual completion date	Construction database and/or Financial database	Date of closeout and/or date of final invoice
5	Change orders	Construction database	Listing of change orders' details
6	General	Construction database and/or Financial database	Fiscal year, job number, etc.

Data Compilation and Validation

The data collection phase was critical to this research effort and yielded valuable challenges and areas of further analysis. This phase of the research proved to be more challenging and time consuming than the researchers and the UC had anticipated. The goal was to gather data on all contracted construction work at the UC from 2011-2013, which was estimated to involve more than 700 projects. The group decided to first run a test on the data due to the multiple database sources and potential for inconsistencies. The test would involve the following procedure: data mining (UC programmer), data compilation (UC programmer), data validation (research team), and data analysis (research team). To ensure data integrity in the mining process, the research team had a control group of five projects with known values that were used to validate the data at every stage of the analysis and would send the personnel in the contracts management department intermittent reports to ensure that the data being mined was accurate.

The first data mining was a test run on 10 projects and lasted a total of 3 months. The challenges the group ran into in this test were: inconsistent job numbers, duplicated jobs, and inconsistent data across all 10 projects. Upon reviewing the results of the 10 project test, the programmer needed to revisit the data point mapping and ensure that the C++ programming language was in fact calling out the correct source fields. The programmer wrote a total of 2 pages of C++ code in order to generate a more simplified report. The time that elapsed between the identification of the issues with the 10 project test and the resolution with new code, was 1 month.

Despite the previous struggles with their internal data sources, the UC decided to continue with the data collection and considered all projects completed. After data mining and compilation, a validation report was created and found to have jobs with incomplete information (missing completion date, duplicated job numbers, etc.). The programmer had to revisit the programming language to ensure the data wasn't duplicating jobs or calling out cancelled jobs.

Data Analysis

After numerous further validation reports were generated, a report with an anticipated quantity of jobs was produced (549 jobs over 3 years). The following inconsistencies were discovered: incorrect job numbers, numerical values that exceeded the average job values by over 300%, missing data, and duplicated jobs. The UC did not have an accurate way of noting when a job was cancelled or on hold. As a result, all jobs with inconsistencies across the 2 database sources were removed. A total of 78 were removed due to data inconsistencies, leaving 471 jobs to be analyzed.

The completed construction jobs were analyzed to determine the cost change order rate, schedule delay rate, and average unit costs. The total awarded cost of the 471 jobs analyzed was $39,277,593. Yearly, an average of 157 projects were completed (Table 2). The average project size was between $10,000 and $49,999. The characteristics of these construction jobs were: utility related, earthwork (boring and trenching), electrical (underground only).

Table 2

General Project Information

No.	Criteria	Total	Average	2013	2012	2011
1	Total Number of Projects	471	157	180	171	120
2	Awarded Cost	$ 39,277,593	$ 13,092,531	$20,223,681	$12,085,775	$6,968,137
3	Awarded Duration	18,341	6,114	8,625	5,765	3,952

The analysis revealed a cost change order rate of 4% and a schedule delay rate of 269% (Table 3). The change order rate was measured as the difference between the awarded cost and the actual invoiced cost. The data was mined from the financial and construction databases. The schedule delay rate was measured as the deviation in duration of the awarded versus the actual start date and date of final payment. The schedule dates were mined from the financial database as the construction database did not contain the accurate dates. No data was found regarding quality measures or customer satisfaction, which are also components of contracting performance.

Determination regarding the source of change is important for an organization to determine how to improve performance. The change order rate was divided into categories based upon the database entry of the reason for the change, which was entered by the UC personnel during the time of processing the change order. There were six categories: 1) Change Site Condition (occurred when the contract document were different than the condition of the physical site); 2) Design Deficiency/Omission/Changes (due to design-related issues); 3) UC Impact (anything caused or initiated by the UC, such as scope changes); 4) Municipality (any issues pertaining to the authority having jurisdiction); 5) Defective Equipment/Material (the UC provides the material portion of the jobs); and 6) Contractor Caused (or issues pertaining to entities sub-contracted by the main contractor).

The normalized total was calculated by taking the dollar value for that specific category of change order and dividing it by the total dollar value of all change orders. The highest change order rates overall were experienced in the following categories: change site condition (43%), design deficiency/omission/changes (35%), and UC impact (17%) (Table 4). Existing site conditions are experienced as a common constraint for utility construction projects (Anspach, 2013; Sweeney, 2010). Design and UC impact have both experienced increased change order rates from 2012-2013. UC impact has experienced an increase across 2011-2013, while design experienced a decrease from 2011-2012. Another notable data point is that there have been 0% contractor caused change orders. The schedule delay rate could not be divided into categories of change, like the change order rates, due to the database not capturing this information.

Table 3

Cost Change Order and Delay Rates

No.	Criteria	Total	2013	2012	2011
1	Overall Change Order Rate	4%	2%	2%	10%
2	Overall Delay Rate	269%	50%	799%	1091%

Table 4

Normalization of Cost Change Orders by Category

No.	Category	Normalized Total	2013	2012	2011
1	Change Site Condition	43%	3%	16%	82%
2	Design Deficiency/Omission/Changes	35%	71%	11%	19%
3	UC Impact	17%	45%	34%	21%
4	Municipality	4%	7%	29%	79%
5	Defective Equipment/Material	1%	79%	21%	0%
6	Contractor Caused	0%	0%	0%	0%

Results

Unit costs were also analyzed in response to the research questions, with the data coming from the financial database. The jobs were divided into three main types: boring, trenching, and trench & boring (combined). The job types were taken from the construction database, with only 335 having these job type designations and the remainder missing job information. The analysis of costs for these projects showed increased unit costs from 2011-2012 (Table 5 and Figure 3), with trench & boring (combined) experiencing the sharpest increase in unit costs during that timeframe. Decreased unit costs for all job types were observed from 2012-2013, which capture the most recent years. Therefore, the UC's concerns over cost increases did not match the results of the data analysis.

The reasons for the unit cost changes over time were found to have been potentially from some organizational changes that were occurring at the UC. In 2012, the UC changed their contracting strategy from having subcontracts with each discipline, to packaging multiple jobs of trench and boring (combined) into a singular contract which could explain the large deviation ($902/FT). The intent of this strategy was to award both types of work to a single vendor to perform, similar to a prime contracting strategy. Further, due to user complaints and confusion, the UC implemented a newer and more robust financial database system in 2012. This new system was said to track costs more clearly and simply for the user inputting the data, as compared to the 2011 system.

Table 5

Unit Cost by Job Type

No.	Job Type	Unit	Average	2013	2012	2011
1	Trench	$/FT	$ 61	$ 32	$ 40	$ 15
2	Boring	$/FT	$ 30	$ 29	$ 58	$ 32
3	Trench & Boring (Combined)	$/FT	$ 544	$ 868	$ 1,070	$ 168

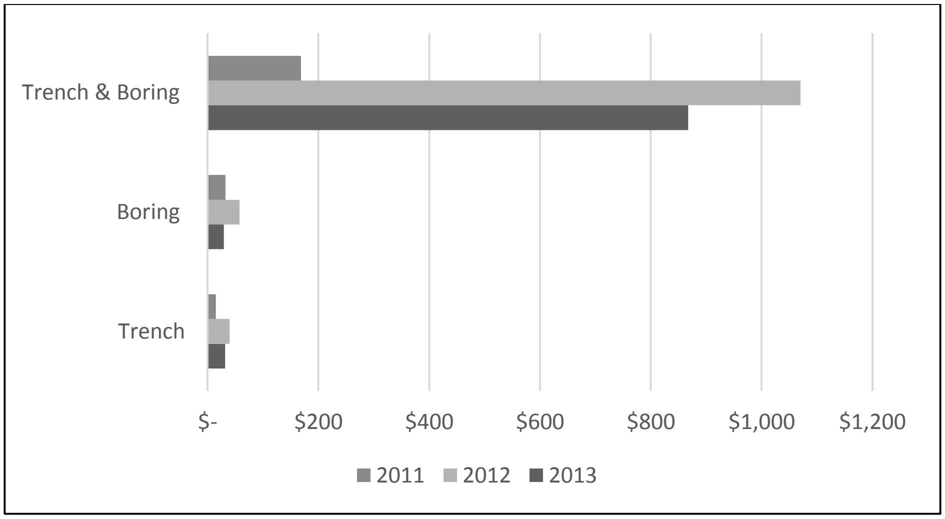

Figure 3 – Unit Cost Trends by Job Type

Industry Indicators

In the southwestern USA, some industry indicators can be analyzed in order to put the UC's results into perspective. The costs of construction in the utilities sector can vary largely based on location and type of utility (i.e. electricity transmission, distribution, coal based power plants, etc.). Overall, national standards and indices such as IHS Global Insight - Power Planner and Handy-Whitman Indexes are used to determine regional and sector-specific cost estimates (SCE, 2013). In 2007, utility construction costs were on the rise and predicted to increase over the next twenty years due to material and labor cost increases (Chupka & Basheda). The escalation indexes used to calculate the operation and maintenance (O&M) of public utilities could be a general indicator of cost increases. The O&M costs by the Four Corners Generating Station (FC) and Palo Verde Generating Station (PV) show that from: 2011-2012 a decrease in O&M costs was experienced while the UC experienced an increase in construction costs, and 2012-2013 O&M costs decreased along with the UC's construction cost decreases (Table 6).

Table 6

Utility O&M Indicators

No.	Year	Unit	Average	FC	PV
1	2010	Percent Change	3.15%	3.10%	3.19%
2	2011	Percent Change	4.59%	5.02%	4.16%
3	2012	Percent Change	2.57%	2.82%	2.32%
4	2013	Percent Change	1.63%	1.46%	1.79%

Discussion

The purpose of this research study was to measure the performance of a large Utility Company's (UC) current construction contracting environment and to determine solutions to the perception that construction costs were rising dramatically over the last few years. The research team developed three research objectives: determine and measure the performance of the UC's current contracting environment based on completed projects, then to analyze the costs of those projects, plot the costs out over time, and finally determine if increases in construction costs were realized. If these cost increases were effectual, a course of action(s) to mitigate this issue would have to be developed. The results of the first research objective revealed that the UC's cost change order rate was quite competitive at 4% compared to other industries (Sullivan, 2011). The UC's schedule delay rate was concerning (at 269%) and the research team proposes to dissect the sources and reasons for these delays, similar to how cost change orders are assigned a category.

Regarding the second and third research objectives, the unit rates were found to have decreased over the past two years (2012-2013). An increase from 2011-2012 was observed and a potential source of the UC's contracting strategy points to a potential source. The unit cost trends could be improved and expanded upon if a longer range of time were under consideration and data were collected (longer than three years).

Combining the results of the three research objectives, the UC can improve performance through mostly schedule-related initiatives. Time is essentially a resource and has associated costs (which could also impact realized unit costs). Further analysis into the cost component would provide a more complete representation of the contracting environment. No data was found regarding quality measures or customer satisfaction, which are also components of contracting performance. A system to capture this information would also provide beneficial contributions to an analysis of performance.

The UC also had some valuable lessons learned from this research. This research was the UC's first attempt at analyzing their existing data, which revealed many areas of improvement. The main areas of improvement to the UC's data were: 1) need to note when job was cancelled or on hold; 2) for the issues pertaining to missing or incorrect values, the UC utilized this analysis to retroactively repair the incorrect data; 3) schedule impacts need to be more closely measured and assigned categories; 4) access to the data and reports was prohibitive; 5) data needed to be analyzed more frequently to "audit" values to ensure they were accurate.

The intent of this research was not meant to make changes to the existing databases, but resulted in important findings regarding the data recording and reporting process. The lessons learned were summarized into five key areas: 1) databases/sources of construction drivers must have the proper communication networks established with existing databases/sources of business drivers; 2) access to the data must be permitted for the entire organization; 3) the capability of reporting or outputs must be accessible to the entire organization; 4) the data points must be aligned with construction drivers (cost, schedule, and quality); 5) the data must be effectual. In order for the data to be effectual, it must be analyzed in such a way that it can be easily used by executives to make data-driven decisions that will be effectual. From this, a revised performance mapping model was derived that is more proactive in nature (Figure 4). Development of a proactive tool to measure performance and risk would also be beneficial in generating plans for mitigating issues (Perrenoud et al., 2014)

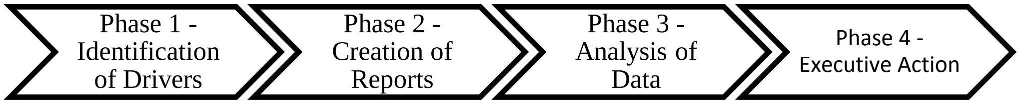

Figure 4 – Revised Performance Mapping Model

Conclusions and Future Research

The value of performance data is in its ability to help an organization become more efficient through data-driven decisions. If the data drivers a company is seeking cannot be easily found with a reasonable amount of time, the data has essentially become of no economic value due to the resources needed to be invested just to gather and analyze the data (Frank, 1985). Thus, outsourcing organizations must have a clear plan regarding how to either improve their existing data drivers or to improve their access and use through the map presented in this paper. A proactive model for performance metrics was proposed (Figure 4).

Both outsourcing and non-outsourcing utility organizations can benefit from the performance information presented in this paper and consider setting a similar performance information baseline internally. Using the data presented in this paper, organizations can also consider comparing their performance information. Close attention should be paid to the categories having the highest rate of change (i.e. change site condition, design deficiency/omission/changes, and internal impact) and identification of internal measures that can mitigate these categories of change (i.e. site surveys, utility mapping, design review/audit, and internal deficiency mapping).

Future research can draw upon the lessons learned from the performance mapping efforts of the UC and how to set up a more streamlined system for organizations to obtain and use their performance information. Careful attention to how to track categories of delay rate (similar to change order categories), ensure that data entry is complete (including all information needed to classify the job – job type, cost, etc.), closely monitor unit cost rates throughout the year, develop metrics for quality, and consider a more streamlined approach to report creation that does not require computer programming knowledge should be considered.

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