Conceptual Estimating in Project Capital Planning and Validation.

Scott Morton[1] and Glenn Ballard[2]

ABSTRACT

Cost modeling for capital construction projects is a critical aspect of the funding approval process. Traditional conceptual cost-modeling efforts have been undependable because they lack connection to the specific program, quality, site and locality characteristics of the project owner's expectations. Underestimating construction costs will jeopardize project success; overestimating costs will put project approval at risk. Either diminishes the effectiveness of the project owner's business planning.

This paper describes a process for evaluating the completed financial performance of multiple projects on the basis of a building's program, quality factors, and site and locality characteristics. These same factors can be used as a cost-modeling tool that dramatically increases the dependability of the outcome. The tool allows for real-time cost modeling and evaluation of multiple project considerations or solutions. The output of the cost model provides an achievable yet challenging starting point for an effective integrated target value design effort, with individual component target costs defined in addition to overall project target cost.

The process is illustrated with a case study and compared to other approaches to conceptual estimating. The paper concludes with suggestions for future research.

KEY WORDS

Capital planning, conceptual estimating, cost modeling, target costing, target value design

INTRODUCTION

Target costing, also known in construction as target value design, has the client include in their project business plan an allowable cost, what they are able and willing to pay to get what they want. What's wanted and the corresponding allowable cost are then shared with key members of the team that will deliver the project if funded. Together, client, designers and constructors validate and improve the business plan. The validation process involves evaluating the allowable cost against an expected cost (Ballard, 2008). Given that project business plans are produced prior to design, the expected cost must be determined through conceptual estimating.

Historically, conceptual estimates have been considered to vary in accuracy with the degree of project definition. Estimates with different levels of accuracy have been considered appropriate for different uses. For example, a level of project definition[3] of

[1] VP Project Development, Oscar J. Boldt Construction Company. Scott.Morton@boldt.com
[2] Associate Adjunct Professor, University of California, Berkeley. ballard@ce.berkeley.edu
[3] "…roughly corresponding to percent complete of engineering" (Dysert and Christiansen, 2003)

1% to 15% is said to be accurate within 3-12% in predicting actual cost, and to be suitable for determining the feasibility of a project, but not suitable for establishing a control budget (Dysert and Christiansen, 2003). The challenge posed by target value design is to determine expected cost directly from customer requirements, prior to design, then to set target costs (budgets) equal to or lower than allowable cost. In Pennanen and Ballard's 2008 paper, a highly accurate method of conceptual estimating was presented capable of determining the expected cost for a project directly from customer requirements.

This paper presents another equally accurate and also parametric conceptual estimating method (Dysert, et al., 2004), based on benchmarking healthcare projects. In the following, first the development of the method is described, then its use illustrated through a case study. The paper concludes with recommendations for future research.

PROJECT EVALUATION

Construction largely is a one-of-a-kind business, and almost every project is a prototype. Evaluating the outcome of an individual project can be challenging, and comparing projects to each other is even more difficult. Meaningful project evaluation and comparison in terms of cost and value has, by its nature, been a subjective undertaking. The idea that project evaluation has been subjective is less important than the fact that the subjectivity has had no basis for consistency.

A project typically is judged in part on the basis of budget and schedule performance. In most instances, a project's construction manager or constructor has significant influence in establishing the budget and schedule, so even though a project's outcome may be impressive against these metrics, there is little assurance that the original benchmarks were appropriate. Changes in scope during the execution of the project and the impact of unforeseen conditions also make a direct comparison of project outcomes to original project criteria of limited value.

Projects also are compared against each other. This is generally done on a cost-per-square-foot basis. Differences in reported costs for an individual project and the variability among program and other characteristics make this type of analysis interesting, but of little practical use.

Lack of valid project evaluation can critically handicap the conceptual estimating efforts used for appropriation level estimates. The timing of these financial evaluation efforts often dictates that they be completed with a limited amount of information. Lacking a better method, cost-estimating efforts generally fall back on an evaluation of a similar project or group of projects on the basis of cost/sf. Even if a fairly extensive database of project information exists, this method is fraught with risk. The project development team is left to begin the design and construction process with a firm budget but with limited project scope description or assurance that the budget is appropriate.

In addition, a basic tenet of Lean Project Delivery is the ability to verify continuous improvement. In order to do this, a method for evaluating the effectiveness of the project delivery process is required. The system of evaluation often must compare the relative value of projects that have only marginal similarities. More specifically, a comparison of relative benefit in relation to cost is needed. The task is defined as calculating a project "benchmark index," measuring the nature and quality of a project that is directly related to the project cost.

Working from an assumption that such a relationship does exist and that it can be calculated, the conceptualized nature of the relationship would be as shown in Figure 1. Each incremental increase in the "Project Benchmark Index" (PBI) would imply an incremental increase in cost. For projects with the same PBI, the lower cost project would have the higher value. If projects have the same cost, higher PBI would correlate to higher value.

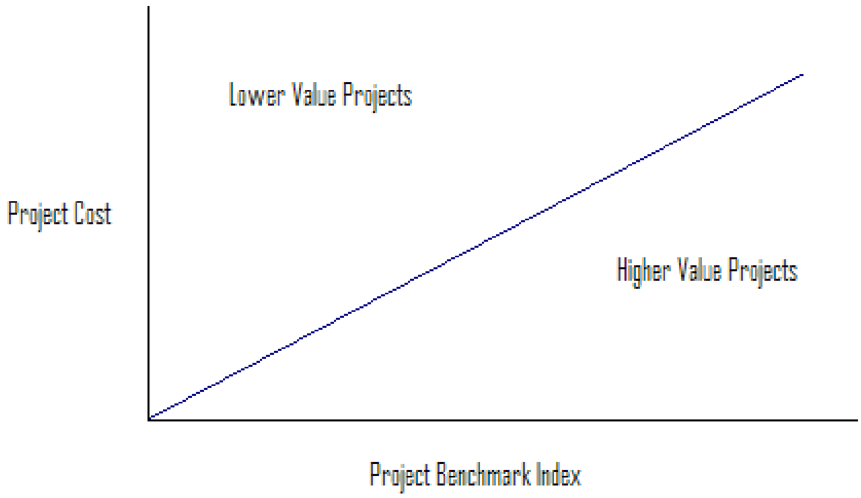

Figure 1: Project Benchmark Index

PROJECT COST CALCULATION

Calculating project cost for comparison requires a standard method. For this evaluation, the cost includes building construction cost only and is calculated on a cost per unit of area. Site development cost, including mass site excavation and extraordinary soil retention or foundation requirements have been excluded. Special building systems, such as security systems, design costs and other project "soft costs," also have been omitted from the evaluation.

To the extent possible, costs should be compared on an equal basis and should be adjusted for historical cost indexes. Local permits, fees, sales tax rates and their applicability also must be considered as these variables are not influenced by the design or the construction of the project.

Project costs are affected by a locality's relative costs for materials and labor. These differences can be defined by a company's own data or by utilizing one of the many publications that evaluate construction cost differences by city or region. Consistency is more important than which method is used.

Contractual issues also should be accounted for and necessary adjustments to equalize costs made. Differences due to bonding requirements and fee levels should be negated.

PROJECT BENCHMARK CALCULATION

Several factors define a project's nature and must be evaluated to determine the PBI. The specifics of these factors must be determined for each type of project, but in general, the factors are: functional program; project size; building quality factors; site conditions; and local construction requirements and code issues. The calculation of project PBI does not need to be complicated. As with project cost analysis, consistency of methodology is the most significant requirement.

The relative intensity of a building's program is the principle driver the PBI. If all other project attributes were equal, the building program would be the only factor required and the sole determinate of cost. The program elements' relative intensity is determined by evaluating the cost of constructing each program element with all other factors equalized. A representative sampling of program element intensity factors for healthcare construction is shown in table 1.

Table 1: Element Intensity Factors

Central Sterile Processing	1.90
Central Storage	0.53
Emergency	1.16
General Clinic	0.84
Radiology	1.65
Surgery	1.80

A building's overall program intensity can be calculated as a weighted average of all individual program areas in the project.

$$\frac{\sum \text{(program factors x program areas)}}{\text{Total building area}} \quad \text{(Equation 1)}$$

Project size also should be considered in determining the PBI. Other factors being equal, a larger project with greater repetition of spaces and components will be constructed more economically than a smaller one with less repetition. This difference in costs does not reflect a variation in value. From a given baseline area, the impact (greater cost) of the economy of scale of a project increases relatively quickly as the project area approaches 0, and will be less dramatic (lower cost benefit) as the project size increases. Based on empirical data, this variation can be approximated by an increase or decrease in project cost of 3% as the project size is reduced by half or doubled.

$$\text{Size Factor} = \log_2(\text{project area / baseline area}) \times 0.03 \quad \text{(Equation 2)}$$

There are many ways of constructing a building to accommodate a particular program. The design and selection of the materials and systems used to create a building's structure, exterior enclosure, interiors, and mechanical and electrical systems impact the value of the facility. Life expectancy of the facility, operation and maintenance costs, and the image of the facility are factors that may be important to the building owner but are unrelated to program function.

The broad categories included in the evaluation are: *building type; exterior enclosure; interior finishes; and plumbing, mechanical and electrical systems.* These components typically account for 75 – 80% of a projects cost. They also account for the highest percentage of a project's constructed variability.

In order to evaluate the range of potential impact that each of these elements contributes to the overall project cost, definitions need to be created. Building type is less dependent on preference than are the other attributes. The ratings categories used are: *wood-framed; unprotected steel frame; two-hour rated construction; and high-rise construction*. Each of these levels of construction has appropriate applications and related benefits and costs.

In addition to level of quality and image, the remaining building subsystems are affected by the building's configuration and by program, engineering and code requirements. For each subsystem, four levels of quality were established: *economy; standard; high; and premium*.

The nature of the building site also can have a great deal of cost impact on the project. The variability ranges from a new building on a greenfield building site to a phased in-place renovation of single or multiple existing departments. This is considered a value comparison as opposed to strictly a cost issue, due to the benefit that may be achieved by the building owner. Requirements to maintain appropriate adjacencies play a large part in decisions about where a project will be constructed. The evaluation levels defined for this aspect of project delivery were: greenfield construction; *limited access; restricted access; and severely restricted access.*

Requirements due to local geologic and environmental conditions comprise the final category of evaluation factors. Buildings constructed in a location with a high or very-high risk for earthquakes have very different requirements than those constructed in low-risk areas. If the nature of the building is such that it must be self-sustaining in a major earthquake event, the demands are even greater. Likewise, buildings constructed in a temperate climate have less severe requirements that those constructed in areas that have more extreme climates. These factors affect the complexity of the constructed systems and, therefore, the relative cost for buildings of similar value in terms of comfort, quality, and image characteristics.

For each of the attributes listed above, the factors for the range of constructed value should represent the range of costs that will be experienced as the component quality increases from *economy* to *premium*. The factors can be determined by conceptualizing the systems that meet the definitions for each level and calculating the effect as a percentage of overall project cost each will impose on the project. The PBI is the product of the factors assigned to the different levels for each of the listed attributes.

Figure 2 includes the results of the initial study performed for nine projects completed for the ThedaCare Health System in Wisconsin.

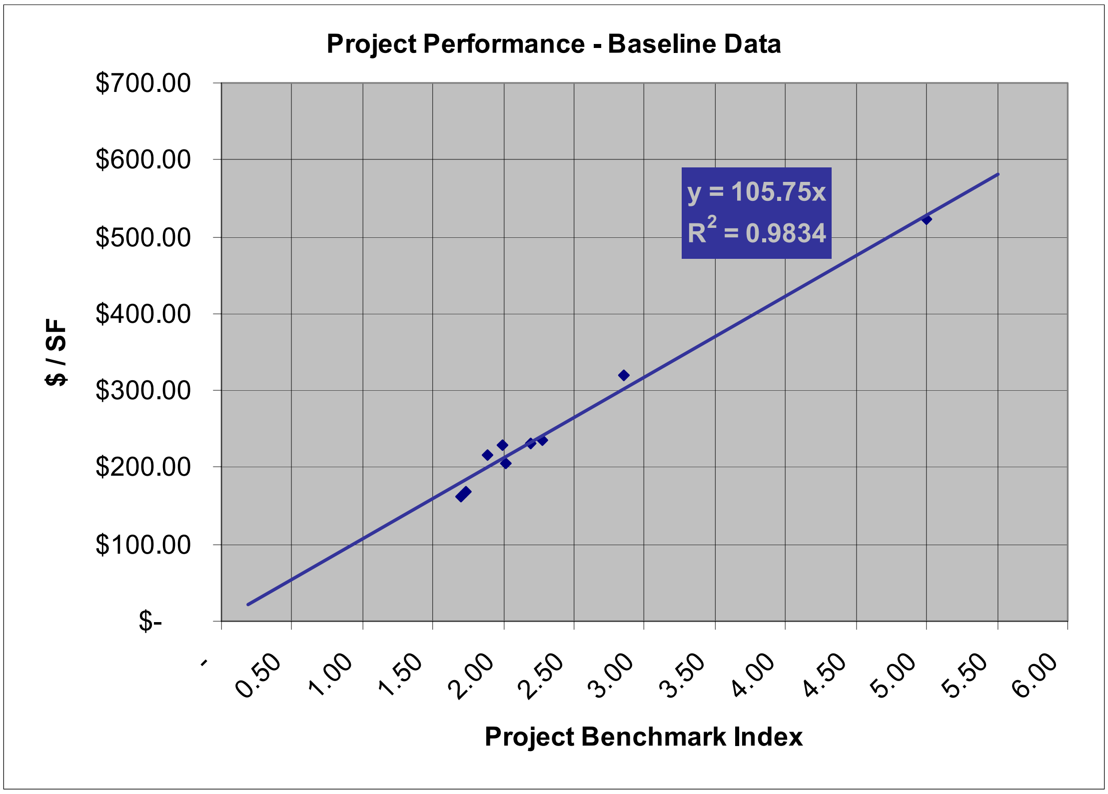

Figure 2: Baseline Data

In this graph, the trend line is forced through the point (0.0, $0.00), implying that a project with no program or attributes will have no cost. Since the standard formula for a line of is $y = mx+b$, m can be shown to be the expected cost multiplier for a project with a PBI of x and an equalized cost per square foot of y. The reliability of m as the cost factor is indicated by the square of the Pearson Product for the given values of x and y. The R^2 value can be interpreted as the proportion of the variance in y attributable to the variance in x. An R^2 value of 1 is the highest value of correlation and -1 the lowest. In this sampling of projects, $R^2 = 0.9834$.

THE VALUE INDEX

The cost factor for a particular project can also be calculated from the standard line formula m = y/x where y is the equalized cost per square foot and x is the PBI. Comparing the cost factors for the individual projects provides an indication of the relative value achieved. In order to maintain a consistent comparison, a value index was created. The *Value Index* is a comparison to the original m_{avg} calculated for the baseline projects, it is adjusted for cost escalation and is calculated as:

$$\text{Value Index} = \frac{\text{Baseline } m_{avg}}{(\text{Project } m)} \times \frac{(\text{Current Cost Index})}{(\text{Initial Cost Index})} \quad \text{(Equation 3)}$$

In this study, the current cost index used is *R.S. Means Quarterly Construction Cost Data* published by Reed Construction Data. The initial cost index is the cost index used for the calculation of Baseline m_{avg}.

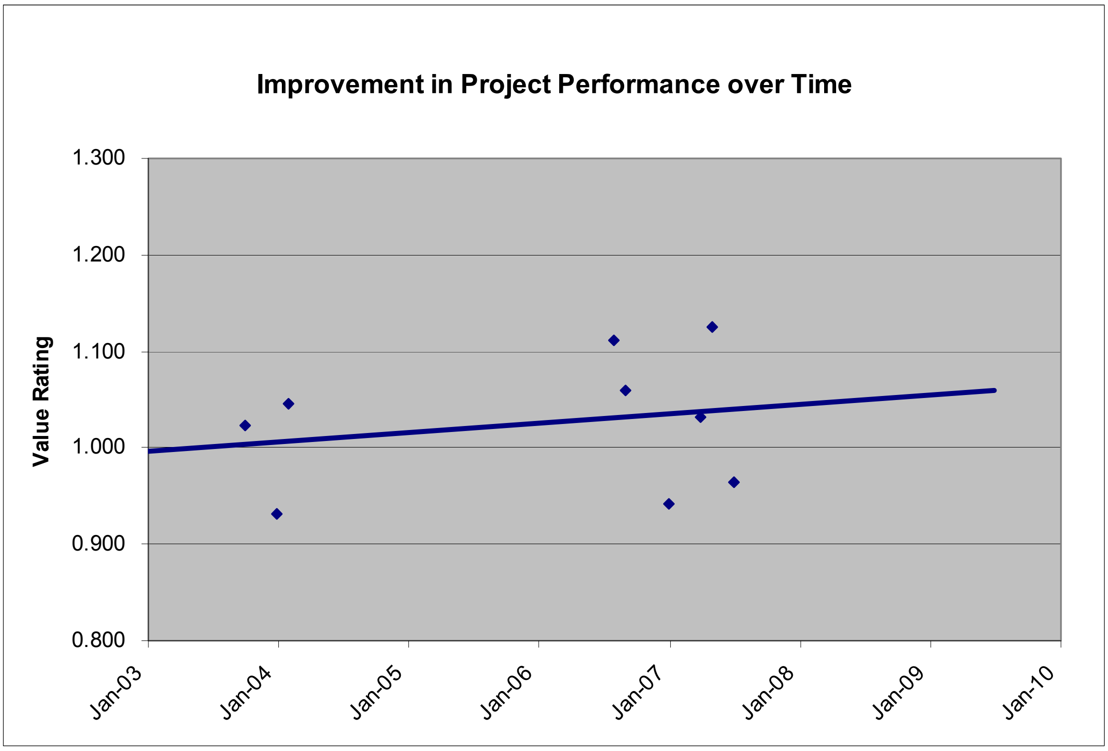

Figure 3: Improvement over Time

Graphing the value index for the nine initial projects – with the value ratio on the y axis and the completion date on the x axis – provides evidence that the outcomes for the projects constructed for ThedaCare have improved by approximately 1% per year for projects completed from 2003 through 2008 (Figure 3). Maintaining the demonstrated improvement over time for a larger sampling of projects has been set as a key metric in the ThedaCare's project delivery team's self evaluation. The addition of five additional projects to the evaluation, including two that will be completed by mid-2009, helps to confirm this annual performance improvement (Figure 4).

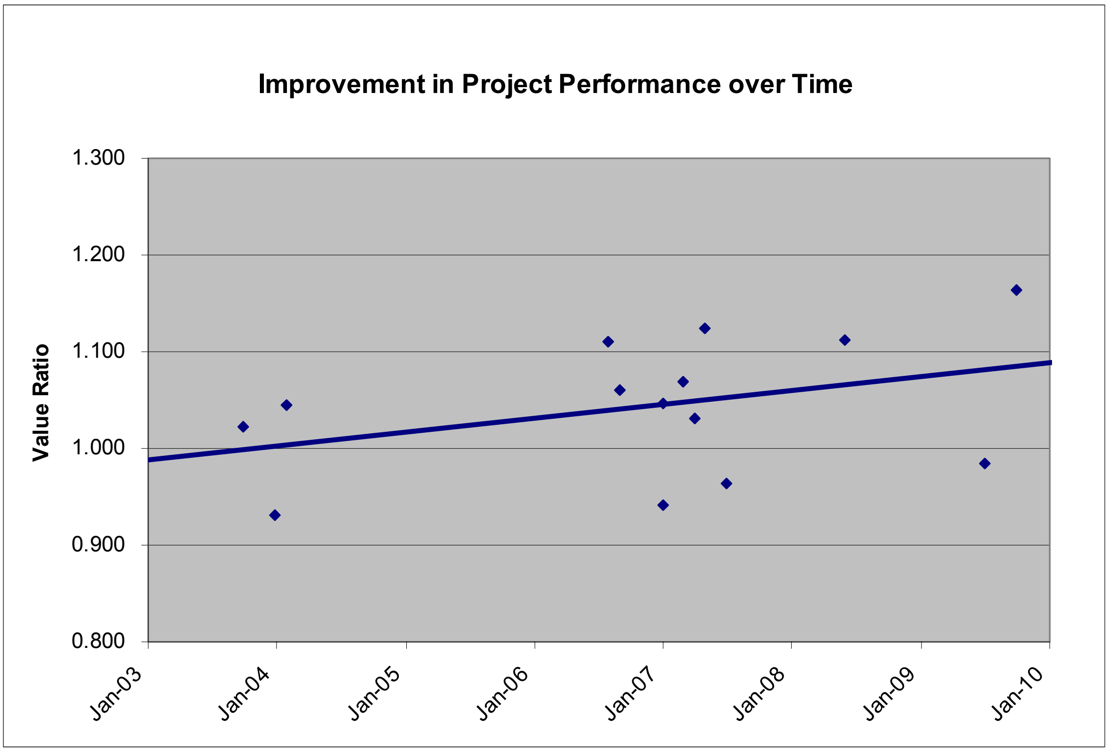

Figure 4: Improvement over Time

USING THE PBI IN COST MODELING

Since the PBI for a building project does not depend on the stage of project completion, it can be calculated or estimated at any stage of project conceptualization, design or construction. It also can be used to develop a cost model that is specific to the project program, quality factors, and site and locality characteristics. Although it may be necessary to approximate the project program intensity in the very early evaluation of the project business case, all other attributes in the calculation can be selected and, if desired, modified to generate a cost model that will satisfy the business case requirements. Knowing the PBI, the estimated construction cost is calculated as:

$$\text{Projected cost} = \text{PBI} \times \text{Baseline } m_{avg} \times \frac{\text{(Current Cost Index)}}{\text{(Initial Cost Index)}} \div \text{Value index} \quad \text{(equation 4)}$$

The value index should take into account the anticipated improvement in project performance over time. This projected improvement sets a target cost that is below the historical baseline, requiring the project team to continue to seek opportunities to improve performance or eliminate waste in the process.

CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

The Project Baseline Index has been shown to be an accurate and feasible method for determining expected cost directly from customer requirements. It also provides a way to set targets for improvement over time in the cost of facilities with various index ratings in the PBI.

Future research is needed to confirm these initial findings with additional data points and clients, and also to extend the PBI to other types of constructed facilities beyond healthcare. Research is also needed to understand the differences and similarities of the PBI to Haahtela's TaKu method[4]—the two methods thus far found to be adequate to the demands of target value design. Do the two methods achieve similar results, but through different processes? Is one superior to the other, either universally or in specific circumstances?

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[4] Pennanen & Ballard, 2008