TARGET VALUE DESIGN AS A METHOD FOR CONTROLLING PROJECT COST OVERRUNS

Doanh Do[1], Chao Chen[2], Glenn Ballard[3] and Iris D. Tommelein[4]

ABSTRACT

Since its introduction in 2002, Target Value Design (TVD) has become more commonly used and accepted by the construction industry in the United States. Several researchers have reported that TVD projects are good at maintaining a predictable project cost and controlling cost overruns. The case studies, reported in the literature, show that TVD projects have generally been completed at 15% to 20% below market price without compromising schedule or quality. Little research, however, has been conducted to generalize the findings to the wider population of TVD projects. No statistical analysis has been conducted to compare TVD projects with projects that do not use TVD. In this paper, we present the results of several statistical analyses on a sample set of 47 TVD projects. We compared cost overrun (spent-budget ratio) and contingency percentage of these TVD projects with a dataset of non-TVD projects from the Construction Industry Institute. The results show that TVD projects are less likely to go over budget even though the contingency of TVD projects is less than that on non-TVD projects. A theory is introduced to explain the findings from the statistical analysis. The theory and the findings were presented to industry leaders in the AEC industry and their feedback was incorporated into this paper.

KEYWORDS

Target Value Design, Lean Construction, Target Costing, Cost Overrun

INTRODUCTION

Target Costing is a management practice that has been used in Japanese manufacturing for profit planning since the 1980s (Monden and Hamada 1991, Cooper and Slagmulder 1997). Nicolini et al. (2000) reported the use of Target

[1] PhD Student, Civil and Environmental Engineering. 407 McLaughlin Hall, Univ. of California, Berkeley, CA 94720-1712, USA, Phone +1 (714) 622-9754, doanhqdo@berkeley.edu

[2] PhD Candidate, Civil and Environmental Engineering. 407 McLaughlin Hall, Univ. of California, Berkeley, CA 94720-1712, USA, Phone +1 (510) 816-0766, chaochen@berkeley.edu

[3] Research Director of the Project Productions Systems Laboratory (p2sl.berkeley.edu), 215-A McLaughlin Hall, Univ. of California, Berkeley, CA 94720-1712, USA, Phone +1 (510) 530-8656, ballard@ce.berkeley.edu

[4] Professor, Civil and Environmental Engineering Department, and Director of the Project Production Systems Laboratory (p2sl.berkeley.edu), 212 McLaughlin Hall, Univ. of California, Berkeley, CA 94720-1712, USA, Phone +1 (510) 643-8678, tommelein@ce.berkeley.edu

Costing in the construction industry. Unfortunately, the application was not successful: a number of commercial practices and deficiencies in developing accurate cost estimates prevented the UK construction industry from effectively adopting Target Costing (Nicolini et al. 2000).

Target Value Design (TVD) is an adaption of Target Costing to the AEC industry. Ballard and Reiser (2004) documented the first successful TVD project in the United Stated. Since its introduction, TVD has become more commonly used and accepted by the construction industry in the United States. Several researchers have reported that TVD projects have been completed at 15% to 20% below market price without compromising schedule or quality (Ballard and Rybkowski 2009; Zimina et al. 2012). Ballard (2006) hypothesized that implementing Target Costing reduces the uncertainty of the project ends and means, which will in turn reduces the contingency required to absorb variability.

In this paper, we present several statistical analyses on a sample set of 47 TVD projects. We compared cost overrun and contingency percentage of TVD projects with a dataset of non-TVD projects from the Construction Industry Institute (CII). The results show that compared to non-TVD projects, TVD projects are better at controlling cost overruns and carry less contingency as a percentage of project cost. On the basis of our analysis, we introduce a theoretical model to explain these findings.

METHODOLOGY

This study examines the following hypotheses:

1. The implementation of TVD does not affect the likelihood and magnitude of project cost overrun.
2. The implementation of TVD does not reduce the contingency percentage in project budget.

VARIABLE DEFINITIONS

The purpose of this research is to evaluate the role of TVD in controlling project cost performance. Project cost performance can be measured from many different perspectives. This study defines the following metrics:

$$\text{Spent-budget ratio} = \frac{\text{Project actual cost}}{\text{Project budget}} \qquad \text{(equation 1)}$$

The spent-budget ratio measures the project cost overrun or underrun. A ratio greater (less) than 1 indicates that a project spent more (less) money than its original budget. Spent-budget ratio is a commonly-used measurement for cost performance and is among the top management priorities for every project manager.

$$\text{Contingency percentage} = \frac{\text{Total amount of contingency in project budget}}{\text{Total project budget}} \qquad \text{(equation 2)}$$

Contingency percentage is a measure of the proportion of contingency in project budget. A higher percentage means more contingency per a certain amount of project budget. Contingency percentage is a measurement for project cost performance that reflects the confidence level of risk management.

DATA SOURCES

The statistical analysis in this paper is based on data from two sources: (1) the Construction Industry Institute (CII) and (2) two healthcare organizations that implemented TVD on their projects.

The CII Benchmarking & Metrics program uses an online survey and asks CII member companies to report their project data and performance. All projects in the CII database are either reported by owners or contractors. These projects typically use traditional project delivery methods such as Design-Build, Design-Bid-Build, and CM at risk. To the best of our knowledge, they did not apply TVD.

In order to keep the homogeneity of the data, only the owner-reported projects from CII were analyzed. We filtered the CII database (which contains over 1900 project) to include only "hospital", "laboratory science", and "pharmaceutical secondary manufacturing" projects because they are the most comparable to the dataset of TVD healthcare construction projects. Finally, 180 projects were selected from the database spanning from September 29, 1995 to July 17, 2010, which met these criteria. Of these 180 projects, 168 (3 hospital; 97 laboratory; 68 pharmaceutical) contained data on the spent-budget ratio and 134 (0 hospital; 73 laboratory; 61 pharmaceutical) contained contingency data.

The TVD project data were provided by two healthcare owners: Company X and Company Y. Forty-seven TVD projects were completed by Company X between 2008 to 2013. These projects range in total cost from $100,000 to over $17 million. The dataset from Company X includes the allocated funds at the start of the project and the total cost at the end of the project. This dataset was used to test our first hypothesis that TVD projects are better at controlling cost overruns. Since contingency data was not available within the Company X's dataset, we collected contingency data from 9 TVD projects from Company Y delivered within the same time span. Based on interviews, we concluded that the contingency percentages of the two companies are similar.

Since all data used in the statistical analysis are owner reported, we are able to remove some biases that might skew the results. First, since different construction and design companies participated on these TVD projects, the results show that to some degree the effect of using the TVD method rather than the technical capabilities or managerial practices of these companies. Second, since the TVD projects from Company X are spread throughout the United States, the findings can be generalized to a broader geographic region.

Note that TVD projects typically use Lean Construction methods and tools, e.g., the Last Planner™, Choosing By Advantages, A3, Set-Based Design, Value Stream Mapping, 5S, etc. (Ballard 2011). Both Company X and Company Y have been active members of the Lean Construction Institute (LCI) since 2007 and 2004 respectively. As a result of their involvement with LCI, the two owners have required that architects, contractors, and subcontractors be trained in and use Lean Construction methods and tools on their projects. Additionally, TVD has been used with either with Design-Build or Integrated Project Delivery (IPD). Practices such as co-location and big-room meeting are more common on TVD projects than non-TVD projects.

Limitations of this study include: (1) no data was available about how TVD was implemented (i.e., the extent to which TVD application followed the prescribed TVD process benchmarks (Ballard 2011)), (2) it is unclear from the dataset whether or not non-TVD projects used Lean Construction methods and tools, (3) other tools and practices such as IPD, co-location, and BIM may also affect the project performance, (4) owner reported data from the CII may be skewed and not truly reflect the industry average, (5) TVD being a new practice, companies may intentionally place their best people on TVD projects and thus skew the performance data.

It is important to note that the comparison contains several degrees of nuances and it is difficult to draw a clear-cut line. Despite the aforementioned limitations listed, a comparison of TVD vs. non-TVD projects can still contribute to the knowledge by using quantitative evidence to link project performance with the practice of TVD. The results of the statistical analyses can be used to guide the direction of further research into TVD.

STATISTICAL METHODS

We used a combination of statistical tools and techniques in this study to investigate the research hypotheses. The data analysis was conducted in the statistical programming language R (www.r-project.org).

For explanatory data analysis (EDA) purposes, we developed boxplots and scatterplots to visualize project data and identify patterns. To compare the TVD and non-TVD projects, we conducted three statistical tests, namely Student's t-test, Mann-Whitney U test (Mann and Whitney 1947), and Kolmogorov-Smirnov (K-S) test (Kolmogorov 1933, Smirnov 1948).

A Student's t-test is often used to check the equality of two group means (Harper 1984). It is used in this study to compare the cost overrun and contingency percentage between TVD and non-TVD projects. A significant p-value indicates the difference in cost overrun or contingency percentage between the two types of projects, in other words, implementing TVD affects project cost performance.

In order to get reliable results from a t-test, several conditions need to be satisfied. They include (1) normality, (2) same variance for two samples, and (3) simple random sample condition (the data were sampled independently from the population). The two samples in this study differ largely in size and variance. To accommodate this, we conducted a Welch Two Sample t-test (Welch 1947), which is insensitive to equality of the variances or sample sizes.

To account for the normality assumption, we used the Mann-Whitney U test to complement the t-test. The Mann-Whitney U test is a nonparametric test of the null hypothesis that two samples have the same population. The Mann-Whitney test is more robust than the t-test on non-normal distributions and any potential outliers (Lehamnn 1999), and therefore works as a good complement to the t-test.

To add more credibility to this analysis, we also conducted the Kolmogorov-Smirnov test, which is one of the most useful and general nonparametric methods for comparing two samples. It tests the equality of two continuous, one-dimensional probability distributions. In this study, these are the distributions of cost overrun and contingency percentage for TVD and non-TVD projects.

In practice, it is very difficult to justify that samples are simple random samples from the population. Efforts were made to make sure that the datasets used were as close to independent samples as possible. By using not one but three statistical tests, the reliability of the findings will be enhanced.

RESULTS AND DISCUSSION

Table 1 shows a summary of the datasets on cost overruns and contingency. TVD projects, on average, have a lower ratio of spent-budget funds, a lower standard deviation, and a tighter range of the spent-budget ratio. Of the 47 TVD projects studied, the worst project had a cost 7.3% over budget and the best project had a cost 25% below budget. The CII healthcare dataset shows that the worst project had a cost 70% over budget and the best project had a cost 42% below budget. This suggests that the final cost of TVD projects is more likely to be close to the project budget.

Table 1: Summary table for Spent-budget ratio and Contingency percentage

		Sample size	Mean	Standard deviation	Range
Spent-budget ratio	CII (health care)	168	0.986	0.132	0.584 – 1.702
	TVD (Company X)	47	0.946	0.071	0.752 – 1.073
Contingency percentage	CII (health care)	134	0.079	0.035	0.013 – 0.254
	TVD (Company Y)	9	0.035	0.005	0.03 – 0.043

According to the results of the statistical analysis, the average spent-budget ratio for TVD is 0.946. At first this may seem contradictory to the reported results from the literature that TVD projects have been delivered 15% to 20% below market price (Ballard and Rybkowski 2009; Zimina et al. 2012). The spend-budget ratio for TVD is not necessarily related to the final cost of the project relative to the market price. Typically, the TVD process starts at the beginning of the project definition phase where the owner determines the worth of the project (allowable cost) and the constraints (e.g., schedule and cost). The Target Cost is set below the Market Price to spur innovation (equation 3). During the design stage, the project's design is steered so as to meet its constraints (the Target Cost is one such constraint). During the Design Development (DD) phase, the TVD team and the owner agree on a budget for the project. The spent-budget ratio is the ratio of the final cost relative to the established budget.

$$\text{Allowable Cost} \geq \text{Market Price} \geq \text{Target Cost} \qquad \text{(equation 3)}$$

One possible explanation for the lower ratio of spent-budget funds is that perhaps TVD projects carry more contingency than non-TVD projects. A higher contingency may buffer the initial cost estimates and result in more projects delivered under-budget. To test this hypothesis, we compared the contingency data from TVD and non-TVD projects (Table 1). Our findings show that TVD projects carry on average 3.5% construction contingency while projects that do not use TVD carry on average 7.9% construction contingency. The range and standard deviation of project contingency was also less for TVD projects (Figure 1).

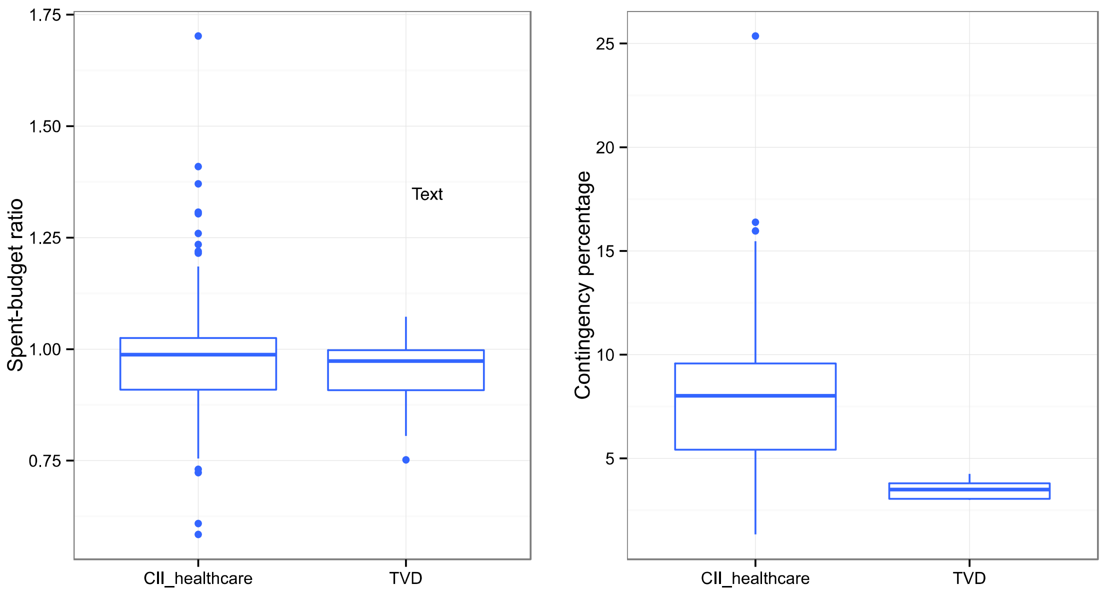

Figure 1: Boxplot of Spent-budget ratio and Contingency percentage

Table 2 shows the statistical analysis of the dataset. P-values less than 0.05 indicate a strong statistical significance. In both the spent-budget ratio and the contingency percentage, all three statistical tests show a strong significance between the two datasets.

Table 2: Statistical test results summary

		Student's t-test	Mann–Whitney U test	K-S test
Spent-budget ratio	Test statistic	t = 2.6985	W = 4697	D = 0.2567
	p-value	0.0039	0.024	0.0079
Contingency percentage	Test statistic	t = 12.22	W = 845	D = 0.8731
	p-value	0	0.0002	0

Figure 2 shows no correlation between project size (measured by total project budget) and cost overrun ratio detected for either TVD or non-TVD projects. The Pearson correlation coefficient for TVD projects is 0.138 with a p-value 0.355. These results show that the likelihood of cost overruns on TVD projects is not affected by project size.

INTERVIEWS

We conducted supplemental interviews with TVD project participants to fill in the gaps from the statistical analysis. We interviewed 5 participants on a TVD project from Company X and 5 participants on a TVD project from Company Y. The interviews lasted between 30 minutes to 1 hour each. The participants includes: two owners, one project executive, two project managers, two architects, one mechanical subcontractor, one electrical subcontractor, and one structural engineer. The interviews confirmed the findings from the statistical analysis. Industry practitioners agreed that one of the biggest advantages of TVD is the method's ability to control the project's budget. Instead of cost becoming an outcome of design, it is a design constraint that is considered early on. The early involvement of trade partners during the design leads to better coordination, better thought-out plans, and fewer questions in the field.

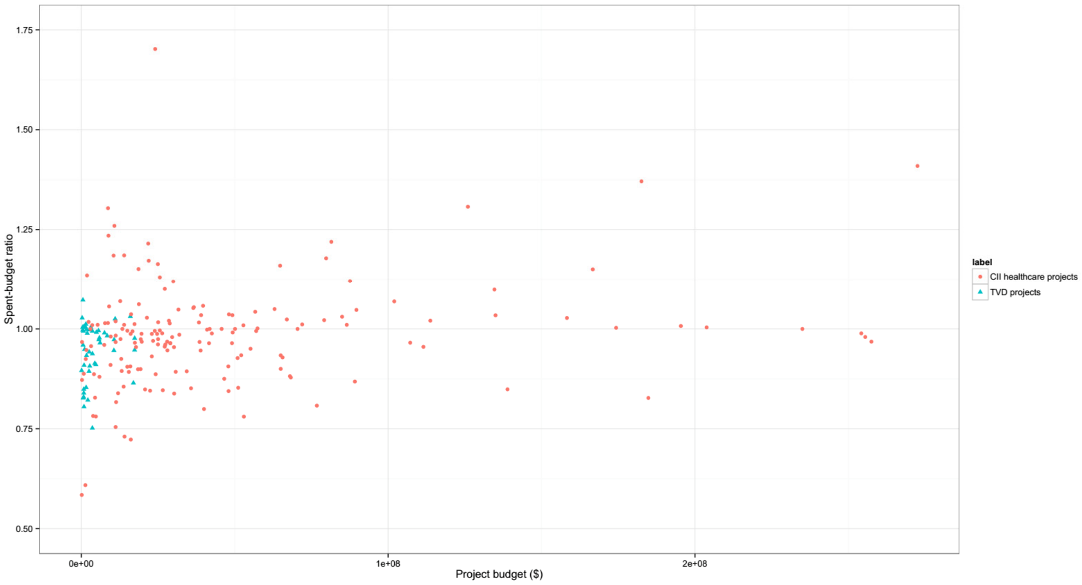

Figure 2: Spent-budget ratio for various project sizes

Based on the interviews, we developed a theoretical model to explain the findings of this research; i.e., why TVD projects are better at controlling cost overruns and require less contingency than non-TVD projects.

THEORETICAL MODEL

Figure 3 shows the breakdown of a project's costs. The total project cost includes: the cost of work, contingency, and profit. The cost of work can be further broken down into direct- and indirect cost; it is the sum of all the participant's costs of work.

Compared to projects that do not use TVD, less contingency was required on TVD projects because the entire project contingency was pooled together instead of being carried individually by each participant. By pooling the contingency together, the project team needs to allocate less contingency to cover the same amount of uncertainty in the project. This reduction in contingency can be explained by the central limit theorem where, given the same level of uncertainty, if the buffers are separated then a larger sum of the buffers is required.

On all projects, a number of forces are likely to drive up the total cost. These forces include uncertainty, miscommunication, missing details, miscoordination, change orders, lack of trust, litigation, etc. When these forces drive up the total project cost, cost overrun naturally results since there are few, if any, incentives from the team to reduce the actual cost of work.

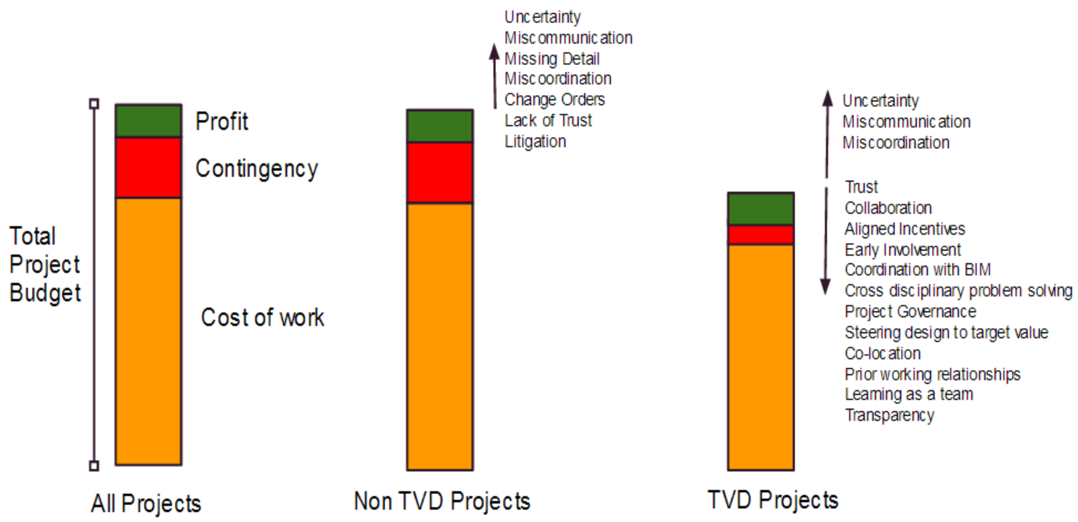

Figure 3: Cost control mechanisms

Under *Spearin vs. United States* (1918), the contractor is not liable for missing details in the construction documents and can increase the cost of the project (and his profits) by issuing change orders. Designers and architects adhere to a Standard of Care in which they must provide a level of service that is reasonable for their profession (Sweet and Schneier 2009). Since designers are typically compensated by a time-and-materials contract, they have no skin in the game. The incentive system for designers and contractors is fragmented, not aligned with the owner's interest, and does not promote cost savings. As a result, missing details and miscommunication between the participants are, out of necessity, often paid for by the owner. TVD incentivizes the team to reduce cost by using a shared pains and gains mechanism (Lichtig 2006; Ballard 2011). The observed projects either used Design-Build or Integrated Project Delivery (IPD), which enables more collaboration, early involvement of the contractors, co-location, Building Information Modeling (BIM) etc.

In Newtonian physics, the sum of the forces is equal to the change in momentum (momentum p is the mass times velocity, or $p = m \times v$) over time ($\sum F = \frac{dp}{dt}$). We argue that a similar equation can be applied to construction cost ($\sum F = \frac{dc}{dt}$). In this situation, the sum of forces is equal to the change in cost over time. A number of forces can drive up and a number of forces can drive down the project cost. TVD promotes the use of Lean tools and behaviors that drive down the project cost while non-TVD projects might not explicitly reinforce those forces. It is important to note that some of the forces that can drive up the cost of the project still exist on TVD projects and that TVD does not completely remove all risks of cost overruns. Forces such as miscommunication, miscoordination, and uncertainty are inherent in every project. With TVD, the forces that drive down the cost can counteract those that drive up the cost. Forces such as trust and collaboration can work in both ways and can either increase or decrease the project cost. The magnitude of each of the forces will depend upon the team's experience and capabilities and can vary from project to project. Ultimately, the sum of the forces determines the direction of movement and theoretically the project cost can either increase or decrease over time.

This model also proposes that the project cost is not predestined to take on a certain value. At any point in the project opportunities always exist to decrease the project cost; although the impact of changes in later phases may have less of an impact than changes in the earlier phases of the project.

CONCLUSION

In this paper we were able show the following results through statistical analysis:

1. The implementation of TVD reduces the likelihood of cost overrun.
2. The implementation of TVD reduces the contingency percentage in project budget.

Additionally, we were able to show that the project cost overrun was the same for large and small projects for both TVD and non-TVD projects. This suggests that TVD can be applied to projects of all sizes. We proposed a theoretical model to explain the results of the statistical analysis. Our model suggests that Lean tools and behaviors are the drivers of cost reductions on TVD projects. The implication of this research is that collaboration, alignment of incentives, and shared risks may be suitable for managing the risk of project overruns.

LIMITATIONS

Limitations of this study include:

The TVD projects in the sample had significantly smaller budgets than the non-TVD projects (Figure 3). Factors such as complexity and uncertainty, which can increase with project size, may not be taken into account.

There is no data about how TVD was implemented (we relied on the owner reported information about TVD application).

The dataset from the CII database included hospital, laboratory sciences, and pharmaceutical secondary manufacturing projects, which were chosen because they are most similar to healthcare construction projects. The extent to which this is a fair comparison is a limitation of this research.

It is unclear from the dataset whether or not non-TVD projects used Lean Construction methods and tools.

Other factors such as IPD, co-location, and BIM may also affect the project performance.

Owner reported data from the CII may not truly reflect the industry average.

As a new practice, companies may intentionally place their best people on TVD projects and thus skewing the performance data.

The proposed model was based on research of private healthcare construction projects and therefore may or may not be applicable in other areas of construction.

The proposed model was based on interviews with project participants (architects, engineers, contractors, and trade partners) who are at the end of the supply chain. The extent to which this model can be extended throughout the supply chain is an area for future research.

ACKNOWLEDGMENTS

We would like to thank the Construction Industry Institute for making their data available for the analyses presented. We would also like to thank the members from the UC Berkeley Project Production Systems Laboratory's Target Value Design Research Group for their financial support and participation in this study. The members of this P2SL TVD Research group include ACCO, Berg Electric, Boulder Associates, Capital Engineering, DPR Construction, Degenkolb, Devenney Group, The Engineering Enterprise, Forell Elsesser Engineers, HGA, KPFF Consulting Engineers, Herrick, Johnson Controls, JW McClenahan, Rosendin Electric, Rutherford Chekene, Southland Industries, and Superior Air Handling. For more information about the P2SL TVD Research Group please visit p2sl.berkeley.edu.

REFERENCES

Ballard, G. (2006). "Rethinking Project Definition in terms of Target Costing." Proceedings of the 14th Annual Conference of the International Group for Lean Construction (IGLC-14), Santiago, Chile, July, 77-90.

Ballard, G. (2011) "Target Value Design: Current Benchmark." Lean Construction Journal, 79-84. www.leanconstructionjournal.org

Ballard, G. and Reiser, P. (2004). "The St. Olaf College Fieldhouse Project: A Case Study in Designing to Target Cost." *Proc. 12th Annual Conference of the International Group for Lean Construction* (IGLC-12), Elsinore, Denmark.

Ballard, G., and Rybkowski, Z.K. (2009). "Overcoming the Hurdle of First Cost: Action Research in Target Costing." *2009 Construction Research Congress*, ASCE, Seattle, WA, 1038-1047.

Cooper, R. and Slagmulder, R. (1997). *Target Costing and Value Engineering*. Productivity Press, Portland OR.

Harper, J.F. (1984). "Peritz'F-test: basic program of a robust multiple comparison test for statistical analysis of all differences among group means." *Comput. Biol. Med.* 14:437-445

Kolmogorov A. (1933). "Sulla determinazione empirica di una legge di distribuzione." *G. Ist. Ital. Attuari* 4: 83-91.

Lehamnn, E.L. (1999). *Elements of Large Sample Theory*, Springer.

Lichtig, W. (2006). "The Integrated Agreement for Lean Project Delivery." *Construction Lawyer,* 26 (3)

Mann, H.B. and Whitney, D.R. (1947). "On a Test of Whether one of Two Random Variables is Stochastically Larger than the Other." *Annals of Mathematical Statistics* 18 (1): 50-60.

Monden, Y. and Hamada, K. (1991). "Target Costing and Kaizen Costing in Japanese Automobile Companies." JMAR Volume 3. Fall.

Nicolini, D., Tomkins, C., Holti, R., Oldman, A. and Smalley, M. (2000) "Can Target Costing be Applied in the Construction Industry?: Evidence from Two Case Studies." British Journal of Management, 11 (4) 303-324.

Smirnov, N. (1948). "Table for estimating the goodness of fit of empirical distributions." Annals of Mathematical Statistics 19:279-281.

Spearin v. United States, 248 U.S. 132 .1918

Sweet, J. and Schneier, M.M. (2009). *Legal aspects of architecture, engineering, and the construction process.* 8th Ed., Cengage Learning, Stamford, Conn.

Welch, B.L. (1947). "The generalization of "Student's" problem when several different population variances are involved". *Biometrika* 34 (1-2) 28-35.

Zimina, D., Ballard, G., and Pasquire, C. (2012). "Target Value Design: Using Collaboration and a Lean Approach to Reduce Construction Cost." Construction Management and Economics, 30(5), 383-398.