IMPACT OF COST CONSTRAINTS ON AESTHETIC RANKING FOLLOWING TARGET VALUE DESIGN EXERCISES

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PURPOSE: Target Value Design (TVD) is a project delivery subset that shares methodologies with Target Costing and Value Engineering, but is performed within the context of lean construction. TVD has been shown to generate first cost savings of approximately 20% on case study projects. A concern voiced by some architects, however, is that TVD may produce aesthetically inferior designs. Addressing this concern, we explore whether there is a relationship between cost and aesthetics.

METHODOLOGY: Eighteen postgraduate-level university students were asked to design a functional wine stand using a restricted pallet of materials—Styrofoam cups and plates and 8 1/2” x 11” sheets of paper within one hour—(a) without cost constraints and (b) with cost constraints. The resulting wine stands were photographed and then graphically rendered to remove confounding variables, permitting comparisons between them. Over one hundred twenty subjects were surveyed and asked to rank the stands according to their preferences. Ratings were then correlated with costs using Spearman’s Rank-Order coefficient.

FINDINGS: We found there was a very mild negative correlation (r_s=-0.214) between final cost of the individual stands and their aesthetic rankings. The result suggests that popular aesthetic preference, as measured in wine stand design, is very slightly correlated with higher cost, and that other factors (not investigated) have a greater influence on aesthetic rankings.

IMPLICATIONS: The findings suggest that TVD does not necessarily compromise the popular aesthetic quality of a simple product design, such as a wine stand, and similarly, may not substantially compromise the final aesthetic of building design.

KEYWORDS: Target Value Design, target cost, value engineering, aesthetics, lean construction

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INTRODUCTION

Target Value Design (TVD) has emerged from Lean Construction as a means to reduce waste and add value to a project, a fundamental tenet of lean construction (Koskela et al. 2002; LCI 2011; Rybkowski 2009). TVD shares roots with several precursors, among them target costing and value engineering. Because understanding these precursors is fundamental to understanding TVD, they are introduced here.

According to Cooper and Slagmulder (1997), target costing is "a disciplined process for determining and realizing the total cost at which a proposed product with specified functionality must be produced to generate the desired profitability at its anticipated selling price in the future." Mathematically, the intent of target costing translates into a simple equation; the price that a customer is willing to pay for a product is determined first, and then a target margin is subtracted to yield a target cost, as shown in **Equation 1.**

Target Cost = Target Price – Target Margin (**Equation 1**) (Clifton et al. 2004)

Once a target cost has been determined, the design team works collaboratively to design and redesign, iteratively, until the target cost has been met. A fundamental rule is that the *target cost must not be exceeded*. If the target cost cannot be met, it is preferable to cancel the project altogether than to proceed with an unprofitable project (Clifton et al. 2004).

Like practitioners in the product design industry, stakeholders in the building industry are also exploring target costing (Nicolini et al. 2000). The lean construction community began experimenting with target costing as a means to lower cost by reducing waste and adding value, and has realized significant savings (approximately 20%) by implementing the process (Ballard and Reiser 2004; Granja et al. 2005; Robert and Granja 2006; Rybkowski 2009). The term Target Value Design (TVD) entered the literature when Macomber et al. (2005; 2008) used it to refer to target costing in construction. According to Lichtig (2005), "Target Value Design…is similar to Target Costing, but may be broadened to encompass design criteria beyond cost, including time, work structuring, buildability, and similar issues."

The TVD process engages stakeholders in successive, iterative cycles of alternative development and analysis, not unlike the Value Engineering (VE) process. The similarities between VE and TVD are important because some industry partners—especially architects—have expressed concern that VE compromises the aesthetic quality of a building, especially when VE is applied after much of the building has already been designed. In fact, VE has a negative reputation among architects and engineers because these professionals view the process as a cost-cutting strategy that may diminish the value of the building (Russell 1991; Mckew 1999). Architects, especially, have expressed concern that intangible measures of quality, such as aesthetics, may be compromised by value engineering because aesthetic value is not easily quantifiable and, therefore, may be easily sacrificed during the VE process (Russell 1991).

From a trained architect's perspective, many elements of Western architectural theory are rooted in a treatise by the 1st century BCE Roman architect and engineer, Marco Vitruvius Pollio, entitled *De Architectura*. Vitruvius defined architecture as a synthesis of firmness, commodity and delight (Pollio 1998). Twentieth century architectural theory has accommodated nuanced complexity through movements that include (but are not limited to) Art Nouveau, Art Deco, Arts and Crafts, Modernism, Brutalism, Postmodernism, and Deconstructivism, and New Urbanism (Kostof 1995). Aesthetics in architecture have been influenced by cultural and historical ideologies rooted in place and time. Complicating the discussion are modifying influences, such as the subjectivity of individual aesthetic tastes. Reviewing the richness of architectural discourse is an inexhaustible task and is beyond the scope of this paper.

Despite the seemingly overwhelming nature of the subject matter, preliminary exercises in TVD and VE have demonstrated there is a need to try to determine whether or not there might be some correlation between a type of aesthetic "consensus" and cost.

For example, Niukkanen (1980, as reported in Pennanen and Koskela, 2005) investigated the possibility of such a correlation by comparing architectural merit rankings against bid prices for a building design competition. Although the least expensive design proposals exhibited poor architectural merit, the most expensive proposals were not the most architectural meritorious either. In fact, the design that fared the best architecturally sat squarely in a mid-priced range. The reported study offers some indication that cost and aesthetics are not necessarily correlated. There is a need to develop and refine the investigation by using a statistically significant sample size free from confounding variables. This research attempts to fill this need.

METHODOLOGY

We investigated whether or not there is a correlation between aesthetic quality and cost by examining the aesthetic rankings of a physical product, using it as a proxy for the aesthetic rankings of an architectural building. The decision to design a furniture product is rooted in the tradition that many celebrated architects also design chairs (e.g. Frank Lloyd Wright, Charles Rennie Mackintosh, Eero Saarinen, Mies van der Rohe, Charles-Édouard Jeanneret (Le Corbusier), and Frank Gehry, to name a few). A wine stand was selected because the culture of wine is as much aesthetically-driven as it is functionally-based. The research strategy draws on the well-developed science of *experimental psychology*. This methodology permits observation of human behavior in controlled contexts and then applies statistical analysis to the interpretation of the results (Leedy 2010; Shadish et al. 2002). One benefit associated with experimental psychology is that controlled experimentation brings certainty, thanks to the elimination of confounding variables. However, there is also a drawback associated with laboratory-based experimentation; results must be externally validated to ensure they are applicable in a natural setting (e.g. beyond the confines of a laboratory environment). Despite this real limitation, we, as researchers, decided that the benefits gained from implementing these methodologies outweigh the drawbacks.

The study took place in two phases: *Phase I*, developing the wine stands, and *Phase II*, ranking the aesthetic value of the wine stands. The development of the experimental stimuli (the wine stands)—as well as the survey that followed—were approved by the Institutional Review Board at Texas A&M University before implementation.

PHASE I: *Developing the wine stands:* 18 postgraduate students were recruited to participate in a timed TVD simulation experiment. Their educational backgrounds included architecture, civil engineering, and construction management. Participants were divided into groups of three and were tasked to design and construct an approximately 2 ft. tall prototype for a wine stand within one hour, using a restricted supply of provided materials including white Styrofoam cups, 8 ½ x 11" sheets of white paper, glue, tape, and 9" diameter white Styrofoam plates. Instructions to the groups were as follows: of the six groups, two were asked to design a stand *without* financial constraints, two were asked to design a stand *with* financial constraints, and two were asked to design two stands in succession—once *without* financial constraints and once *with* financial constraints.

When building with financial constraints, participants were provided with a unit price list for all materials and were given a not-to-exceed total price ceiling for the wine stand design. In design cases *without* cost constraints, all three group members participated in the design process. In design cases *with* cost constraints, one participant was solely dedicated to continuous re-estimation of the project cost while two group members focused exclusively on the design process. In all cases, the wine stands were considered successful only if the finished product could support the weight of a long-stemmed, water-filled wine glass. Wine stand designs were photographed alongside their creators. In total, eight unique wine stand designs were developed. One example is shown in **Figure 1.**

Figure 1. Example of a wine stand developed by participants during the TVD exercise.

PHASE II: *Ranking the aesthetic value of the wine stands:* To determine if a correlation exists between the relative aesthetic ranking of each wine stand and its total material cost, we attempted to remove confounding variables, as much as possible, by individually rendering each stand using Google SketchUp. Images were modeled in white with shadows against a blue background and included a filled glass of wine on the horizontal "table-top" portion of the stand. Images of the stands were randomly arranged in two rows on an 8 ½" x 11" paper. 120 passersby on a university campus were randomly selected to respond to a survey, asking them to rank the stands from 1 to 8 in terms of aesthetic preference as follows: 1 = most aesthetically pleasing ←→ 8 = least aesthetically pleasing, as shown in **Figure 2**. Additionally, respondents were asked the following questions: (1) What, specifically, do you think made you rank the first picture as the *most* aesthetically pleasing? And (2) What, specifically made you rank the last picture at the *least* aesthetically pleasing? Data was gathered about the respondent's (a) gender, (b) academic role (i.e., student (undergraduate or graduate), faculty, or other), and (c) departmental affiliation, if at the university. Note that, for this study, *no* formal definition of aesthetics was proposed to the survey participants. Participants were simply asked to rate how aesthetically pleasing they personally considered a wine stand to be.

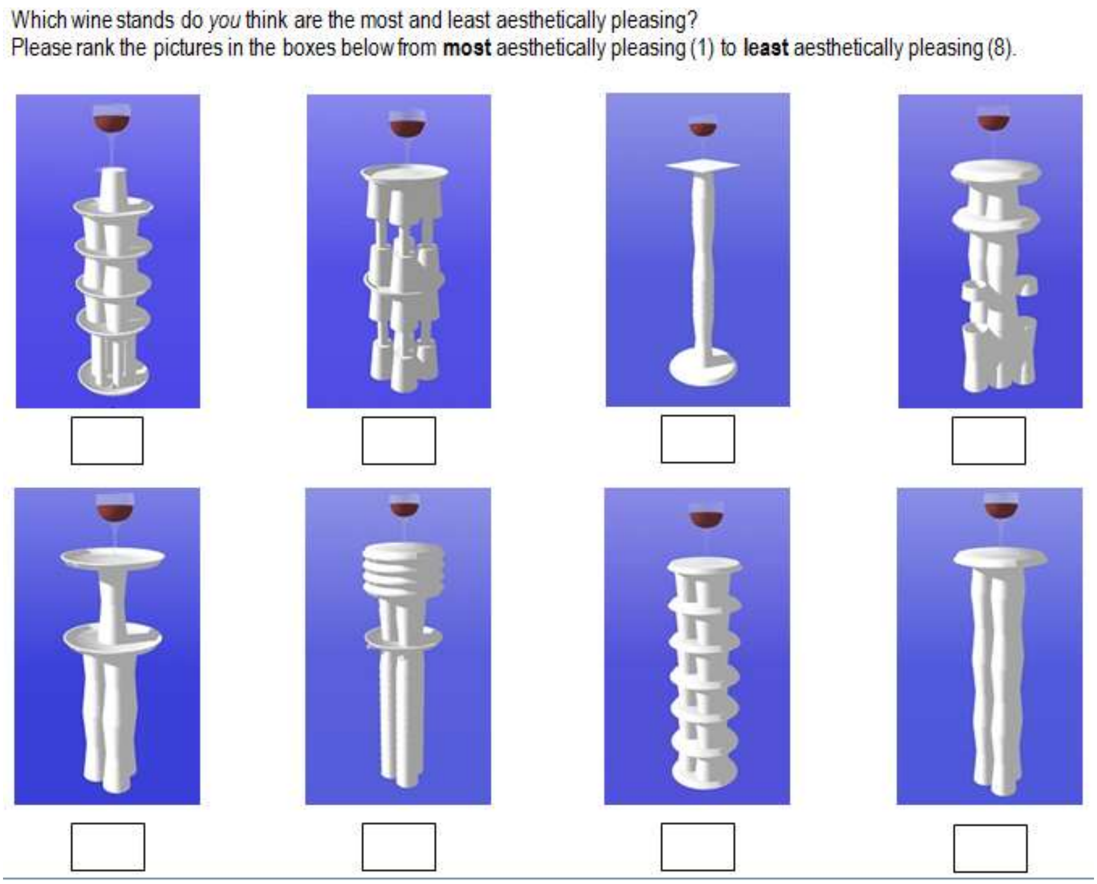

Figure 2. Survey respondents were asked to rank eight wine stands in order of aesthetic preference. Before data analysis, stands were labeled from left to right as follows:
top row: A, B, C, D; *bottom row:* E, F, G, H.

RESULTS

Mean (μ) ranks were computed for each stand design and their corresponding ordinal ranks determined, as shown in **Table 1**.

Mean ranks were plotted against total cost per stand as shown in **Figure 3**. Spearman Rank-Order Coefficient was calculated as shown in **Equation 2.**

$$r_s = 1 - \frac{(6 \Sigma d^2)}{n(n^2 - 1)} \qquad \text{(Equation 2)}$$

Table 1. Mean (μ) and ordinal values indicating cost and aesthetic ranks of the 8 wine stand designs.

	Value		Rank			
	Cost	*Aesthetics (μ)*	*Cost*	*Aesthetics*	*d*	d^2
A	7.02	5.08	8	6	2	4
C	7.17	3.98	7	3	4	16
E	7.61	3.46	6	1	5	25
B	8.09	5.29	5	7	-2	4
G	8.66	4.13	4	4	0	0
H	8.96	3.56	3	2	1	1
D	10.31	5.73	2	8	-6	36
F	17.16	4.77	1	5	-4	16
						102

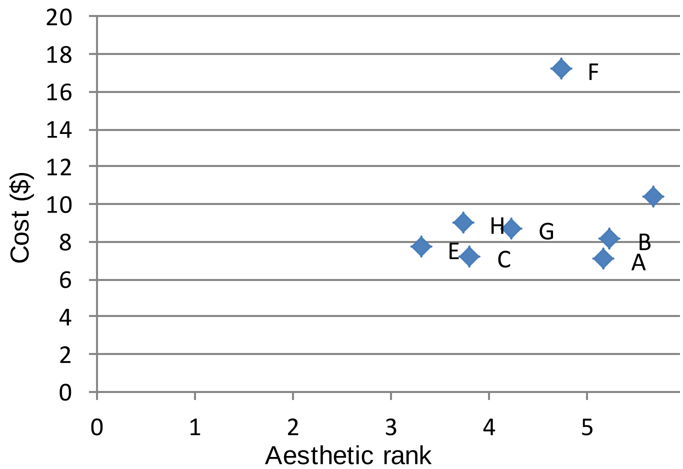

Figure 3. Plot of aesthetic rank versus cost for wine stand designs A through H.

Costs and mean values of aesthetic rank, as well as corresponding ordinal ranks, are plotted as shown in **Figure 4.**

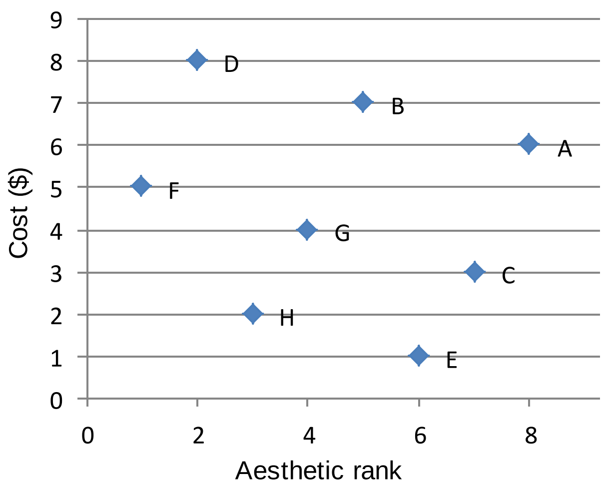

Figure 4. Plot of ordinal aesthetic ranks versus ordinal cost ranks of wine stands

Using values from Table 1, the Spearman Rank-Order Coefficient may now be calculated:

$r_s = 1 – [(6 \times 106)/8(64 - 1)]$

$\mathbf{r_s = - 0.214^*}$

Note that generally:
$0.9 \leq r_s \leq 1.0$ indicates very strong correlation
$0.7 \leq r_s \leq 0.9$ indicates strong correlation
$0.5 \leq r_s \leq 0.7$ indicates moderate correlation

The computed Spearman Rank-Order Coefficient of -0.214 indicates there is *a very mild negative correlation* between cost and aesthetic value of the final product. In other words, higher cost might support better aesthetic quality in design, but the influence is quite mild compared to other factors (not investigated in this study). The result (Df=118, $p<0.05$) is statistically significant.

DISCUSSION

The Spearman Rank-Order coefficient of -0.214 suggests there is *a very mind negative correlation* between the aesthetic ranking of the stand and its final cost.

In addition to ranking the stands by overall mean, responses were sorted by departmental affiliation. **Table 2** displays mean aesthetic ranks for the wine stands based on departmental affiliation. Since the stands were constructed of similar materials, the difference in ranking suggests that aesthetic preferences were likely based on arrangement and proportion of material assemblies, rather than on total cost.

Interestingly, there is some aesthetic ranking consensus among respondents with backgrounds in architecture, construction science, and other fields. However, those with engineering backgrounds assigned rankings that differed more than 2 points above or below the standard ranking given by those with non-engineering backgrounds, for stands B, C, D, and H.

Table 2. Ordinal aesthetic ranking of wine stands according to background of participants. Ratings which differ substantially from responses in other subject areas (outliers) have been circled for emphasis. Note that outlier participants come from the discipline of engineering.

	Architecture *n=21*	*Engineering* *n=29*	*Construction* *n=22*	*Other* *n=48*
A	5	8	6	6
B	7	**3**	7	7
C	3	**6**	1	3
D	8	**4**	8	8
E	1	1	3	1
F	4	5	5	5
G	6	2	4	4
H	2	**7**	2	2

Comments about stands ranked as *most* aesthetically pleasing, included:

- "It is slender, purposeful; I like the lean look. It is not overdone (or) too robust."
- "The form is continuous and simple, giving me an impression of fluency. And the proportion looks comfortable for me. Besides I like the curves."
- "The structure seems more stable."
- "Looks sophisticated, elegant and pleasant. It also looks like it will be stable as a wine stand. Looks harmonious."
- "…it was simple, yet elegant. The design was not too over-the-top and…very pleasing to the eye."

Comments about stands ranked as *least* aesthetically pleasing, included:

- "It's so thin. I am worried that it will fall down."
- "It looks like it might collapse—not good."
- "Out of balance."
- "It looks bulky."
- "Clumsy look, too bulky, too thick, plump."
- "The form is too busy and it looks gaudy."
- "Looks very heavy."
- "The design is overly complicated."

Differences in rankings suggest that those with engineering backgrounds may be responding to different criteria when assessing aesthetics from those from non-engineering backgrounds. Embodiment of "stability" was a commonly cited aesthetic criterion given by those who declared engineering backgrounds.

CONCLUSION

Although wine stands are not the equivalent of building architecture, the researchers drew from the methodological traditions of experimental psychology and developed the wine stands as a proxy for architectural aesthetic preferences. Final results suggest there is a very mild negative correlation between aesthetic preference and cost—a finding that may offer some reassurance to architects who are concerned that designing to a reduced cost will necessarily compromise aesthetic quality of the final design. Duplicating the survey using practicing professionals as respondents (versus university-affiliated individuals), is worthy of investigation.

It must be acknowledged that designer concerns about compromising aesthetic quality due to cost constraints may have less to do with final aesthetic resolution than with the creative inhibitions such constraints might induce. Determining the nature of designers' concerns should be explored.

Results from this simple experiment suggest lowered cost may not necessarily compromise the aesthetic quality of a simple wine stand, as identified by a random survey of various user groups. Externally validating this research as a proxy for aesthetic preferences of buildings is a topic worthy of further investigation.

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