THE ST. OLAF COLLEGE FIELDHOUSE PROJECT: A CASE STUDY IN DESIGNING TO TARGET COST

Glenn Ballard[1] and Paul Reiser[2]

ABSTRACT

Consumer product development uses a technique called 'designing to target cost' to systematically improve product profitability. In brief, a manufacturer sets a cost for a product to be developed that will allow an acceptable profit given the price that product is expected to fetch in the market. That target cost for the product is then split into target costs for each functional system within the product. In effect, the 'buyer' is setting the price he is willing to pay for each system. This can be extended to subsystems and components, and even to parts of components where the relevant buyer is able to impose on or negotiate prices with their suppliers.

Target costing is used in the initial development of a product, in subsequent product modifications, and in the manufacturing of the product throughout its life, where the focus shifts to the production processes themselves.

Designing to target cost is very likely done in some form in construction, but is not well documented and could potentially benefit from a more systematic approach. The Boldt Company very successfully introduced a form of target costing at the facility system level on a design-build project, the St. Olaf Fieldhouse project. This paper presents a study of the Fieldhouse project intended to reveal the potential for positive impact on project performance of designing to target cost, and to support the need for further research into target costing. It concludes with recommendations for next steps in developing a methodology for designing to target cost in the construction industry.

KEYWORDS

Contingency, cost, cost control, cost management, design, designing to target cost, lean enterprise, project financial management, target cost, target costing

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[1] Glenn Ballard is Research Director for the Lean Construction Institute and Associate Adjunct Professor at the University of California, Berkeley, ballard@ce.berkeley.edu.

[2] Paul Reiser is VP of Quality and Productivity Improvement at the Boldt Companies, preiser@boldt.com

INTRODUCTION

Designing to target cost[3] is a product development practice that converts cost into a design criterion rather than a design outcome. As such, it belongs to the more general practice of designing for target characteristics, commonly referred to as DfX, which is currently a hot research topic in mechanical engineering and design[4].

Designing to target cost has been used most consistently by Japanese manufacturers as a means for systematic reduction in product costs and consequently improvement in profitability (Cooper & Slagmulder, 1997). The practice has been used in construction to some extent, especially by design-build contractors, though details and extent of that practice have not been well documented[5]. There may be opportunity to expand and improve the practice through better understanding its use both in product development and in construction.

This paper will provide such an overview, explore the relationship with value generation, present a case study of target costing in construction, suggest ways in which construction could benefit from a more conscious and comprehensive implementation of target costing, and propose further research.

DESIGNING FOR TARGET CHARACTERISTICS

Cost is but one possible target characteristic of a product to be achieved through design. DfX, Design for X, is the generic name for the process of designing for target characteristics, which may include design for manufacturing, design for assembly, design for sustainability, reliability, constructability, operability, cost, weight, acceleration and many more. DfX faces three primary challenges:

1. How to incorporate the relevant specialists in the design process, both as regards knitting organizations together through contracts and effective processes for collaborative design.
2. How to make tradeoff decisions between the characteristics.
3. How to drive design decisions to achieve the targets.

We limit ourselves to consideration of cost targets and to challenge #3 in this paper.

The traditional practice in construction is to produce design to some degree of supposed completion, estimate its cost, then try to alter the design in order to bring expected cost within budget. This approach is wasteful, yielding rework and frustration, and arguably generates less value for customers and providers[6] than alternatives. A better approach is to

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[3] As shorthand, we will occasionally use the expression “target costing” as equivalent to “designing to target cost”. Neither should be confused with “target cost contracts”, in which “...the difference between actual and target cost is shared in a specified way between the client and contractor.” (http://wwwdfid.gov.uk/policieandpriorities/files/africa/ev_s249a.htm and Bös (1996)).

[4] For example, see Shah, et al. (2004).

[5] See Knott (1996) for an excellent example of the target costing process applied in construction.

[6] We use the term “provider organization” to indicate the organization that has responsibility for delivery of the facility to the client. This may be a design-build firm, a joint venture, a construction management firm, etc.

anticipate the cost consequences of different possible designs or design decisions, and limit eligibility to those that fit within the target cost. No doubt, we need to learn better how to do that, but it is done now by conceptual estimators and others who know what things will cost to build, so it can be done. Until designers develop more advanced conceptual estimating skills, designing to target cost will have to be done through cross functional teams. Indeed, given the wide range of desired product characteristics, it is evidently very rare for a single individual to possess all the necessary knowledge and competencies. Hence, cross functional teams will always be required.

Another critical support tool needed for designing to target cost is an integrated product/cost model. When the cross functional teams producing design do so in nD models which quickly reveal the cost implications of potential design actions, it will be much easier to avoid producing design outputs that do not meet target costs.

Value engineering (VE) is used extensively in product development to support achieving cost targets[7]. It is most often used in construction as an after-the-fact review of a previously produced design, rather than as a means for generating and selecting design alternatives that meet or beat target costs. Functional analysis, at the heart of VE, seems best used in the original design process, and should become a competence of the cross functional team rather than an add-on or afterthought.

Granting the need for such tools, nonetheless designing to target cost may be successfully accomplished in construction today without them, though perhaps with varying degrees of success. Consider the example of a design-build specialty contractor who has committed to a guaranteed maximum price (GMP). The contractor is responsible for both design and construction, and has design capability in-house. Ways are found to prevent the project cost exceeding the guaranteed maximum price, else the contractor's profit is reduced. What is not known is the extent to which that GMP is achieved through the traditional process: design-estimate cost-redesign-reestimate cost-and so on. Having both design and construction done by a single company does not necessarily change the way design and construction personnel relate to one another or the way the design process is structured and operates.[8]

Simply having a guaranteed maximum price does not reveal how that price was determined. In true designing to target cost, cost reductions necessary for achieving target profitability are incorporated into the targets. In construction, standard practice seems rather to establish GMPs based on expected costs rather than target costs. Apart from the inaccuracy of estimates due to market uncertainty, costs are taken as given and are not conceived as a variable subject to management action.

Analogically, the provider organization plays the role of the manufacturer that launches a product development project.

[7] The seminal text in VE is Miles (1961). For its more recent application in manufacturing, see, among many others, Park (1999). A foundation text for VE in construction is Dell'Isola (1975). For the evolution of VE in U.S. construction, see Dell'Isola (2003). For a different evolution in Europe/UK, see Kelly, et al. (2003).

[8] The Lean Construction Institute and Southland Industries, a design-build mechanical engineering firm, are producing a report on the integration of detailing and engineering, the benefits of which were demonstrated by the unprecedented quality and completeness of design documents produced by Southland for their Glendale Hospital Project.

TARGET COSTING AND VALUE GENERATION (CUSTOMER RELATIONSHIPS)

The relationship between a manufacturer and its customers is typically quite different than that relationship in construction. One consequence is that the manufacturer uses target costing to increase his own profitability, without explicit regard for the interests of their customers. In construction, target costing can be used as a tool for generating both customer value and provider profitability.

There are at least three types of construction industry situations in which designing to target cost could play a role: 1) Where the client has a limited amount of money to spend and wants to spend all of it to the extent that value adding investment opportunities can be found, 2) Where the provider needs or wants to commit to a fixed price or guaranteed maximum price, and 3) Someone developing a product for the construction market targets a production cost to generate a desired profit margin, assuming an achievable sales price; i.e., the traditional product development application. For lack of space, we restrict our consideration in this paper to the first type of situation, which is illustrated by the St. Olaf College case study described here.

TARGET COSTING AND SUPPLIER RELATIONSHIPS

The ability of a manufacturer to extend target costing further down the supply chain, from systems to subsystems to components to parts, is a function of the relationship between the manufacturer and the relevant suppliers. In Japan, where the practice was developed, a manufacturer such as Toyota will typically have long term relationships with its suppliers, and typically not only with the first tier but also second and even third tier suppliers. In construction, long term relationships with even first tier suppliers is still relatively rare. The good news is that target costing can in part be extended more deeply into the product hierarchy working through first tier design-build specialty contractors. The influence however of the first tier specialty contractors with their own suppliers tends to be greater with service providers than with product suppliers, who are often much larger than the specialty contractors, and in many cases, larger than the general contractor themselves.

CASE STUDY

The Boldt Company is committed to the development and implementation of lean principles and practices. Project financial management, production management and designing to target cost are key developmental areas. Boldt's first systematic application of designing to target cost occurred during the design and construction of a fieldhouse (athletic center) for St. Olaf College in Northfield, Minnesota in 2001-2002.

The project was funded by a $13,000,000 gift from an alumni family, who designated $1,000,000 for operating expenses. The intent was to spend the remaining $12,000,000 on value additions to the fieldhouse, as opposed to trying to minimize spending to a pre-established scope.

Boldt has a longstanding relationship with St. Olaf College. Boldt did not attempt to maximize its profit on the job, but rather subordinated any opportunity for additional profitability to generating value for its customer[9]. Although previous projects at St. Olaf provided high levels of facility value, the Fieldhouse project measured in many ways, a new level of value, customer satisfaction, and success for the entire project team. Key differences in the management of this project included:

1. Boldt held the contract of the architect, Ellerbe Becket, which was a reaction to previous project experiences, where the design was driven by the stakeholders without sufficient regard to budget. Incidentally, Boldt changed from an American Institute of Architects form to a Design Build Institute of America form of contract in an attempt to better balance the interests of the designer and constructor.
2. The design architect was a graduate of St. Olaf, and approached the project not only as a designer but as a stakeholder in the final product.
3. Boldt's interface with the client was formalized in periodic reports and structured through a project Steering Committee.
4. Target costing was introduced at a rudimentary level, after the completion of schematic design, but nonetheless enabled a much more disciplined management of scope and cost together.

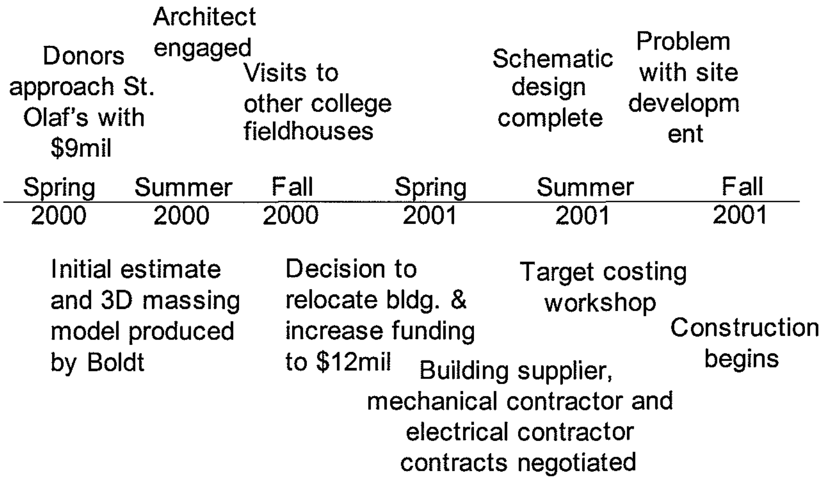

Figure 1: Fieldhouse Project Preconstruction Timeline

The preconstruction period (see Figure 1) was critical in the identification and generation of value to the donor and the College. Boldt was involved from the beginning, providing cost estimates and massing models. Ellerbe Beckett, the architectural/engineering firm, was engaged shortly after on a cost-plus-fee basis, with an amount not to be exceeded. They began exploring alternatives within the College master plan and eventually developed the schematic design. Visits to other fieldhouses were made during the Fall of 2000 involving the donors, St. Olaf's personnel and Boldt personnel. These led to a decision to relocate the building from its initial location and to increase funding from $9 million to $12 million, all changes agreed with the donors to be value adding. The prefabricated metal building

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[9] Boldt's fee was a percentage of final construction costs.

supplier, mechanical contractor and electrical contractor were brought on board prior to the completion of schematic design and participated in its final stage.

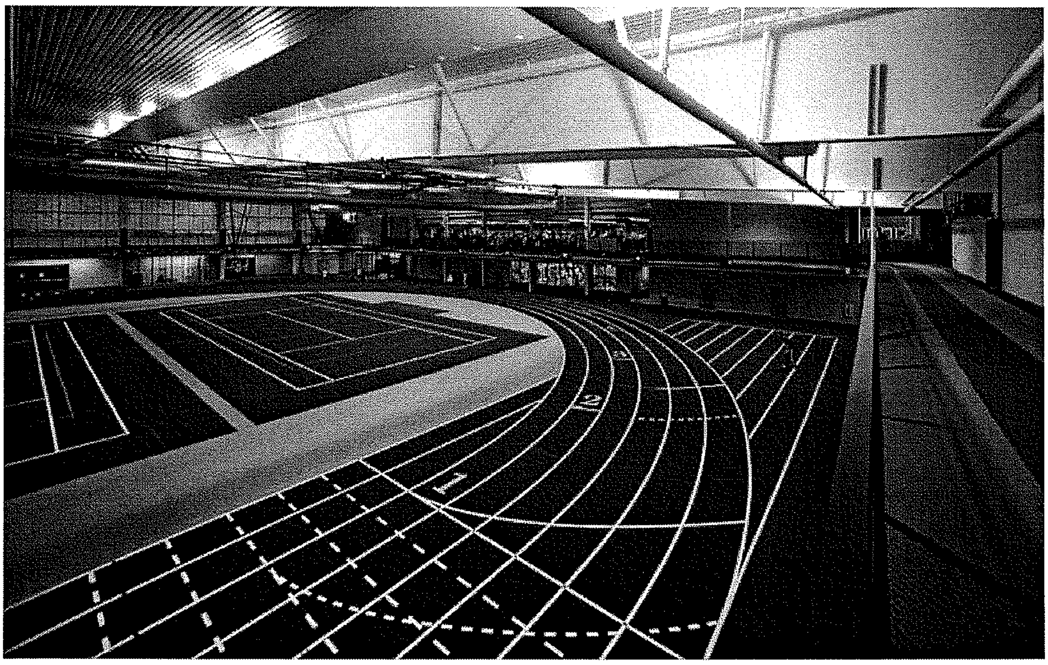

Figure 2: St. Olaf's College Fieldhouse

TARGET COSTING WORKSHOP

> *The deliverable product resulting from Target Costing is a Scope of Work document that includes a description of quantities, quality and cost. The work of the cross-functional teams translates the Voice of the Customer into technical design, and ultimately aids in defining the scope of the project. By working through a systematic and collaborative process, Target Costing produces a commitment from the entire project team to design and build according to the scope and budget defined by the process. The benefit is maximum value for the customer and minimum waste in the delivery process.* (excerpted from Reiser (2003)).

A two-day target costing workshop was held on June 25-26, 2001. Participants included representatives of the electrical contractor (People's Electric), the mechanical contractor (Hi Mech) and the pre-engineered metal building contractor (Ceco), along with the alumni donor, Boldt personnel, St. Olaf's people, and Ellerbe Becket architects, mechanical engineer, electrical engineer and structural engineer. Participants were given an orientation to the project, initiated by the donors describing their vision and challenging them to meet or beat the target costs.

The Last Planner system of production control (Ballard (2000)) was introduced. Although Last Planner was used during construction, it was not used to manage design production[10]. Consequently the relationship between designing and constructing often felt like traditional practice.

Bob Huber, Boldt's internal scheduling consultant, did interactive scheduling, a form of the Lean Construction Institute's phase scheduling (Ballard, 1999), at the workshop, then every six weeks thereafter.

On Day Two, the team went directly into target costing. Based on Boldt's estimate of the schematic design, organized in accordance with Uniformat II (Charette and Marshall, 1999) funds were allocated to the various facility 'systems' as shown in Table I. In addition, funds were allocated to design services ($504,885+$41,600), owner reserves (343,115), project administration ($425,179), general conditions ($585,832), construction management fee ($326,787), and construction contingency $587,774). Site, enclosure, interiors, mechanical and electrical teams were formed, each consisting of 3-6 people drawn from Ellerbe Becket, Boldt, specialty contractors, and St. Olaf. Each team was challenged to complete the design with savings beyond their target cost[11].

The donors challenged the teams to reduce actual cost below the targets so more money would go to the operating fund. Everyone was given a target costing spreadsheet and quantities without dollars (e.g., x square feet of ceramic tile without the cost per tile). For example, Mechanical was given a target cost of $1,111,402, with subtargets for Plumbing ($85,927), HVAC ($824,160), Fire Protection ($109,740) and Testing & Special Mechanical ($91,575).

Design information available at that time included: floor plans, some elevations, only a little if any mechanical and electrical, very preliminary site work, conceptual substructure system consisting of spread footings, and a well evolved schematic design and programming.

The teams worked together during Day Two of the workshop to explore how to fit scope and funds together, but at that time, only one of the teams was able to report a plan that did not require all of their target. Some small things were discovered; for example, that customary tile had been omitted in the bathrooms. St. Olaf College coffee mugs were awarded to the team with the most savings.

IMPACT OF THE TARGET COSTING WORKSHOP

At first glance, the workshop does not appear to have produced very much of importance. However, sharing of explicit cost targets and initiating collaboration across teams and companies proved to be valuable, as is indicated by the project being completed within $100,000, less than 1%, of its initial target cost, by the quality of the facility produced, and further, by the team players' ability to fund value adding scope changes for St. Olaf.

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[10] At that time, Boldt had just begun using Last Planner in the design phase of their projects. It is now becoming standard practice.

[11] In traditional designing-to-target-cost, the target cost is set to achieve the desired savings.

Worth/Cost Model

Value Engineering Study

Legend:

	Cost TOTAL per SF	D-B TOTAL per SF
Worth (Target)		
Current Estimate	101.06	105.86

Project: Fieldhouse Expansion
Location: St. Olaf College Northfield MN
Phase of Design: Schematic Target
Date: June 21, 2001

Construction	+	Owner Reserves	+	Escalation	=	Construction TOTAL	Design-Build TOTAL
11,178,100		343,115				11,521,215	12,067,681

Incl Design at $504,886+41600

NOTES:
Bldg. Type: Recreational
Target (SQFT) 114,000
Floors: Single story plus mezzanines

SITE WORK	BUILDING
594,500	10,583,600

SITE WORK		
Site GC OH&P		
G10 Site Prep, Demo & Excav		146,500
G20 Site Improvements		373,000
G30+40 All Utilities		75,000
G90 Other Site Structures		

SHELL		4,334,488
A10 Foundation A20 Basement		1,006,004
B10 Superstructure		1,218,797
B20 Exterior Closure		2,007,061
B30 Roofing		102,626

INTERIOR		1,710,386
C10 Interior Construction		528,427
C20 Stairs		62,639
C30 Interior Finishes		1,069,320
D10 Conveying		50,000

MECHANICAL		1,111,402
D20 Plumbing		85,927
D30 HVAC		824,160
D40 Fire Protection		109,740
Testing and Special Mech		91,575

ELECTRICAL		794,890
D5010 Service and Distribution		739,390
D5020 Lighting & Branch Wiring		
D5030 Security Comm/Data		
D5090 Other Electrical		55,500

SPECIAL		706,862
E10 Specialties & Equipment		492,534
E20 Furnishings Fixed/Movable		34,000
F10 Special Construction		89,520
F20 Selective Demolition		90,808

GENERAL		1,925,572
Z1010 Project Administration		425,179
Z1030 General Conditions		585,832
Z1060 Fee		326,787
Z20 Risk and Contingency		587,774

Table 1: Worth/Cost Model

PROJECT EXECUTION

VALUE ENGINEERING

A quote from Pete Sandberg, Facilities Director for St. Olaf:

> *"Overall, I think that the St. Olaf/Boldt team on this project had VE so ingrained in their way of thinking that a ton of stuff happened "just because" we almost cannot help it. We did on the fly life-cycle analysis of most everything. This resulted in the ceramic floors in all public spaces that didn't have sport floors, the stainless bath fixtures and dividers, the air "socks" for quiet, appearance, and life in an athletic facility (no baseball damage to duct and diffusers). We did a hard core value/life analysis of roof and wall panels and selected the most expensive first cost system, that was wildly less expensive in terms of dependability, service and life cost. The athletic lighting in the fieldhouse volume evolved this way as well. The electrical project manager proposed using an "off the shelf" high bay fixture, but arrayed in such a way that they did not affect over head tennis play and still provided theillumination that was needed, but not more, and inexpensively. This person had been part of two other St. Olaf/Boldt VE teams and that time paid off big time.*

The authors agree that most of the project team worked toward collaborative value generation. However, working toward this versus applying a disciplined process is quite different. There was too much opportunity left uncovered through lack of formal process. Despite the accomplishments, more can be done. We return to these opportunities for improvement below.

A CHALLENGE TO TARGET COSTING

Soon after the target costing workshop, site work exploded beyond its $595,000 target. Existing asphalt could not be reused as intended. There were drainage and storm sewer issues. The increased cost for site work drew down Boldt's contingency by $300,000, more than half their total contingency. Site work cost exceeded its target of $600,000 by $500,000. The remaining $200,000 was obtained from other teams which had managed to under run their target costs. See the contractor contingency log, Table 3, from which the sum of additions to contingency was $197,308, some from better market pricing than expected.

USE OF CONTINGENCY

As the project progressed, Boldt was very explicit about scope changes and the impact on client contingency. Boldt's contingency was to accommodate inability to achieve target costs (known unknowns), whereas the owner's contingency was to accommodate scope changes (unknown unknowns). The intended purpose for owner contingency was first to cover scope omissions, then to fund value adding scope changes with any remaining funds. $343,115 was allocated for this purpose at the time of the Target Costing Workshop. $298,963 in value adding scope changes were funded by scope reductions and transfers ($227,377) plus $71,586 from owner contingency.

Table 2: Owner Contingency—to fund value adding scope changes

Original Guaranteed Maximum Price	$11,645,250

Progress Report	Use/Source of Funds	Amount	Total Remaining
Oct 01	Add metal panels to Fieldhouse ceiling and interior walls	116,756	11,762,006
Nov 01	Electrical rough-in for running track sound system	12,000	11,774,006
	Reduction in track starting equipment budget	(4,700)	11,769,306
Jan 02	Transfer testing and inspection budget to St. Olaf	(15,000)	11,754,306
	Change elevator cab material to stainless steel	515	11,754,821
May 02	State Fire Marshall occupancy requirements funded through construction contingency	0	11,754,821
	Additional tile at atrium stair North wall	16,405	11,771,226
	Add copper fascia panels at lobby	16,780	11,788,006
	Delete new lockers and relocate existing lockers from Skoglund	(20,088)	11,767,918
	Add bouldering wall at atrium stairs	19,800	11,787,718
	Delete burnished masonry at Stair B	(6,705)	11,781,013
	Relocate existing lockers	8,417	11,789,430
	Omit millwork for reception desks	(6,884)	11,782,546
Aug 02	Addition of 8 operable windows at Skoglund curtainwall	9,600	11,792,146
	Installation of additional batting cage below elevated track	3,500	11,795,646
	Install enclosure wall at Fitness Area	40,000	11,835,646
	Fabricate and install wire screen barriers at sprinkler valve location and AHU platform access	12,000	11,847,646
	Transfer Athletic Equipment/Furnishings from Boldt budget to Owner	(174,000)	11,673,646
	Custom color work and cancelled order for lobby ceiling grid	350	11,716,836

Contractor contingency was intended to first cover cost variability, then to fund value adding scope changes with any remaining funds. $587,774 was allocated to contractor contingency. Its use is shown in summary form in Table 3. Note the Aug-01 $303,663 draw for site development.

Table 3: Contractor Contingency—buffer against cost variability

Jul-01 $587,774

Progress Report	**Use/Source of Funds**	**Amount**	**Total Remaining**
Aug-01	Further site development	(303,663)	284,111
Sep-01	Site development/Entrance/Link/Fitness	(157,940)	126,171
Oct-01	Buyout savings	67,351	193,522
Nov-01	Various budget changes	(107,852)	85,670
Dec-01	Misc budget adjustments	7,330	93,000
Jan-02	Buyout savings	29,670	122,670
Feb-02	Additional materials/sub revisions	(85,577)	37,093
Mar-02	Reductions in sub/matl/labor	72,994	110,087
Apr-02	Add'l materials/sub revisions	(25,522)	

	84,565
May-02	
Struct steel/Conc lbr & mtl/carpentry	
	(30,132)
	54,433
Jun-02	
Field labor offset by reductions in Proj Mgt	
	19,963
	74,396

Fortunately, cost varied both down and up. Under-runs added $197,308 to contractor contingency. After occupancy a number of value adding scope changes were funded by remaining contingency. This practice makes financial contingency more like schedule contingencies that are intended to be spent.

SUMMARY OF ACCOMPLISHMENTS

Implementation of the target costing methodology played a substantial role in the success of the Fieldhouse project. The project was delivered on time and within budget, more value was provided to the client than would otherwise have been provided, and the provider, Boldt, made a reasonable profit.

Redoing the same project with different methods is rarely possible in construction, but a close approximation occurred in the case of the St. Olaf Fieldhouse and another fieldhouse project for a private college in the same city. Carleton College had a new fieldhouse constructed by a different contractor and contracting method, starting in the Spring of 1998 and completing in April 2000. The Carleton project was delivered according to traditional Design-Bid-Build contracting. The St. Olaf Fieldhouse was delivered based on a Design-Build contract integrating Lean Construction principles and practices including target costing and Last Planner production management. The Carleton project took ten months longer to complete compared to St. Olaf Fieldhouse and cost 15% more.

The functional program of the facilities is similar. Both are indoor athletic centers designed for athletic competition, physical education, instruction, student recreation, and campus wellness programs. They both include a 200 meter competition track surface, athletic courts, climbing wall, fitness center, and running track.

Table 4: Fieldhouse comparison

	St. Olaf Fieldhouse	**Carleton College Recreation Ctr**
Completion Date	August 2002	April 2000
Project Duration	14 months	24 months
Gross Square Feet	114,000	85,414
Total Cost (incl. A/E & CM fees)	$11,716,836	$13,533,179
Cost per square foot	$102.79	$158.44

OPPORTUNITIES FOR IMPROVEMENT REVEALED BY THE CASE

The following opportunities for improvement were developed in discussions with St. Olaf and with Boldt.

1. Use collaborative workshops to produce schematic design.[12] (As previously noted, on the Fieldhouse Project, target costing and value engineering were started after schematic design.)
2. Be more formal and rigorous about creating the target cost. On the Fieldhouse project the project team really committed to the current estimate and then informally built improvements into the target costs. A more formal and aggressive application of target costing throughout all phases of the project could have created additional savings and generated greater value.
3. Do target costing at every level, beginning at systems, then down into subsystems and components. Use function analysis as a tool for achieving target costs. Note: The donors came with a donation and a vision for the college. At the highest level, perhaps there was no need for examining function, but there was opportunity at lower levels.
4. Learn how to use value engineering to facilitate integrated product/process design. Note: Boldt spent $10,000 additional to fabricate a structural steel device for placing pre-cast elements below a roof overhang because the installation process had not been thought through in detail. The “king truss” at the climbing atrium is another example of expensive fabrication and installation that did not necessarily create appropriate value.
5. Determine the appropriate use of life cycle costing in the context of target costing. Note: Life cycle costing is more useful in some cases than others; e.g., facility equipment like chillers or air handling units tend to require replacement during the life of the facility, whereas elements like pavers either are rarely replaced or relatively inexpensive.
6. Explore the feasibility of incorporating failure mode analysis[13], especially for facility equipment, into design processes using a life cycle costing methodology.

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[12] See Kristofferssen (2003) for an apparently successful method of doing schematic design, into which target costing and VE might be incorporated.

[13] See McDermott, et al., p.3: “An FMEA is a systematic method of identifying and preventing product and process problems before they occur.”

7. Bring pre-caster and curtain wall contractors on board earlier, along with design-build electrical and mechanical contractors.
8. Explore what subcontracts, if any, should be bid. (On this project, all subcontracts were bid except for the engineered metal building, mechanical and electrical.)
9. Engage suppliers and installers in the search for new ideas and better ways of doing things—the sheet metal foreman on the Fieldhouse Project had the idea of using an 'air sock' for air distribution instead of sheet metal duct. That kind of innovation could be increased.
10. Change terminology from 'conceptual estimating' to 'cost modeling' to stress the desired change from reactive estimating, and use nD modeling for all the benefits it brings, but specifically to facilitate rapid costing of design alternatives.

These recommendations appear to be appropriate for all who try to 'design to target cost'.

CONCLUSION

We have presented an overview of the designing-to-target-cost methodology and illustrated its application in construction with a case study. The case study, together with previous successful applications (Knott, 1996) suggests that designing to target cost can have a beneficial impact on at least certain types of projects, beneficial both for the client and for the provider. The findings support the need to implement a more complete research program.

There are many research issues and areas that need to be developed. We recommend as next steps:

- Descriptive research
- Translation of concepts and techniques from other domains
- Determining the appropriate applications of target costing in construction
- Understanding the change in roles and relationships
- Understanding the conditions for producing a target cost

As this is a new area of research, descriptive studies are much needed to determine the extent to which designing to target cost is currently done in construction, how and why it is done, and how well it is done. Another area of research needed is in translating/applying concepts and techniques from product development to construction projects, recognizing their differences. For example, in addition to VE's function analysis, what other tools commonly used in product development can be beneficially applied in construction? Cooper & Slagmulder (1999) mention kaizen costing, various forms of value analysis (Zero-look, 1st-look, 2nd-look), teardown methods, and others. Finally, research is needed on the issue of the proper application of target costing in construction. For example, as one reviewer asked, does it best apply to the design of subsystems rather than to conceptual product development? As regards roles and relationships, the case study revealed a very different relationship between the general contractor and the client than the traditional relationship. How should such changes be understood and what are the implications for contract structures, business alliances, and such? Finally, what information and what competencies are required to produce a target cost? Who needs to be involved when?

For our part, Boldt and the Lean Construction Institute are continuing their collaborative experimentation with target costing, refining and extending what was done on the Fieldhouse Project. In so doing, we will have the opportunity to contribute to the target costing research. We look forward to sharing our findings with the community of researchers and to learning from what others discover and develop.

REFERENCES

Ballard, Glenn (1999). *Phase Scheduling.* Lean Construction Institute White Paper #7, available at www.leanconstruction.org.

Ballard, Glenn (2000). *The Last Planner System of Production Control.* PhD dissertation, Dept. of Civil Engineering, University of Birmingham, UK.

Bös, Dieter (1996). "Incomplete Contracting and Target-Cost Pricing". University of Bonn, Germany. Discussion Paper Series A, no. 524, June, 1996.

Charette, Robert P. and Harold E. Marshall (1999). *Uniformat II: Elemental Classification for Building Specifications, Cost Estimating and Cost Analysis.* National Institute of Standards and Technology, Washington, D.C., October, 1999. Available at http://www.bfrl.nist.gov/oae/publications/nistirs/6389.pdf.

Cooper, Robin & Regine Slagmulder (1997). *Target Costing and Value Engineering.* Productivity Press, Portland OR. 379 p.

Cooper, Robin & Regine Slagmulder (1999). *Supply Chain Development for the Lean Enterprise: Interorganizational Cost Management.* Productivity Press, Portland, OR. 510 p.

Dell'Isola, Alphonse J. (1975). *Value engineering in the construction industry.* Van Nostrand Reinhold Co., NY, NY.

Dell'Isola, Alphonse J. (2003). *Life cycle costing for facilities: economic analysis for owners and professionals in planning, programming, and real estate development: designing, specifying, and construction: maintenance, operations and procurement.* Reed Construction Data, Kingston, Massachusetts.

Kelly, John and Steven Male (2003). *Value Management in Design and Construction: The Economic Management of Projects.* Spon, London, UK.

Knott, Terry (1996). *No business as usual.* British Petroleum Company, London, UK.

Kristofferssen, Anders Kirk (2003). "Building Value into the Design Process". LCI Congress, Blacksburg, VA, August, 2003. Available at www.leanconstruction.org

McDermott, Robin E., Raymond J. Mikulak and Michael R. Beauregard (1996). *The Basics of FMEA.* Productivity Press, Portland, Oregon. 75 p.

Miles, L.D. (1961). Techniques of Value Analysis and Engineering. McGraw-Hill, NY, NY.

Park, Richard (1998). *Value Engineering: A Plan for Invention.* St. Lucie Press, Boca Raton, Florida. 340 p.

Reiser, Paul (2003). *Target Costing and Value Engineering on Projects.* The Boldt Companies, Appleton, Wisconsin.

Shah J., Zhao Z., Vaidya A., Tharakan and P. Wright, (2004). "Developing Theoretical Foundations of DfM", Proceedings of NSF Design, Service and Manufacturing Grantees & Research Conference, January 5-8, 2004 Dallas, Texas.