DEVELOPMENT OF A PILOT STUDY SIMULATION TO INVESTIGATE THE IMPACT OF TARGET COSTING ON TEAM DYNAMICS AND DESIGN AESTHETICS

A Thesis

by

UDAYA NAIDU GOTTIPATI

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

August 2010

Major Subject: Construction Management

Development of a Pilot Study Simulation to Investigate the Impact of Target Costing on Team Dynamics and Design Aesthetics

DEVELOPMENT OF A PILOT STUDY SIMULATION TO INVESTIGATE THE IMPACT OF TARGET COSTING ON TEAM DYNAMICS AND DESIGN AESTHETICS

A Thesis

by

UDAYA NAIDU GOTTIPATI

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Approved by:

Co-Chairs of Committee,	José L. Fernández-Solís
	Zofia K. Rybkowski
Committee Member,	Wei Yan
Head of Department,	Joe Horlen

August 2010

Major Subject: Construction Management

ABSTRACT

Development of a Pilot Study Simulation to Investigate the Impact of Target Costing on Team Dynamics and Design Aesthetics.

(August 2010)

Udaya Naidu Gottipati, B.Arch., Jawaharlal Nehru Technological University

Co-Chairs of Advisory Committee: Dr. José L. Fernández-Solís
Dr. Zofia K. Rybkowski

Target costing is widely accepted across the automobile manufacturing industries such as the Toyota Corporation followed by other manufacturing companies such as Nissan, Chrysler, Boeing, Sony, etc. However, its use in the construction industry has been limited. The application of target costing in the construction industry has been referred to as Target Value Design (TVD), which forms an important fragment of the whole lean delivery system, Integrated Project Delivery. For the purpose of studying the team dynamics and the impact of cost on aesthetics, this research is split in to the following two parts.

1. Conducting simple experiments /simulations with students, such as designing and building a product to target cost to explore the impact of cost on the design of the product and the team dynamics.

2. Exploring the challenges faced by the teams while working on TVD through literature review and Focus Group Interviews with construction industry professionals with experience in the TVD process.

Similar to other lean simulations like the airplane game and the dice game, aimed at demonstrating the impact of lean, this simulation of designing a two feet (2') tall wine glass holder with materials such as paper, Styrofoam plates, cups etc. is an attempt to understand the challenges of designing to target cost process. The simulation conducted is to mirror the real world TVD process. Results of the experiment conclude that cost does not have a negative influence on the design. There is no correlation between the high costs and better design, that is, the most expensive solutions are not always the best solutions. However, correlation existed between the target cost and the design aesthetics. Indeed, cost as a constraint aided the team in focusing on the design and developing solutions within the project constraints. The results of the experiment are similar to the practice of the TVD in reality as case studies and interviews arrive at similar conclusions. Finally, the experiment depicted that collaborating and working in a team might result in arguments but generates competitive design solutions without affecting the team dynamics. The research is of significance to construction industry professionals and owners to investigate the challenges and implications of implementing target costing in designing to target cost.

.

DEDICATION

Dedicated to my father

SUDHAKAR RAO GOTTIPATI

for his undying belief in me

and to my mother

SWARNALATHA GOTTIPATI

for her immeasurable love and support.

ACKNOWLEDGEMENTS

I would like to thank my committee Co-chair, Dr. José L. Fernández-Solís, for his extensive efforts in teaching me the foundations of research as part of the sometimes lengthy research meetings and for his constructive criticism. A special thanks to the co-chair of my committee, Dr. Zofia Rybkowski, for taking such immense interest in my research, for her invaluable suggestions, for all the research meetings at the Muldoon's coffee house, for guiding me through the whole process of research, and for being a guru in the true sense. I thank Dr. Wei Yan, my committee member, for his guidance and support throughout the course of this research.

Thanks also go to my friends and colleagues and the department faculty and staff for making my time at Texas A&M University a great experience. I thank Dr. Glenn Ballard, professor at the University of California, Berkeley, for sharing his knowledge with me and for providing me with industry contacts to conduct interviews with industry professionals for the purpose of my research. It would have been extremely difficult to correspond with all these professionals without his reference. I extend my thanks to all my friends and colleagues who very enthusiastically participated in both the first run study and the final study of the experiment. I thank architects, project managers, and construction managers for their willingness to share their knowledge with me and for their quick response to my requests.

Finally, I thank my sister Chaitanya, my brother-in-law Mario, my best friends Srikanth and Sahana for their timely help and constant support in everything I have undertaken and especially throughout the course of this research.

NOMENCLATURE

CHH	Cathedral Hill Hospital
IFOA	Integrated Form of Agreement
IPD	Integrated Project Delivery
JIT	Just-in-Time
LCI	Lean Construction Institute
MEP	Mechanical, Engineering and Plumbing
SMCV	Sutter Medical Castro Valley
TVD	Target Value Design

TABLE OF CONTENTS

Page

LIST OF FIGURES

Page

LIST OF TABLES

Page

Page

1. INTRODUCTION

Target costing (TC) originally began in 1960's in Japan and as "*Genka Kikaku"* which translates as "Target Costing" in English (Kato 1993). Since then, target costing has been adopted not by only Japanese manufacturing companies like Toyota, Nissan, Matsushita Electronics, Sony but also other companies like Mercedes, Kodak, Boeing, Chrysler, and Goodyear in the US and Europe (Ansari et al. 1997;Cooper & Slagmulder 1997; Kato 1993). Many credit the Japanese for the application of target costing in manufacturing; however, Shank and Fisher (2006) propose target costing as a method adapted from Value Engineering (VE) developed by the American manufacturing industry. Cheah and Ting (2004) further propound VE as a concept initiated by Lawrence D. Miles of General Electric (GE), post-World War II, as Value Analysis (VA). Jariri and Zegordi (2008) categorize target costing as an approach to design cost management. Extensive literature on target costing is available in Japanese journals; however in the West, the literature on target costing in English is limited (Ansari et al. 1997). One significant reason for the lack of availability of literature on target costing is its implementation in the initial stages of product development, at which time companies maintain a high degree of secrecy. This has resulted in insufficient analyses of its effects on the manufacturing process (Kato 1993).

This thesis follows the style of *Journal of Architectural Engineering.*

A classification of literature on target costing as shown in Fig.1and Table 1.

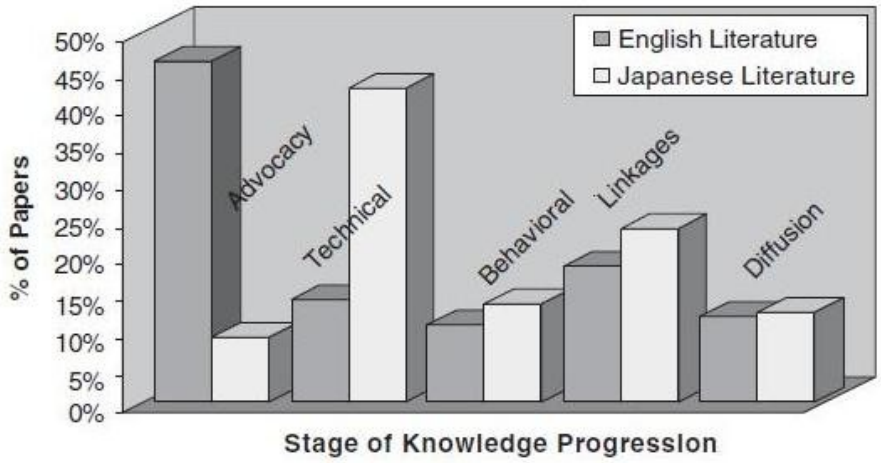

Fig. 1. Classification of literature by state of knowledge
(Reprinted from Ansari et al. 2007)

Table 1. Classification of literature by state of knowledge
(Reprinted from Ansari et al. 2007)

Primary Focus on	English (%)	Japanese (%)
Development and advocacy	46	9
Technical refinement	14	42
Behavioral and cultural context	10	13
Linkage with other tools/processes	18	23
Institutionalization and diffusion	11	12
Total	100	100

Gagne and Discenza (1995) conclude that the available literature on target costing focuses on the following three aspects:

1. Target costing benefits;
2. Target costing practices; and
3. Maximum profits of target costing in certain environments

In spite of its successful implementation in manufacturing, target costing application in capital-intensive sectors such as construction, is limited (Nicolini et al. 2000). Granja et al. (2005) argue that target costing is a powerful strategy in reducing costs in the construction industry and adds Kaizen to target costing to achieve continuous cost reduction. Jacomi et al. (2008) concludes that statistical data on the implementation of target costing for construction projects is not yet available. Further, the authors state that full length implementation of target costing in the construction industry is not applicable because of current practices and industry weaknesses relating to cost models. Howell (1999) explains the construction industry's resistance to change is primarily because construction projects are unique and are like manufacturing. Unlike manufacturing, construction projects are unique and complex, with time and budget constraints and a high degree of uncertainty.

Nicolini et al. (2000) applied target costing to the British construction industry and concluded that time and loopholes in the construction industry itself are constraints to successful implementation of target costing. Ballard and Reiser (2004) documented the first successful implementation of target costing on the St. Olaf Fieldhouse project at Minnesota. Pennanen et al. (2005) discuss the application of TC to the Finnish construction industry in the 1980's.

1.1 Research Questions

Ansari et al. (2009) posed a number of research questions on target costing, which are of concern for researchers in the field. One of these addresses the team dynamics within cross-functional teams involved in the target costing process. Future research at the organizational level can clarify what dynamics and cultural elements support target costing and; what factors inhibit its application and effectiveness. The core essence of target costing is in the potency of the team structure and dynamics. Yet as of now, there is limited research on how team dynamics lead to achieving targets with respect to cost, quality or time. The research context is especially suited for experiments that compare individual work patterns in a linear mode to a concurrent cross-functional team structure. The dependent variables in such studies could be achievement of costs, quality and time targets. An independent variable would be the number of design changes initiated within the development process. The analysis may reveal that cross-functional teams can function with fewer design changes in the project process. Eckes (2003) defines team and team dynamics as "a group of two or more individuals engaged in some joint action with a specific mission or goal. Team dynamics are defined as the motivating and driving forces that propel a team toward its goal or mission."

Ballard (2008) suggests that experimentation and research methodology should document case studies referencing the concepts and outcomes. Beyond this, the analyses should aid in developing hypotheses for the optimal implementation of target costing in construction.

1.2 Research Objectives

The objective of this research is to investigate team dynamics and the impact of cost, time constraints on design aesthetics, and observe possible downsides of the target costing process. This will be accomplished through a pilot study simulation and discussions with construction industry professionals.

1.3 Delimitations

This research does not deal with the process of setting target costs or determining the target cost for a product. No more than 20 projects have implemented Target Value Design and there is no documentation available on such projects. Interviews with architects and engineers are limited, due to lack of their availability and busy schedules. For the simulation, unlike construction projects, there was no allowable cost. While in reality there is an incentive pool for the team members if the project is designed to target cost, this experiment has no incentive pool, hence both the allowable cost and the target cost are considered the same.

2. LITERATURE REVIEW

2.1 Target Costing

"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" (Cooper and Slagmulder 1997).The well-known formula used for TC is

Target Cost =Target price - Target profit (Clifton et al. 2004)

Target price for a new product is set based on market research (Ansari et al. 1997; Ax et al. 2008; Ballard & Reiser 2004; Cooper and Slagmulder 1999; Clifton 1998; Gagne & Discenza 1995; Granja et al. 1997; Kato 1993; Monden 1989). In order to achieve this target price, all team members of a team in an organization work toward designing a product to the target cost. This is achieved through cross-functional teams conducting Functional Cost Analysis (FCA), which is a group activity involving employees from various disciplines, such as marketing, design, engineering, production, purchasing, and accounting sections and proposes alternatives for reducing the overall product cost. FCA requires the preparation of a logical diagram for each function of the product. However, this is not the same as creating a diagram for each part of the product. The function of each part of the product creates market success (Gagne and Discenza 1995).

The difference between traditional costing and the target costing is that target costing follows price driven cost approach where as traditional costing follows cost driven pricing based on the costs of designing and producing the product (Clifton et al. 2004). The difference is shown in Fig. 2.

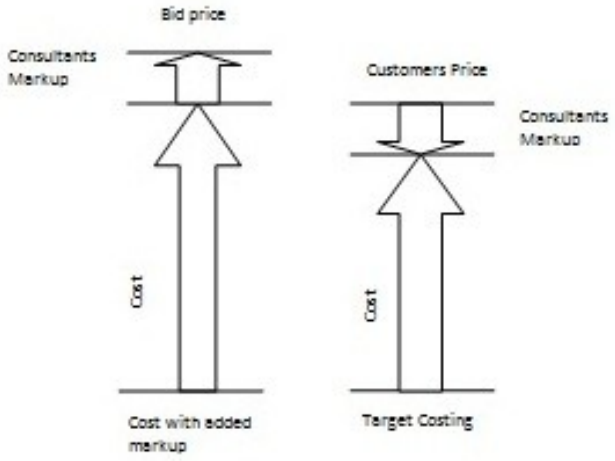

Fig. 2. Cost with added markup versus target costing
(Reprinted from Rybkowski 2009)

2.2 Cardinal Rule of Target Costing

Typically, for a manufacturing company, it is not feasible to introduce a product into the market if the cost of the product is above the target cost. This is the cardinal rule of target costing. However, in some exceptional cases, the company can produce the product based on market competition for that particular product (Cooper and Slagmulder 1999).

2.3 Target Costing in the Construction Industry

In an industry where construction disputes and resistance to change are regular features, VE and designing to allowable costs or target costing are hollow concepts (Jorgensen 2008).The traditional approach to pricing construction products follows cost driven pricing, as shown in the formula;

Price = Costs + Benefits (including profit) (Jorgensen 2008).

Garnja et al. (2005) claim that the construction environment has the potential to develop more collaborative measures among clients and contractors, thus generating methods to increase value, maintain profits and improve consistency within the market requirements. Since each construction project is unique and has considerable variables, implementation of target costing is limited when compared to the applicability of target costing in mass manufacturing. Jorgensen (2008) articulates this situation by embedding production organization from the early stages of design and working toward waste elimination further enhancing value. Indeed design-to-cost is not a brand new concept; it has roots in the U.S. Department of Defense. A few authors refer to design-to cost as a forerunner to target costing (Everaert 1999).

According to Ballard (2008), in a construction setting, designing to target cost plays a role in the following situations:

1. The client has limited funds to finance the construction project and is interested in value adding investment opportunities.
2. Guaranteed Maximum Price (GMP) is agreed on by the service providers

3. Someone developing a product for the construction market targets a production cost to generate a desired profit margin

Ballard and Reiser (2004) proposed the following three main challenges that occur while designing to target cost:

1. Integrating the necessary specialist consultants into a collaborative design process
2. Balance the dynamics of trade-off decisions with the product characteristics
3. Derivation of appropriate design decisions to achieve the requisite targets

2.3.1 Market Cost

Market cost is the benchmark cost. This cost based on the current best practices is comparable to other similar projects. In other words, this is the existing price in the market for similar products (Ballard 2008).

2.3.2 Allowable Cost

Allowable cost is the maximum amount a client is willing is pay or spend on the project. The determinants of allowable cost always include capital availability and ability to repay/recover (Ballard 2008).

2.3.3 Expected Cost

Expected cost is the calculated or projected cost of a project in its existing stage during the TVD process and it is iterative with each design option (Ballard 2008).

$$\text{Allowable costs} \geq \text{Expected costs} \geq \text{Target costs}$$

The target cost is always set below the allowable and expected costs to spur innovation from the design team and to provide value to the client. During this whole process, following the cardinal rule of target costing, if the expected cost of the project is higher than the allowable cost (the maximum amount a client can afford), then the project must be abandoned, revised or redesigned (Ballard 2008). The different terms of costing associated with target costing are shown in Fig. 3.

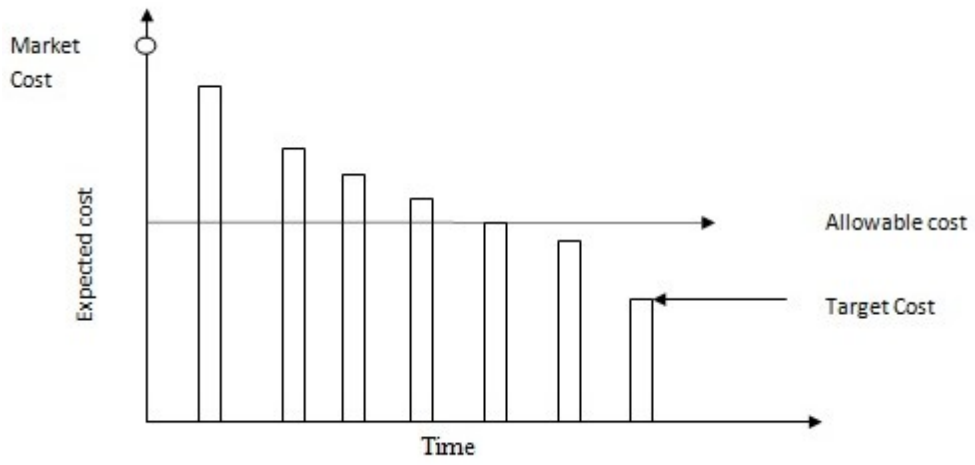

Fig. 3. Costing terms associated with TVD
(Reprinted from Rybkowski 2009)

2.4 Value Engineering (VE)

The difference between Value Analysis (VA) and Value Engineering (VE) is that while the former is implemented during the post-production stages aimed at reducing maintenance costs, while the latter is exercised during the pre-production stages to cut costs out of a design (Cheah and Ting 2005). Jorgensen (2008) advocates VE techniques

as being important in the target costing process. In the construction industry, VE, to an extent has a negative reputation among designers, as it comprises cost-cutting activities. Rybkowski (2009) attributes this negative association to the cutting of costs post design completion, which might result in the negation of special design features; which make the design interesting and unique and may compromise other attributes such as functionality and durability. Contrary to this situation, the application of target costing is to eliminate waste and add value continuously. Applying VE in this way ensures that each subsystem generates total savings. Jorgensen (2008) explains the subtle difference between VE and design-to-target cost. Design-to- target cost is designing costs out of a product and VE is necessarily a tool to cut costs out of a product.

2.5 Target Value Design (TVD)

Macomber et al. (2005) coined the term Target Value Design in reference to the application of target costing in the construction industry. Ballard (2008) defines TVD as "a management practice that drives design to deliver customer values, and develops design within project constraints*".* To achieve greater cooperation and lower conflicts in construction projects, setting up common objectives and values are crucial. In order to achieve client/user satisfaction and improved productivity, the key is to set up value parameters at the start of the project since value is the end- goal (Emmit et al. 2004).

According to Christoffersen (2003), Value has the following characteristics:

1. The individual perception of value is subjective and value differs from the objective best value as agreed by a group.
2. Value changes time to time.

If value is perceived objectively, it is the result of collaborative efforts of the parties participating in the processes of design and construction, rendering a comprehensive framework that is primary to all productiveness (Emmitt et al. 2004).

Every construction project has soft values, such as quality and aesthetics, and a quantitative description of these soft values proves to be difficult. Pennanen et al. (2005) attributes the association of soft values to people's cultural background. So how does target costing deal with soft values? A study on the correlation between architectural quality and building costs by the architect Niukkanen shows a correlation between minimum cost and poor building quality however, the correlation ceases between average building price and the building quality. Another interesting observation is that the most expensive designs are not always the best possible solutions; they, in fact, are rather poor in quality. Even though high price does not prevent good quality, the study shows best quality is achievable at a reasonable price (Pennanen et al. 2005).

The concept of TVD largely depends on a precise comprehension of the client's financial capabilities (Rybkowski 2009). TVD itself is not a project delivery system but forms one important element of the lean project delivery system i.e., Integrated Project Delivery (IPD). The application of target costing in construction projects is vastly different from its use in the manufacturing industry. Most of all there is a completely different relationship between the manufacturer and the customer, when compared to the

relation between the service provider and the client. In the manufacturing industry, target costing allows an increase in profits for the manufacturer irrespective of customer interests, while target costing in the construction process allows an opportunity to increase the value for the service provider and client/owner (Ballard 2008). Because of the soft values involved and the complexity of the client needs, the client in general prefers control on programming and design, with a concern that since soft values are immeasurable the contractor makes profit by giving up these values (Pennanen et al. 2005).

TVD involves working with project constraints such as location, cost, time and regulations. The relationships between meeting the ends through means with project constraints are shown in Fig. 4.

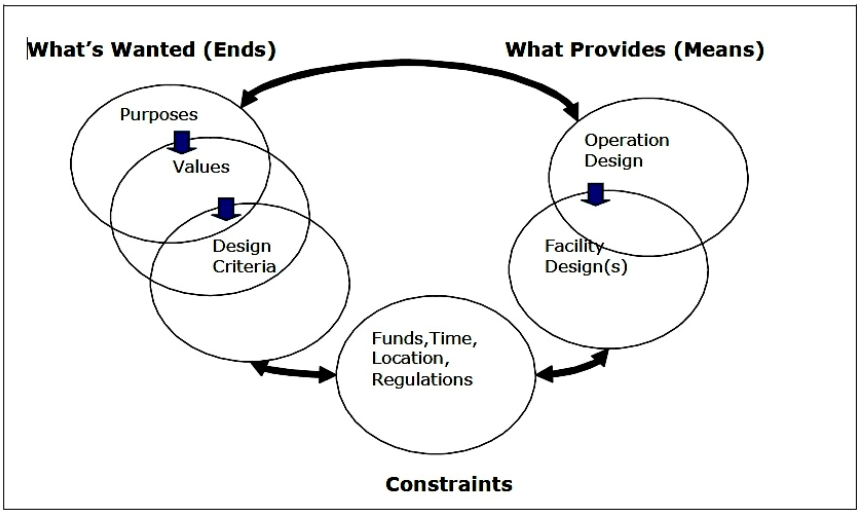

Fig. 3. Project Constraints
(Reprinted from Ballard 2008)

Macomber et al. (2007) outline the following differences in approach for target value design, as opposed to current design practices:

1. Reversing the approach, allowing design to evolve from detailed estimates as opposed to the conventional approach of creating estimates based on a finished design;
2. Creating designs with respect to constructability issues rather than compromising on finished designs to slot into available construction techniques;
3. Designing as a collaborative process considering inputs from all consultants, instead of a hierarchical process with the design being handed from consultant to consultant;
4. Provide a wider range of solutions to design issues instead of restricting the design aspects based on real world constraints
5. Allowing consultants a chance at team work, viewing the evolving design as a collaborative venture rather than a fragmented approach of each person taking an individual stance on various design concerns.

The Project Production Systems Laboratory (P2SL) at the University of California, Berkeley, has developed the process of Target Value Design as shown in the Fig. 4.

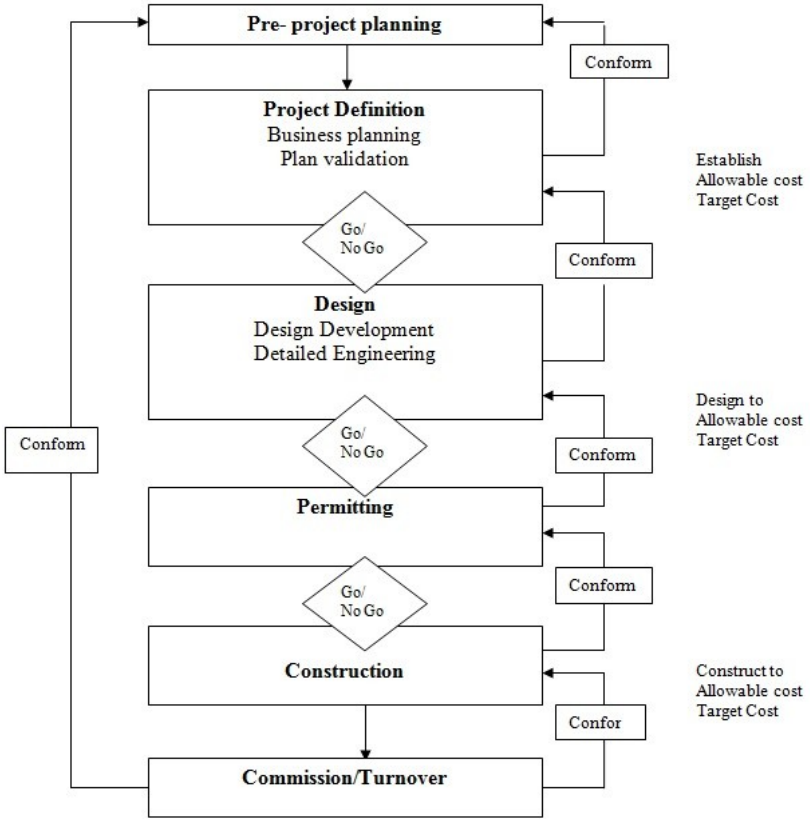

Fig. 4. Target Costing process in the construction industry as developed by P2SL (Reprinted from Ballard 2008)

In addition to the nine foundations of TVD, the current best practices guide published by P2SL recommends the following target costing process steps, suggestions and challenges based on observations from implementing target costing.

2.6 Prior Experiments in Target Costing

Nicolini et al. (2000) conducted action research on two pilot British construction projects. The study applied the target costing process, but achieved only limited success.

The research concluded that current practices of collaboration and cost estimation procedures within the UK construction organization culture are potential barriers and contributed to the limited success of target costing. The study also suggests that successful target costing is possible if a considerable amount of time is spent on the project and if supply chain relationships are modified to include more collaborative measures to achieve the design to cost.

In another project, the implementation of target costing played a vital role in the success of the St.Olaf Feildhouse project, by adhering to the project deadline and budget. A comparison of St.Olaf project to a similar project, a field house at Carleton College, built between 1998 and 2000 shows that Carleton project was 15% more expensive and lasted 10 months longer in schedule than St.Olaf project (Ballard and Reiser 2004).A comparison between the two projects is shown in Table 2.

Table 2. Comparison of project costs between a target cost project and traditional costing project
(Reprinted from Ballard and Reiser 2004)

	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

2.7 Gaming and Simulations

The adaption of simulation/gaming as an effective research tool for experiential studies, professional training and teaching purposes, has become extensive in recent years. Simulations/games actively represent and mirror complex events and apply to a wide spectrum of events such as conflict, intergroup relations, language, behavior and interpersonal communications. Use of simulation in the classroom environment is that simulation is based on the premise that simulation is a motivating learning tool that involves more fun, when compared to conventional methods. Simulations encourage active participation aiding participants in understanding complex situations, and producing better performance and greater retention. Hence, simulation as a tool links the real world and the classroom (Crookall et al. 1988).

Simulations are generally perceived in two ways. One is the representational point of view, i.e., viewing the simulation as a simple representation of the real world system with an assertion that it imitates some aspect of a real system. The other, less commonly held, perspective is the reality perspective, which holds that a simulation does not necessarily have to mirror reality but has its own approach in operating realities. The two main purposes of a simulation are for participants to develop and interpret a deeper understanding of the situation represented; to learn and refine participant skills. Game is the term applied to simulations that depend on the players' decisions partially or wholly. In a gaming-simulation, participants have roles to play, e.g., achieve goals, work with constraints, and perform activities, with positive and negative payoffs as outcomes of

their actions. These goals, constraints, consequences and activities are links connecting the gaming-simulation to real world systems (Greenblat 1988).

2.7.1 Lean Games

Academicians use lean games to demonstrate the practical implications of lean production concepts such as the impact of uncertainty on productivity, project duration push and pull approaches to production or the impact of multi-tasking (Alarcón and Ashley 1999). To demonstrate the consequences of uncertainties in the production rate of a project, Howell (1998) and Ballard (1999) used the "dice game" in a classroom environment. The Goldratt's Boy Scout hike game (Alarcón & Ashley 1999) inspired the dice game. Tommelein (1999) further studied the dice game to document the impact of lean on workflow and productivity rate. Popovska and Nielsen (2005) used the airplane game to teach students the concept and advantages of creating flow in work processes. They concluded that lean games are effective methods to convey the main ideas and concepts from lean philosophy to students/practitioners even if they have not previously used them Badurdeen et al. (2007) also used simulations and games to teach lean manufacturing. Lean Construction Institute (LCI) has consistently used the airplane game as a teaching simulation to introduce and demonstrate lean concepts to construction industry practitioners (Rybkowski et al. 2008).

Similar to lean games like the dice game and the airplane game which are used to explain different lean concepts, this research conducts a lab experiment with students to understand the implications of target costing.

3. RESEARCH METHOD

Ansari et al. (2007) proposed the following ten different research methods to study target costing:

1. Description based on secondary sources
2. Theoretical or conceptual frame work
3. Single-site case study
4. Multi-site case study
5. Written or interview based survey
6. Lab Experiment
7. Analytical modeling
8. Analysis using archival data
9. Simulation
10. Ethnographic field studies

Ballard and Reiser (2004) proposed the following steps for target costing research in design to target cost:

1. Descriptive research, translation of concepts and techniques from other domains, determining appropriate applications of target costing in construction; and,
2. Understanding the change in roles and relationships, and, understanding the conditions for producing a target cost.

This thesis utilizes lab experiment and telephone interviews to study the roles and relationship aspect of the target costing process. Procedures to conduct both interviews and simulation are explained in detail in the data collection section.

3.1 Data Collection

Data collection began after approval was granted by the Institutional Review Board (IRB) from the university to conduct research involving human subjects. (See appendix for IRB approval form).

Data collection took place the simulation and Focus Group Interviews (FGI); simulation participants were students and telephone interview participants were construction industry professionals who took part in a target costing process on construction projects. This research refers to the IPD case studies report published by the American Institute of Architects (AIA) amassed by Cohen for information on the projects discussed in the interviews section. Data collection and sample size for the study are as follows:

1. Experiment/Simulation with students

   First run study sample Size – 6

   Final study sample Size – 18

2. Telephone Interviews with Construction Industry Professionals

   Sample Size – 5

Both the telephone interviews and the focus group interviews were transcribed using a voice recorder with the consent of the participants. Collection of data was also through pictures taken during the simulation process of designing-to-target cost.

3.2 Description of the Simulation

The simulation was to design a two feet (2') tall wine glass holder (three feet tall for the first run study) with materials such as paper, Styrofoam paper plates, and Styrofoam cups, etc., provided by the researcher. (See appendix for the list, quantity and cost of materials) The choice of a wine glass holder for this simulation was based on the aesthetics and vanity attached to the product, a product that demands elegance along with structural stability. Materials such as knives, glue, and scissors had a rental cost associated with each item, similar to renting equipment for construction projects.

3.2.1 Project Constraints

Time and cost were the project constraints for this experiment, along with structural constraints. The structural constraint or the project requirement was that the final product should be structurally strong enough to hold a wineglass filled with water considering that all the materials provided for this experiment were light weight materials.

3.3 First Run Study

To test the validity of the simulation and to set the required rules for conducting the simulation a first run study using two teams, Team 1 and Team 2, with two architecture students and one civil engineering student on each team was conducted. Members were randomly assigned to each team. Both teams were assigned to work on designing and building a wine glass holder and were supplied with equal amounts of materials. During the first hour, both teams worked on designing and building the product without target

cost. Next, both teams worked on the simulation with cost and time constraints, i.e., designing the product to target cost in one-hour and with the same amount of resources (materials). In the case of designing to target cost, one person in each team took the role of an estimator to perform over the shoulder estimating. The target cost was set at $10.00 for the product. In both cases, after finishing the simulation (in one hour), the results were recorded including cost of materials. (See appendix for detailed report)

3.3.1 Focus Group Interview-First Run Study Results

During the Focus Group Interview session, both teams were asked to review their experiences in designing a product to target cost and without target cost. Following are observations of participants from both the teams:

1. Running the same experiment twice with both groups, with and without target cost, was tedious, and diluted the excitement and interest among team members in working on the project.
2. Designing to cost is challenging and interesting but time was a constraint and more time is required to finish the exercise. Both teams were under schedule pressure and pressure to reduce cost.
3. Familiarity among team members resulted in good team dynamics when working on the simulation in both cases.

In conclusion, both the teams suggested that three participants per team is an adequate number to finish the task. However, the height of the wine glass holder should be reduced to two feet, as building the three feet height was in itself a major constraint.

The teams also suggested that better solutions would be possible if the three feet constraint were lowered down to two feet, while keeping the cost and time constraints.(See appendix for detailed report). Following is a summary of the costs of the wineglass holders designed by both Team 1 and Team 2, shown in Table 3 and Table.4

Table 3. Summary of costs of the first run study

Team	Without Target Cost	Aesthetics	With target cost	Aesthetics
Team 1	$24.78	3	$7.00	4.5
Team 2	$12.83	4	$10.58	3

Table 4. Results of the first run study

	Without Target Cost			With Target Cost		
Team	Time	Team Dynamics	Experience	Time	Team Dynamics	Experience
1	Not a constraint	No differences	4	constraint	No differences	4
2	Not a constraint	No differences	3	constraint	Differences	4

To evaluate the design aesthetics of the product, ten randomly chosen students, not involved in the first run study ranked the product on a Likerts scale from 1-5 with 1-poor and 5-best, based on the product images shown by the researcher. In order to avoid

any bias in analyzing the results of the aesthetics rankings, the mode, (the value that occurs most frequently in a data set) is considered, instead of the average. The results of the first run study suggest a correlation between target cost and the aesthetics of the product designed by Team 1; however, in the case of Team 2, there appears to be no correlation between target cost and the design aesthetics of the product. Due to the familiarity among team members, both teams worked without any frustrations and differences, but collaborating and sharing their ideas with other team members to complete the simulation on time and with constraints, which resulted in effective team dynamics (See appendix for the results).

3.4 Final Study –Data Collection

Based on the inputs and results from the first run study, the final study was designed. For the final study the simulation was run eight times with six teams, Teams A, B, C, D, E, and F, with three participants on each team. Similar to the first run study Team E and Team F designed the product twice, first with target cost and second without target cost. Running the simulation twice with Team E and Team F was to observe any significant changes in the team dynamics and the cost versus design aesthetics factor. The simulation was further split into two parts, as follows:

1. Design the wine glass holder to target cost of $6.00 in one hour 20 minutes. Teams A, C, E1 and F1 worked on designing the wineglass holder to target cost.
2. Design the wine glass holder without target cost in one hour. Teams B, D, E2, and F2 worked on designing the wineglass holder without target cost.

All teams were composed of three participants from architecture, civil engineering and construction science educational backgrounds, to encourage the brainstorming activity from presumably different schools of thought and for the researcher to observe the team dynamics. Instead of following the traditional approach of design, followed by estimation and finally construction, the simulation followed the TVD approach, which was to collaborate and work as a team and design to target cost. Constants in this simulation were the quantity of materials supplied to each team.

Upon completion of the project, each participant in each team was asked to participate in a Focus Group Interview (FGI) to reflect on their experiences in working on the project, including the challenges and constraints faced each team. Following are the questions posed by the researcher during FGI to the participants of Teams A, C, E1, and F1, which worked with target cost:

1. How have you managed with the time constraint?
2. What were the dynamics of your team while working on the product to target cost?
3. While working with cost as a constraint, was cost a negative influence on the design?
4. What is the downside to the design to target cost process?

Following are the questions posed by the researcher to the participants of Teams B, D, E2 and F2, which worked on the product without target cost:

1. How did you managed with the time constraint?

2. What were the dynamics of your team while working on the product with no target cost?
3. What is the downside to designing without target cost process?

Refer to the appendix for the focus group interviews presented verbatim.

3.5 Data Analysis

This research follows grounded theory study; data analysis in grounded theory involves open coding, axial coding and development of a theory (Leedy and Ormrod 2005).This research adopts open coding, and development of a theory for the analysis of the data. The experience of each team collected during the focus group interviews is presented in Tables 5-12.

Table 5. Results of FGI with Team A

Designing the wineglass holder to cost				
Team A members	**Is cost a negative influence on design?**	**Is Time a negative influence on design?**	**Team Dynamics**	**Downsides of the process**
Architect A	No	No	Good	-
Contractor A	Yes	Yes	Good	Time is a potential constraint
Estimator A	No	No	Good	Project requirements are not clear

Table 6. Results of FGI with Team C

Designing the wineglass holder to cost				
Team C members	**Is cost a negative influence on design?**	Is Time a negative influence on design?	**Team Dynamics**	**Downside of the process**
Architect C	No	No	Excellent	No pure design phase
Contractor C	No	Yes	Good	-
Estimator C	No	Yes	Good	Design phase

Table 7. Results of FGI with Team E1

Designing the wineglass holder to cost				
Team E1 members	**Is cost a negative influence on design?**	**Is Time a negative influence on design?**	**Team Dynamics**	**Downside of the process**
Architect E	No	Yes	Excellent	No design phase
Contractor E	No	No	Excellent	-
Estimator E	No	No	Excellent	-

Table 8. Results of FGI with Team F1

Designing the wineglass holder to cost				
Team F1 members	**Is cost a negative influence on design?**	**Is Time a negative influence on design?**	**Team Dynamics?**	**Downside of the process**
Architect F	No	No	Excellent	-
Contractor F	No	No	Excellent	-
Estimator F	No	No	Excellent	-

Table 9. Results of FGI with Team B

Designing the wineglass holder without target cost			
Team B members	**Is Time a negative influence on design?**	**Team Dynamics?**	**Downside of the process**
Architect B	No	Good	Lack of design phase lead to random start of the project
Contractor B	No	strained	-
Estimator B	No	Good	No design phase

Table 10. Results of FGI with Team D

Designing the wineglass holder without target cost			
Team D members	**Is Time a negative influence on design?**	**Team Dynamics**	**Downside of the process**
Architect D	Yes	Excellent	No design phase
Contractor D	No	Excellent	-
Estimator D	No	Excellent	No design phase, designing on paper would have been more effective

Table 11. Results of FGI with Team E2

Designing the wineglass holder without target cost			
Team E2 members	**Is Time a negative influence on design?**	**Team Dynamics**	**Downside of the process**
Architect E1	Yes	Good	Not challenging and motivating without cost
Contractor E1	Yes	Good	Not motivating to work without cost
Estimator E1	Yes	Good	Too many materials /options and no cost

Table 12. Results of FGI with Team F2

Designing the wineglass holder without target cost			
Team F2 members	**Is Time a negative influence on design?**	**Team Dynamics**	**Downside of the process**
Architect F1	Yes	Good	Too many materials /options and no cost
Contractor F1	Yes	Good	Designing without cost lead to unfocussed design solution
Estimator F1	Yes	Good	Designing without cost lead to unfocussed design solution

The results of the box plot with aesthetics versus cost are shown in Fig.5.

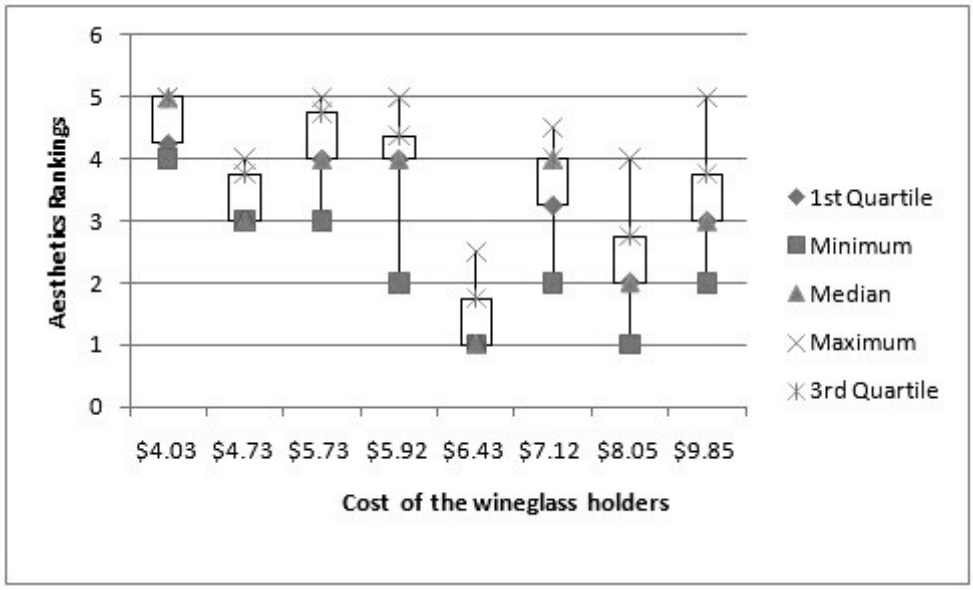

Fig. 5 Box plot showing the results of aesthetics versus cost.

The box plot shows that the aesthetics of the wineglass holders designed to target cost by Team A, Team C, Team E1 and Team F1 that cost of $4.03, $ 4.73, $5.73 and $5.92 respectively, lie within the range of 3 to 5 (Likerts scale of 1-5, 1-poor in aesthetics and 5-best). The aesthetics of the wineglass holders designed without target cost by Team B, Team D, Team E2 and Team F2 that cost $6.43, $7.12,$8.05 and $9.85 respectively, lie within the range of 1-4 (Likerts scale of 1-5, 1-poor in aesthetics and 5-best). Further, cost and aesthetics in the following scatter plot show that the aesthetic quality of the wineglass holders was higher when the product was designed to target cost and lower when designed without target cost. The results of the scatter plot with cost versus aesthetics are shown in Fig.6.

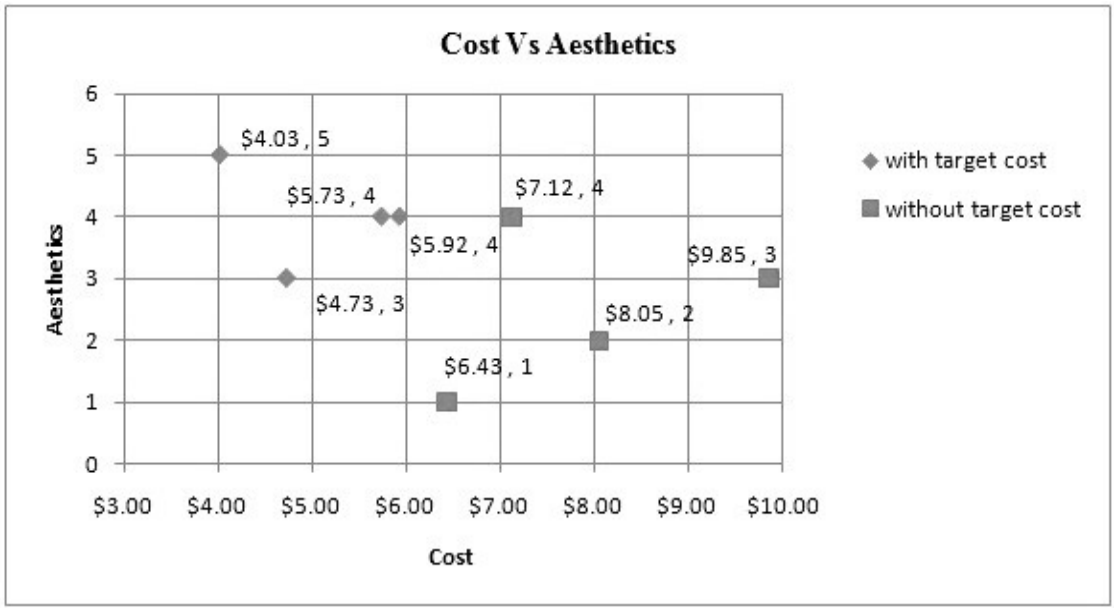

Fig. 6. Scatter plot showing the correlation between aesthetics and cost of the product.

Similar to the first run study, a group of 20 randomly chosen students, not involved in the experiment rated the aesthetics on a Likerts scale of 1-5, 1- poor and 5-the best. The mode of the results was considered the final value for aesthetics, instead of the average of the data set. To avoid any bias, the aesthetics of the product ranked by the team members and the researcher were not considered for this study. The number of design alternatives were what the team considered along with the researcher's observation during product design, in both with the in both with and without target cost groups. Following is the summary of all the team's design of wineglass holders as shown in Table 13.

From the data in the table, one might note the following:

1. From the data collected, analyzed and from the observation of the researcher during the simulation it is inferred that the participants preferred to work with cost, even though cost was as a constraint it was perceived as a motivating factor for the team, aiding the team in focusing on the design, eliminating costly solutions.

Architect E ***"****I think as architects, we like to work constraints...so the cost constraints helped us in designing...I particularly enjoyed designing to cost...The second case was very random... the first option is creatively much better…*"

Architect F "*Working with cost was effective…be it aesthetics, structural stability, meeting the cost and the time everything seemed to go fine…"*

Table 13. Summary of results of the final study

Team	Target Cost	Achieved Cost	Functionality	Aesthetics	Design Alternatives	Time taken to finish	Time allocated	Time spent on Design
Team A	$6.00	$4.73	Structurally feasible	4	2-3	65 minutes	80 minutes	40 – 45 minutes
Team B	-		Strong structure	3	3-4	50 minutes	60 minutes	25-30 minutes
Team C	$6.00	$4.03	Very weak	5	2-3	80 minutes	80 minutes	25-30 minutes
Team D	-		Strong structure	2	2-3	60 minutes	60 minutes	5-10 minutes
Team E1	$6.00	$5.92	Strong structure	4	2-3	70miuntes	80 minutes	35-40 minutes
Team E2	-		Strong Structure	3	4-5	60 minutes	60 minutes	40 minutes
Team F1	$6.00	$5.73	Strong structure	5	2-3	70 minutes	80 minutes	30-40 minutes
Team F2	-		Very Weak	1	4-5	65 minutes	60 minutes	45 minutes

2. In alignment with the observations from the first run study designing to cost demands more time compared to without cost. At least two out of three

participants in each team considered time as a constraint to finish the project while designing to cost.

Contractor A *"… to an extent I am satisfied with the product...but I seriously feel that if we have some more time then we could improve the aesthetics"*

Estimator C "*If we can work out on more options…then the result will be better...So time is more important than the cost. Cost is just fine…we can reach the cost anyways if there is more time.*"

Contractor E *"…Designing with cost constraint was tough…we had slightly more time but cost is a strict constraint here"*

3. In designing the wineglass holder without target cost even though time was a constraint the participants required no extra time to finish the product. Time was not perceived as a negative influence on the design of the wineglass holder.

Contractor B responded "*We have not experienced any time pressure, we were relaxed from the beginning, took around 30 minutes to finalize on the design*

Estimator D *"….1 hour is totally enough…we spent around 40 minutes on the design, because building it does not take much of time…we finished it in 20 minutes.*

While designing without target cost, with no limit to the use of materials and with the variety of materials available to the participants, participants made efforts to be more creative with the materials and spent the maximum amount of time finalizing the design.

Contractor E "*In the second experiment we had total freedom and lot of materials; which kind of made it difficult for us to focus on the design...*

4. Familiarity among team members and the duration of the project itself worked well for team members to collaborate with other participants.

Estimator A *"...we know each other for some time now, hence there is an unspoken understanding and comfort between team members, so there were really no issues working with other team members."*

Contractor C says that "...Y*es, having worked before we are very comfortable with each other and it was great…we concentrated more on finishing the product on time …*"

5. Discussions and differences, though not serious, arose between the team members during the design without target cost phase but not during the design to target cost phase.

Estimator E2 ***"****In the second case…more ideas crept in; everybody wanted to do something else. There was some difficulty in focusing on to one design…I don't call it an issue…it's just that because there was no cost involved, everybody had a different concept...in the first case we had a good alignment…we quickly agreed to each other's solutions.*"

6. On an average, the number of alternatives produced by the teams while designing the product without target cost were greater than those in designing to target cost. Teams A,C,E,F considered 2-3 alternatives while building the product.

Architect A "…*You could have few alternative designs 2, 3 alternatives, see the outcome rather than come up with one design and meet the target cost."*

Contractor C "… *if we have more time then we can come up with better options …definitely yes, every time we have to calculate the cost of the material that we are using, so some time is spent on that...."*

Team B, D, E2, and F2 considered 4-5 design alternatives before setting on the final option.

Estimator F2 "*With time and cost constraint we pretty much hit on one idea and started building it., but in the second part we found it challenging…as I said we had many ideas and in the end we had to come up with something that would support the wine holder."*

Aesthetics rankings as shown in Fig. 6 show that the design to cost wineglass holders of Teams A, C, E1, F1 were aesthetically more appealing than those of Team B, D, E2, F2. Team C and Team F1designed the product to $4.03 and $5.73, respectively, and these products were ranked the best in terms of aesthetics. Team D and Team F2 designed the product to $5.92 and $6.43 respectively, and these products were ranked lowest.

3.6 Survey Interviews -Data Collection

In actual projects, Target Value Design (TVD) as a part of Integrated Project Delivery (IPD) is being implemented on a number of projects, but there are no published reports on case studies yet, except for the IPD case studies report published by AIA. Telephone interviews were conducted with at least one team member involved in the projects listed below and discussed in the IPD case studies report:

1. Sutter Health Cathedral Hill Hospital

   Telephone interview with Architect 1 from the Smith Group Architects

2. Sutter Medical Castro Valley Project

   Telephone interview with the Project Manager, PM of the SMC project

3. Cardinal Glennon Children' Hospital

   Telephone interview with the architect (architect 2), from the architectural firm Christner Inc.

4. St.Clare Hospital

   Telephone interview with Architect 3 and Architect 4 from HGA architectural firm. Telephone interview with Construction Manager CM from Alberici Constructors.

All interviews were transcribed using a voice recorder with the consent of each participant. Following are the questions posed by the researcher to the participants during the telephone interviews:

1. Is cost a negative constraint in the Target Value Design process?
2. Working in cross-functional teams, how are the team dynamics?
3. What are the downsides to the Target Value Design process?

Refer to the appendix for verbatim transcripts of the telephone interviews

3.7 Data Analysis

Data collected from the telephone interviews are summarized in the following Table 14.

Table 14. Summary of telephone interviews

Project	Telephone Interview Participants	Is cost a negative Influence on design?	How are the team dynamics?	What are the downsides of TVD?
Cathedral HillHospital (CHH)	Smith Group Associates Architect 1	No	Good	Not defining the project ends clearly
Sutter Medical Castro Valley Hospital (SMCV)	Sutter Health Project Manager PM	No	Excellent	Requires a fully engaged team
Cardinal Glennon Hospital	Christner Inc. Architect 2	No	Excellent	NA
St.Clare Hospital	HGA architects Architect 2 Architect 3 Alberici Constructors CM	No No No	Excellent Excellent	The lengthy process of TVD

3.7.1 Team Dynamics

Familiarity among team members or prior experience on similar projects enables the team to deliver the project without conflicts and tensions between team members.

Architect 2 *"…the architects, engineers, contractors have all worked together in the phase 1 project…we are quite accustomed to working with the construction team, constructability look at cost estimation, what IPD did to us is, it really gave us is that to bring members in the team representing architectural design, engineering design and constructability and really get things well figured out."*

Architect 3 *" Its positive experience…the main concept of the IPD is to work in team and collaborate with each other and truly work as a team…if we don't trust each other then what's the point of doing IPD…"*

Architect 4*"We worked with people who are familiar with the process…who have worked with us before…that made it a good experience."*

In fact, even if the teams are new to the process , initial discomfort, conflicts, and frustrations arise due to varied perceptions of the team but this is perceived as part of the learning process, thus helping the team achieve the target cost and value for the client.

Architect 1 *"Yes there were some problems between companies...Because what we are asking them to do is very different from traditional project delivery...so its requires a different focus and a different set of behaviors…I think primarily we have to get comfortable with sharing unfinished concepts with team members."*

CM *"….because our specialty contractors doing mechanical and electrical estimating…between reviewing conceptual estimating…draft development of design, we*

found in the estimate they generated we found that ...there were gaps because not all the work designed …that's part of the learning process."

3.7.2 Cost and Time Constraints

Cost is definitely a constraint, but it helps in achieving the client's value. In spite of the constant cost reduction process during the TVD process, cost is perceived as a goal to meet rather than a constraint to design. Cost does not have a negative impact on the design.

Yes...it is... Mainly it's getting the team to use budget as a constraint on design and so it's something that always present in the minds of the team from when they start that one big difference from traditional delivery ….it's the difference mind set of the team that makes the difference…

Architect 3 *"Cost is the biggest constraint…cost scope and schedule."*

Architect 4 *"It's not just the cost…its coming up with best solutions…it could be several different solutions…they all may cost similar to each other…have to weigh the pros and cons of each options,…the best option often look at the life cycle cost it may not be the initial cost that you are looking at it…,may not be the cheapest solutions..."*

3.7.3 Downsides of the TVD Process

The lengthy process of TVD itself is perceived as a downside. Iterative design process is at times tedious for the team and the client has to spend more amount of money on the project during the preconstruction phase.

Architect A *"I don't think we have been in this process long enough to see if this is the downside but in my opinion TVD only work if you bring the more unknown to known. You want to bring down the cost only to increase the cost later because of some other factors, If you don't know your stuff early then TVD won't be showing reduction in costs..."*

PM *"The potential downside is that I think it takes full engaged team, full engaged owner is aware that it is difficult, its difficult because hospitals and big scale projects a, they are tricky things, it takes a lot of work, it's nothing about delivery models, it's just working hard ,people working hard in the right direction."*

4. FINDINGS

4.1 Findings from the Simulation

Results of the simulation indicate a correlation between target cost and aesthetics of the product. To an extent, there is a correlation between the cost (without target cost) and aesthetics but this correlation is not linked to the maximum cost and the aesthetics of the product. Correlation between the target costs versus aesthetics is higher than the cost (without target cost) versus aesthetics. Thus, it can be inferred from the study that higher costs do not necessarily result in better aesthetics and aesthetic quality can be achieved through reduced costs. The results are similar to the study conducted by architect Niukkanen on building cost versus building quality, indicating no correlation between the most expensive buildings and the quality of the buildings (Pennanen et al. 2005). However, while designing-to-target cost, the teams did not consider more design alternatives because of the time constraint. Limited time forced the team members to rule out other alternatives, readily agreeing to each other's ideas as the drive to meet the project requirements among the team members was higher than producing innovative solutions. On an average, the teams that built the product to target cost considered two to three design alternatives.

The teams that worked without cost as a constraint produced costlier designs and were all above the target cost. The researcher's observation and the team members' insight in to the experiment revealed that all team members intended to be more creative and produce aesthetically appealing innovative solutions because of the no cost constraint, which consumed more than 80% of the project time.

Teams that worked with target cost and without target out worked in synergy during the length of the project. There were no major differences or tensions between the team members during the simulation. In this simulation, target cost does not have specific impact on team dynamics. However, Team B and Team F experienced discomfort conveying design concepts to each other. Overall, the team dynamics worked in both cases, i.e., with target cost and without target cost.

4.2 Findings from the Survey Interviews

Interviews with construction professionals involved in different TVD projects conveyed that in real world TVD process even though cost is a constraint, it does not have a negative impact on the design. Target cost was perceived as a goal to achieve. All the parties involved in the above-mentioned projects entered the project with a positive mindset and with a belief in the Integrated Project Delivery (IPD) system. Hence, all frustrations, arguments and discomfort were accepted as a part of the learning process especially if the parties were taking part of the process for the first time. It was obvious from the interviews that familiarity among the team members and previous work experience resulted in true collaboration and solutions produced that value for the client. While the participants stated different opinions on the downsides of the TVD process, a common response to this question was been that if the ends are not clearly stated in the beginning of the TVD process, then TVD might not be very useful. This results in a lengthy preconstruction phase, involving more meetings, and more design iterations for which the owner must allot additional funds and time.

5. CONCLUSIONS

5.1 Summary of Findings

While several conclusions can be derived from this study, two main conclusions from this study are drawn from the simulation i.e., the most expensive design solutions are not the best design solutions in terms of aesthetics. There is no correlation between maximum cost of the wineglass holder and the aesthetics of the wineglass holder. Interestingly, there is a correlation between the wineglass holder designed to target cost and the aesthetic quality of the product. Both the simulation and the survey interviews conclude that familiarity among team members increases comfort among team members and sharing of information becomes more effective. Cost was perceived as a constraint, as a goal to achieve, rather than a negative factor during the design development. The simulation concludes that designing to target cost demands more time to generate alternatives and for producing a better design solution. In fact, cost is not a negative constraint but meeting the project requirements with time constraints emerged as a potential constraint that has an impact on the quality of the product. The simulation results are similar to those of a lengthy preconstruction phase of a TVD process in the practical field of construction. The other conclusion drawn from the survey interviews is that the potential downsides seems to be the requirement of a fully engaged team, including the client and if the project ends are not detailed in the beginning of the project, then the benefits of TVD are not significant.

5.2 Future Research

The experiment used in this research is a pilot study to understand the large-scale issues of TVD on a smaller scale. Further development of the simulation to validate the process, study the concept of team dynamics in designing-to-target cost is needed. A pure design phase was not included in the simulation; for further research, this phase could be included to test the results of this experiment. Validating the results of the simulation with industry surveys and through case studies would be additional avenues for further research.

REFERENCES

Alarcón, L. F., and Ashley, D. B. (1999). “Playing games: Evaluating the impact of lean production strategies on project cost and schedule.” *Proc., 1999 Annual Conf. on International Group of Lean Construction (IGLC-7),* University of California, Berkeley, Ca.

Ansari, S. L., Bell, J.E., and CAM-I Target Cost Group. (1997). *Target costing - The next frontier in strategic cost management*, Irwin-McGraw Hill, N.Y.

Ansari, S., Bell, J., and Okano, H. (2007). "Target costing: Unchartered research territory." *Handbook of management accounting research*, C.S. Chapman., A.G. Hopwood and M.D. Shields, eds., Elsevier Ltd., Oxford, UK., 507-530.

Ax, C., Greve, J. and Nilsson, U. (2008). "The impact of competition and uncertainty on the adoption of target costing." *Int. J. Prod. Econ.,* 115(1), 92-103.

Badurdeen, F., Marksberry, P., Hall, A., and Gregory, B. (2009). “Teaching lean manufacturing with simulations and games.” *Simulation and Gaming,* 1, 1-21.

Ballard, G. (1999). “The dice game.” Game played at the *Neenan Conf. on Lean Construction*, Denver, Co.

Ballard, G. (2008). "The lean project delivery system: An update." *Lean Construction Journa,l* 1, 1-19.

Ballard, G., and Reiser, P. (2004). “The St. Olaf College Fieldhouse project: A case study in designing to target costing.” *Proc., 2004 Annual Conf. of Int. Group for Lean Construction (IGLC-12),* Elsinor, Denmark.

Cheah, Y.J. C., and Ting, K.S. (2004). “Appraisal of value engineering in construction in southeast Asia.” *Int. J. Proj. Manage.,* 23, 151-158.

Christoffersen, A.K. (2003). “Value control in the building process.” *Proc.*, 5th *Annual Lean Construction Institute Congress*, Blacksburg, Va.

Clifton, B. (1998). "Inputs for successful target costing." *American Society of Mechanical Engineers,* 99, 21-27

Clifton, B.M., Bird, B.M.H., Albano, E.R., and Townsend, P.W. (2004). *Target costing: market driven product design*. Marcel Dekker, Inc. N.Y.

Cohen, J. (2010). "Integrated project delivery: Case studies." *American Institute of Architects California Council*, Sacramento, Ca.

Cooper, R., and Slagmulder, R. (1997). *Target costing and value engineering*. Productivity Press, Portland, Or.

Cooper, R., and Slagmulder, R. (1999). "Develop profitable new products with target costing." *Sloan Management Review,* 40(4), 23-34.

Crookall, D., Klabbers, J., Coote, A., Saunders, D., Cecchini, A., and Delle Piane (1988). "Simulation-gaming in education and training." *Proc., 18th Int. Conf. on International Simulation and Gaming Association,* Venice, Italy.

Eckes, G. (2003). *Six sigma team dynamics*. John Wiley & Sons, Inc., Hoboken, NJ.

Emmitt, S., Sander, D., and Christoffersen, A. K. (2004). "Implementing value through lean design management." *Proc., 2004 Annual Conf. of the Int. Group for Lean Construction (IGLC-12)*, HelsingØr, Denmark.

Everaert, P. (1999). "The Impact of target costing on cost, quality and time-to-market of new products: Results from lab experiments." Dissertation, University of Ghent, Brussels, Belgium.

Gagne, L.M., and Discenza, R. (1995). "Target Costing." *Journal of Business & Industrial Marketing,* 10(1), 16-22.

Granja, A. D., Picchi, V. A. and Robert, G. T. (2005). "Target and Kaizen costing in construction." *Proc., 2005 Annual Conf. of the Int. Group for Lean Construction (IGLC-13)*, Sydney, Australia,

Greenblat, C.S. (1988). *Designing games and simulations: An illustrated handbook.* Sage Publications, Newbury Park, Ca.

Howell, G.A. (1998). "The dice game." *Game played at the 1998 Annual Conf. on the Int. Group for Lean Construction (IGLC-1998)*, Guaruja, Brazil.

Howell, G. A. (1999). "What is lean construction -1999." *Proc., Annual Conf. of the Int. Group for Lean Construction (IGLC-7),* University of California, Berkeley, Ca.

Jacomit, M. A., Granja, A. D., and Picchi, V. A. (2008). "Target costing research analysis: reflections for construction industry implementation." *Proc., Annual Conf. on the Int. Group for Lean Construction (IGLC-16)*, Manchester, UK,

Jariri, F., and Zegordi, S. H. (2008). "Quality function deployment, value engineering and target costing, an integrated framework in design cost management: A mathematical programming approach." *Scientia Iranica*, 15(3), 405-411.

Jørgensen, B. (2008) *Designing to target cost: One approach to design/construction integration*. Technical University of Denmark, Denmark.

Kato, Y. (1993). "Target costing support systems: Lessons from leading Japanese companies." *Management Accounting Research,* 3, 33-47.

Leedy, P.D., and Ormrod, J.E. (2001). *Practical research: Planning and design*. Allyn & Bacon, Upper Saddle River, N.J.

Macomber, H., Howell, G. A., and Barberio, J. (2005). "Target-value design: Seven foundational practices for delivering surprising client value." http://www.leanproject.com/community/downloads/Target%20Value%20Design.pdf (August 25, 2008).

Macomber, H., Howell, G. A., and Barberio, J. (2007). "Target-value design: Nine foundational practices for delivering surprising client value." http://info.aia.org/nwsltr_pm.cfm?pagename=pm_a_112007_targetvaluedesign (Fall 2007).

Nicolini, D., Tomkins, C., Holti, R., Oldman, A., and Smalley, M. (2000). "Can target costing and whole life costing be applied to the construction industry? Evidence from two case studies." *British Journal of Management*, 11, 303-324.

P2SL. (2005). "P2SL Report: Current benchmarking in target costing." *Project Production Systems Laboratory (P2SL)*, Dept. of Civ. and Envir. Engrg., University of California, Berkeley, Ca.

Pennanen, A., Haahtela, Y., and Vaananen, H. (2005). "Workplace planning and target costing techniques in project and facility management." *Proc., CIB Conference*, Helsinki, Finland.

Dukovska-Popovska, I., Hove-Madsen, V., and Neilsen, K.B. (2008). "Teaching lean thinking through game: Some challenges." *Proc., 36th Annual Conf. of SEFI*, Aalborg, Denmark.

Rybkowski, Z. K. (2009). "The application of root cause analysis and target value design to evidence-based design in the capital planning of healthcare facilities." Dissertation, University of California, Berkeley, Ca.

Rybkowski, Z.K., Wong, J.M., Ballard, G., and Tommelein, I.D. (2008). "Using controlled experiments to calibrate computer models: The airplane game as a lean simulation exercise." *Proc.*, *Annual Conf. on the International Group for Lean Construction (IGLC-16),* Manchester, UK.

Shank, K. J. and Fisher, J. (2006). "Case study: Target costing as a strategic tool." *Supply chains and total product systems: Our reader*, E.Rhodes, J.P.Warren and R. Carter, eds., Blackwell Publishing, Malden, Ma. 350-364.

Tommelein, I.D. (1999). "Lean construction experiments using discrete event simulation: Techniques and tools for process re-engineering?" *Int. J. Computer – Integrated Design and Construction (CIDAC), Special Issue on Constr. Process Re-engineering,* 1(2), 53-63

Supplemental Sources Consulted

Ballard, G. and Zabelle, T. (2000). “Project definition.” White paper, 9, 1-10.

Ballard, G., and Rybkowski, Z. K. (2009). “Overcoming the hurdle of first cost: Action research in target costing.” *Proc., 2009 Research Congress*, Seattle, WA.

Cooper, R. (2002). “Target costing for new-product development.” *Journal of Cost Management* (May/June): 5-12.

Cooper, R. and Chew, W. B. (1996). “Control tomorrow's costs through today's designs.” *Harvard Business Review*, 88-97.

Dekker, H. and Smidt, P. (2003). “A survey of the adoption and use of target costing inDutch firms”. *International Journal of Production Economics*, Elsevier, New York, 84(3), 293-305.

Ellram, L. M. (2000). "Purchasing and Supply Management’s Participation in the Target Costing Process." *The Journal of Supply Chain Management,* Spring: 39-5

Fisher, J. (1995). "Implementing Target Costing." *Journal of Cost Management,* 9(2), 50-59

Kato, Y., and G. Boeer, et al. (1995). "Target costing: An integrative management process." *Journal of Cost Management,* 9(1): 39-39.

Lee, C., Lee, J.Y., and Monden, Y. (2005). Early evidence on the interactive effects involving product development organizations and target cost management. *Advances in Management Accounting* (14), 189-209.

Lichtig, W. A. (2005). "Sutter Health: Developing a model to support lean project delivery." *Lean construction Journal,* 2, 105-112.

Lichtig, W. A. (2006). “The integrated agreement for lean project delivery.” *Construction Lawyer*, 26(3), 1-5.

Lin, T. W., Merchant, K.A., Yang, Y., Yu,Z. (2005). “Target costing and incentive compensation.” *Cost Management* (March/April), 29-42.

Manus, H. L., Rebentisch, E., and Stanke, A. (2007). “Teaching lean thinking: Principles through hands on simulations.” *Proc., of the 3rd International CDIO Conference,* MIT, Cambridge, Ma.

Matthews, O. and Howell, G. A. (2005). “Integrated project delivery an example of relational contracting.” *Lean Construction Journal*, 2, 46-61

Monden, Y., Hamada, K. (1991). “Target costing and kaizen costing in Japanese automobile companies.” *Journal of Management Accounting Research*, (3), 16-34.

Monden, Y., Lee.Y. (1993). “How a Japanese auto maker reduces costs.” *Management Accounting* (August), 22-26.

Norris, G. (1993). "User perceptions on an application of activity based costing." Working paper of target costing. *International Journal of Production Economics,* 115, 92-103.

Pennanen, A. and Koskela, L. (2005) “Necessary and Unnecessary complexity in Construction.” *Proc., of the First International Conf. on Complexity, Science and the Built Environment in Conjunction with Centre for Complexity and Research*, University of Liverpool, UK, 1-12.

Takai, S., Ishii, K. (2006). "Integrating target costing into perception-based concept evaluation of complex and large-scale systems using simultaneously decomposed QFD." *Journal of Mechanical Design,* 128, 1186-1195.

Tani, T. (1995). “Interactive control in cost management.” *Management Accounting Research,* 6, 399-414.

Williamson, A. (1997). "Target and kaizen costing." *Manufacturing Engineer*, 76(1), 22-24.

Woodlock, P. (1999). “Weighing the options to meet targeted costs” *Journal of Cost Management,* (November/December) 29-35.

APPENDIX

Preliminary Study

Date-20 February 2010

Teams – Two Teams, Team 1 and Team 2 with three participants in each team

Table 15. Quantity of materials provided for each team for the first run study

Target Value Design	**Materials**	**Quantities issued per team**
Structural Items		
	Paper	50
	Plates (Styrofoam)	30
	Plates (paper)	30
	Cups (Styrofoam)	25
Connectors/Structural	Paper clips	25
	Binder clips	3
	Straws	50
	Sticks	200
	Pipe cleaner	50
Tools	Glue	1
	Scissors	1
	Exactoknives	3
	Pencils	5
	Erasers	1
Required	Drop cloth	1
	Measuring stick (42.5")	1
	Tape	1800

Table 16. Cost break down of the materials provided for the first run study

Lean Game to design a Wine Holder					
02-20-2010					
		Cost	Unit	Cost/Unit	Adjusted Cost/Unit
Structural Items					
	Paper	2.97	Nos.	0.01	0.1
	Paper Styrofoam	3.50	Nos.	0.02	0.2
	Plates (Paper)	4.32	Nos.	0.04	0.4
	Cups (Styrofoam)	1.00	Nos.	0.02	0.2
Connectors/Structural					
	Paper clips	1.22	Nos.	0.01	0.01
	Binder Clips	1.37	Nos.	0.11	0.11
	Straws	1.44	Nos.	0.01	0.01
	Sticks	4.97	Nos.	0.005	0.005
	Pipe cleaner	1.97	Nos.	0.02	0.02
Tools					
	Glue	1.47	Nos.	1.47	1.47
	Scissors	1.97	Nos.	1.97	1.97
	Exactoknives	1.47	Nos.	0.74	0.74
	Pencils	3.84	Nos.	0.16	0.16
	Erasers	2.00	Nos.	0.33	0.33
Required					
	Drop cloth	1.27	Nos.	1.27	1.27
	Measuring stick	-	Nos.	-	-
	Tape	2.88	in.	0.003	0.003
	Total				

Fig. 7. Team 1 design of wineglass holder without target cost

Fig. 8. Team 2 design of wineglass holder without target cost

Table 17. First run study results for the design of wineglass holder without target cost

Lean Game to design a Wine Holder							
First Run Study – Without Target Costing							
		Team 1			Team 2		
		Qty.	Actual Cost	Adjusted Cost	Qty.	Actual Cost	Adjusted Cost
Structural Items							
	Paper	115	0.68	11.50	0	-	0.00
	Paper Styrofoam	9	0.21	1.80	5	0.12	1.00
	Plates (Paper)	17	0.61	6.80	0	-	0.00
	Cups (Styrofoam)	8	0.16	1.60	22	0.43	4.40
Connectors/ Structural							
	Paper clips	0	0.00	0.00	0	-	0.00
	Binder Clips	0	0.00	0.00	0	-	0.00
	Straws	0	0.00	0.00	0	-	0.00
	Sticks	35	0.17	0.17	7	0.03	0.03
	Pipe cleaner	0	0.00	0.00	0	-	0.00
Tools							
	Glue	1	1.47	1.47	1	1.47	1.47
	Scissors	0	0.00	0.00	1	1.97	1.97
	Exactoknives	0	0.00	0.00	3	2.21	2.21
	Pencils	1	0.16	0.16	3	0.48	0.48
	Erasers	0	0.00	0.00	0	-	0.00
Required							
	Drop cloth	1	0.00	1.27	1	1.27	1.27
	Measuring stick	1	0.00	0.00	1	-	0.00
	Tape	1	0.00	0.00	1	0.00	0.00
	Total		**4.74**	**24.78**	Total	**7.98**	**12.83**

Fig. 9. Team 1 design of wineglass holder with target cost.

Fig. 10. Team 2 design of wineglass holder with target cost.

Table 18. Cost break down of the materials for the final study

Lean Game to design a Wine Holder							
First Run Study – Design – to - cost							
		Team A			**Team B**		
		Qty.	Actual Cost	Adjusted Cost	Qty.	Actual Cost	Adjusted Cost
Structural Items							
	Paper	1	0.01	0.1	30	0.2	3.00
	Paper Styrofoam	2	0.05	0.4	6	0.1	1.20
	Plates (Paper)	0	-	0	0	0.0	0.00
	Cups (Styrofoam)	10	0.20	2	6	0.1	1.20
Connectors/ Structural							
	Paper clips	0	-	0	0	0.0	0.00
	Binder Clips	0	-	0	0	0.0	0.00
	Straws	0	-	0	12	0.2	0.17
	Sticks	20	-	0.0994	48	0.2	0.24
	Pipe cleaner	0	0.10	0	3	0.1	0.06
Tools							
	Glue	1	-	1.47	1	1.5	1.47
	Scissors	1	1.47	1.97	1	2.0	1.97
	Exactoknives	0	1.97	0	0	0.0	0.00
	Pencils	0	-	0	0	0.0	0.00
	Erasers	0		0	0	0.0	0.00
Required							
	Drop cloth	1	1.27	1.27	1	1.3	1.27
	Measuring stick	1	-	0	1	0.0	0.00
	Tape	1	0.00	0.0032	1	0.0	0.00
	Total		**5.06**	**7.3126**	Total	**5.62**	**10.58**

Fig. 11. Team A design of wineglass holder with target cost

Fig. 12. Team B design of wineglass holder without target cost

Fig. 13. Team C design of wineglass holder with target cost

Fig. 14. Team C design of wineglass holder with target cost

Fig. 15. Team E1 design of wineglass holder with target cost

Fig. 16. Team E2 design of wineglass holder without target cost

Fig. 17. Team F1 design of wineglass holder with target cost.

Fig. 18. Team F2 design of wineglass holder with target cost

Table 19.Cost estimate of the wineglass holder designed by Team A

Lean Simulation to Design a Wine Holder - Final Study								
05/14/2010 3 members per team								
						Target Cost $6.00		
Target Value Design						**Team**	**Actual**	**Adjusted**
		COST	**units**	**Cost/unit**	**Adjusted Cost/unit**	**A**	**Cost**	**Cost**
STRUCTURAL ITEMS								
	paper	2.97	Nos.	0.01	0.1	6	0.04	0.60
	plates (styrofoam)	3.50	Nos.	0.02	0.2	4	0.09	0.80
	plates (paper)	4.32	Nos.	0.04	0.4	1	0.04	0.40
	cups (styrofoam)	1.00	Nos.	0.02	0.2	10	0.20	2.00
CONNECTORS/STRUCTURAL	paper clips	1.22	Nos.	0.01	0.01	0	0.00	0.00
	binder clips	1.37	Nos.	0.11	0.11	0	0.00	0.00
	straws	1.44	Nos.	0.01	0.01	0	0.00	0.00
	sticks	4.97	Nos.	0.005	0.005	6	0.03	0.03
	pipe cleaner	1.97	Nos.	0.02	0.02	0	0.00	0.00
TOOLS	Glue	1.47	Nos.	1.47	1.47	0	0.00	0.00
	Scissors	1.97	Nos.	1.97	1.97	0	0.00	0.00
	Exactoknives	1.47	Nos.	0.74	0.74	1	0.74	0.74
	pencils	3.84	Nos.	0.16	0.16	1	0.16	0.16
	erasers	2.00	Nos.	0.33	0.33	0	0.00	0.00
REQUIRED	drop cloth	1.27	Nos.	1.27	1.27	0	0.00	0.00
	measuring stick (42.5")	-	Nos.	-	-		0.00	0.00
	tape	2.88	in.	0.003	0.003	1	0.00	0.00
Total							**1.29**	**4.73**

Table 20. Cost estimate of the wineglass holder designed by Team C

Lean Simulation Game to Design a Wine Holder - Final Study								
5/15/2010 3 members per team								
						Target Cost $6.00		
Target Value Design						**Team**	**Actual**	**Adjusted**
		COST	**units**	**Cost/unit**	**Adjusted Cost/unit**	**C**	**Cost**	**Cost**
STRUCTURAL ITEMS								
	paper	2.97	Nos.	0.01	0.1	1	0.01	0.10
	plates (styrofoa	3.50	Nos.	0.02	0.2	1	0.02	0.20
	plates (paper)	4.32	Nos.	0.04	0.4		0.00	0.00
	cups (styrofoam	1.00	Nos.	0.02	0.2	11	0.22	2.20
CONNECTORS/STRUCTURAL	paper clips	1.22	Nos.	0.01	0.01		0.00	0.00
	binder clips	1.37	Nos.	0.11	0.11		0.00	0.00
	straws	1.44	Nos.	0.01	0.01		0.00	0.00
	sticks	4.97	Nos.	0.005	0.005	13	0.06	0.06
	pipe cleaner	1.97	Nos.	0.02	0.02		0.00	0.00
TOOLS	Glue	1.47	Nos.	1.47	1.47	1	1.47	1.47
	Scissors	1.97	Nos.	1.97	1.97		0.00	0.00
	Exactoknives	1.47	Nos.	0.74	0.74		0.00	0.00
	pencils	3.84	Nos.	0.16	0.16		0.00	0.00
	erasers	2.00	Nos.	0.33	0.33		0.00	0.00
REQUIRED	drop cloth	1.27	Nos.	1.27	1.27		0.00	0.00
	measuring stick (42.5")	-	Nos.	-	-		0.00	0.00
	tape	2.88	in.	0.003	0.003		0.00	0.00
Total							**1.78**	**4.03**

Table 21. Cost estimate of the wineglass holder designed by Team E1

Lean Simulation to Design a Wine Holder - Final Study								
5/16/2010 3 members per Team								
						Target Cost		
Target Value Design						Team	Actual	Adjusted
		COST	units	Cost/unit	Adjusted Cost/unit	E	Cost	Cost
STRUCTURAL ITEMS								
	paper	2.97	Nos.	0.01	0.1	1	0.01	0.10
	plates (styrofoam)	3.50	Nos.	0.02	0.2	1	0.02	0.20
	plates (paper)	4.32	Nos.	0.04	0.4		0.00	0.00
	cups (styrofoam)	1.00	Nos.	0.02	0.2	20	0.39	4.00
CONNECTORS/STRUCTURAL	paper clips	1.22	Nos.	0.01	0.01		0.00	0.00
	binder clips	1.37	Nos.	0.11	0.11		0.00	0.00
	straws	1.44	Nos.	0.01	0.01		0.00	0.00
	sticks	4.97	Nos.	0.005	0.005	30	0.15	0.15
	pipe cleaner	1.97	Nos.	0.02	0.02		0.00	0.00
TOOLS	Glue	1.47	Nos.	1.47	1.47	1	1.47	1.47
	Scissors	1.97	Nos.	1.97	1.97		0.00	0.00
	Exactoknives	1.47	Nos.	0.74	0.74		0.00	0.00
	pencils	3.84	Nos.	0.16	0.16		0.00	0.00
	erasers	2.00	Nos.	0.33	0.33		0.00	0.00
REQUIRED	drop cloth	1.27	Nos.	1.27	1.27		0.00	0.00
	measuring stick (42.5")	-	Nos.	-	-		0.00	0.00
	tape	2.88	in.	0.003	0.003		0.00	0.00
Total							**2.04**	**5.92**

Table 22. Cost estimate of the wineglass holder designer by Team F1

Lean Simulation to Design a Wine Holder - Final Study								
5/16/2010 3 members per Team								
						Target Cost $6.00		
Target Value Design						Team	Actual	Adjusted
		COST	units	Cost/unit	Adjusted Cost/unit	Livingroom Nos.	Cost	Cost
STRUCTURAL ITEMS								
	paper	2.97	Nos.	0.01	0.1		0.00	0.00
	plates (styrofoam)	3.50	Nos.	0.02	0.2	1	0.02	0.20
	plates (paper)	4.32	Nos.	0.04	0.4		0.00	0.00
	cups (styrofoam)	1.00	Nos.	0.02	0.2	21	0.41	4.20
CONNECTORS/STRUCTURAL	paper clips	1.22	Nos.	0.01	0.01		0.00	0.00
	binder clips	1.37	Nos.	0.11	0.11		0.00	0.00
	straws	1.44	Nos.	0.01	0.01		0.00	0.00
	sticks	4.97	Nos.	0.005	0.005	0	0.00	0.00
	pipe cleaner	1.97	Nos.	0.02	0.02		0.00	0.00
TOOLS	Glue	1.47	Nos.	1.47	1.47	1	1.47	1.47
	Scissors	1.97	Nos.	1.97	1.97		0.00	0.00
	Exactoknives	1.47	Nos.	0.74	0.74		0.00	0.00
	pencils	3.84	Nos.	0.16	0.16		0.00	0.00
	erasers	2.00	Nos.	0.33	0.33		0.00	0.00
REQUIRED	drop cloth	1.27	Nos.	1.27	1.27		0.00	0.00
	measuring stick (42.5")	-	Nos.	-	-		0.00	0.00
	tape	2.88	in.	0.003	0.003	1	0.00	0.00
Total							**1.91**	**5.87**

Simulation – Focus Group Interviews

Focus Group interview with Team A

Participants: Architect A, Contractor A, Civil Engineer/Estimator A.

Team A managed to meet the requirements of the client (which in this case is the researcher) finishing the project ahead of the schedule and below the target cost. The team finished the project in 65 minutes designing the product in $4.63. Focus Group Interview with team members enounced that working with cost as a constraint aided the team in delivering the project ahead of the schedule. While Architect A and Estimator A expressed their satisfaction over the end product, contractor A expressed her dissatisfaction on the aesthetics of the product.

Researcher: How did you manage with time?

Contractor A *"... to an extent I am satisfied with the product...but I seriously feel that if we have some more time then we could improve the aesthetics"*

Researcher: How are the team dynamics?

Estimator A *"...we know each other for some time now, hence there is an unspoken understanding and comfort between team members, so there were really no issues working with other team members."*Discussing about collaborating with other members in the team **Architect A** expressed*"...working in a team helped us in achieving the target cost...If I am the only one working on the cost...Then I would definitely not have the time to look in to design and cost, the only thing is once you are done with design you can go on fast track…but the design phase is the hitch...but we managed to finish it ahead of the schedule*

Researcher: Working with cost as a constraint, does cost have a negative influence on the design?

Architect A "*…You could have few alternative designs 2, 3 alternatives, see the outcome rather than come up with one design and meet the target cost... The other alternative might be a dollar more, say $ 7.00 but if the wine glass holder looks beautiful and is strong enough then I think definitely the customer would not mind spending a dollar more….*"

Contractor A "*….Cost constraint really affected the design… we did consider alternatives but those proved to be costly…we did manage to meet all the requirements in one hour but If we are given one more hour then we could have come up with a more aesthetically appealing product.*

Researcher: What is the downside to this process?

PM "If the requirements were more clear and what is expected from us ...we could have done a better job..I feel what is needed in the end is not defined properly.

Refer to the appendix for the final product designed by Team A.

Focus Group Interview with Team C

Participants: Architect C, Contractor C, Civil Engineer/Estimator C

Team C designed the product in $ 4.03, lower than the target cost. The team took 80 minutes to complete the design. It is the observation of the researcher, from the start of the experiment Team C's concern was about the aesthetics and elegance of the wine holder rather than the structural stability of the product. Each member of the team stressed on workmanship and aesthetic appearance of the product.

Researcher: How did you manage with time?

Contractor C "… *if we have more time then we can come up with better options …definitely yes, every time we have to calculate the cost of the material that we are using, so some time is spent on that...if more time is given then we could have come up with one more alternative…might be more costlier than this option, but definitely not more than the target cost and could have been a structurally stable product.."* Adding to this the other member in team, **Estimator C S**ays *"... having a time and cost constraint helps, you have some framework to work within…it's a challenge. The disadvantage with this is we don't get to think a lot about design, we just had to finish it on time and we have to compromise …which we did. Time was just not enough…more than time it's about cost …which actually drives the whole process… "*

Researcher: Working with cost a constraint, does cost have a negative influence on the design?

Architect C, the designer in the team had a different opinion about the process, according to him *"...because of the cost constraint we restricted the design too much, which we should have not done at the brainstorming stage and be more flexible…We kept on revising the design even while building it…I don't think we need more time for this project ..Because I feel initially we went wrong somewhere during the brainstorming stage…coz if we get it right then...then building the product is just fast track."*

Researcher: How are the team dynamics?

Similar to Team A, familiarity among team members and having worked together before on other academic projects, all the team members worked in synergy. Contractor C says

that "...Y*es, having worked before we are very comfortable with each other and it was great…we concentrated more on finishing the product on time …*"

Researcher: What is the downside to this process?

Estimator C "*If we can work out on more options…then the result will be better...So time is more important than the cost. Cost is just fine…we can reach the cost anyways if there is more time.*"

Focus Group Interview with Team E

Participants: Architect E, Contractor E, Civil Engineer /Estimator E

Researcher: How did you manage with time?

Contractor E *"…Designing with cost constraint was tough…we had slightly more time but cost is a strict constraint here...We actually spent more amount of time designing than building it...Because we first had to make the design economical…the execution part was just 10 -20% of the whole process…but this is much better than the one without the cost constraint.*

Estimator E "*Even if more time is given I don't think we would have come up with a better design …Time did not prove to be a constraint for me...as we progressed with the design…we eliminated some solutions…and fixed on some so that we could reach the target cost.*"

Researcher: Working with cost a constraint, does cost have a negative influence on the design?

Estimator E *"In the first case (Designing to cost) we had so many project constraints, time and cost...but still we managed to finish it ...In the second case, we have so many*

materials but without cost constraint...with some constraints efficiency increases...Otherwise it might go astray.. Schedule Pressure should be there...Unless the individual is highly motivated...I completely feel working with constraints, under pressure is more effective.

Architect A ***"****I think as architects, we like to work constraints...so the cost constraints helped us in designing...I particularly enjoyed designing to cost...The second case was very random... the first option is creatively much better…*"

Researcher*:* How are the team dynamics?

Estimator E "*In the second case…more ideas crept in; everybody wanted to do something else. There was some difficulty in focusing on to one design…I don't call it an issue…it's just that because there was no cost involved, everybody had a different concept...in the first case we had a good alignment…we quickly agreed to each other's solutions.*"

Researcher*: What is the downside to this process?*

Contractor E "*In the second experiment we had total freedom and lot of materials; which kind of made it difficult for us to focus on the design...we would have developed a better design if more time is allotted*

Teams B.D.E &F worked on the project without cost constraint. All the teams followed the collaborative design process but there was no over the shoulder estimation in this process.

Focus Group Interview with Team F

Participants: Architect F, Contractor F, Civil Engineer/Estimator F

Researcher: How did you manage with time?

"*Tim****e*** *was not a constraint ...I think our team did well with the time."*

Researcher: Working with cost a constraint, does cost have a negative influence on the design?

Estimator F "*With time and cost constraint we pretty much hit on one idea and started building it., but in the second part we found it challenging…as I said we had many ideas and in the end we had to come up with something that would support the wine holder."*

Architect F "*Working with cost was effective…be it aesthetics, structural stability, meeting the cost and the time everything seemed to go fine…But in the second part if we had more time we could have come up with different options and definitely a better option*.

Researcher: How are the team dynamics?

Estimator F "*The experience was great ...our team did really good with cost constraint…we came up a good product…but without cost constraint we could manage to do the product coz we had so many ideas and we didn't know where to start...the best thing working with cost is we could optimize on our different alternatives and see which one works in terms of cost..*

Researcher: What is the downside to this process?

Contractor F *"I think the downside is that Even though we have come up with a better product in the first part, we didn't consider many alternatives while designing to target cost. In the second part, we had many alternatives but less time, actually working with cost constraint was way better*."

Focus Group Interview with Team B

Participants: Architect B, Contractor B, Civil Engineer/Estimator B

Team B designed the product without target cost in 50 minutes, 10 minutes less than the allotted time. Project Team Members (PTM's) agreed in unison that even though the team had the freedom to design the product, it could have been more challenging for them to work with cost constraint .Time was definitely not a restriction for the team.

Researcher: How did you manage with time?

Contractor B responded "*We have not experienced any time pressure, we were relaxed from the beginning, took around 30 minutes to finalize on the design , tried with various materials, initially there was some resistance from the estimator B but in the end we agreed on one design …"*

Researcher: How are the team dynamics?

Architect B*"As a team we did good but his experiment can actually be carried out with 2 members; third member's contribution in the team does not make much of a difference, and there was too much discussion which is a waste of time …2 people could have been perfect for this simulation"*

Personal observation of the researcher regarding team B is, Team B did have some conflicts in the initial stages of the design, leading to disagreement between the contractor and the estimator. Much time was spent in resolving the design issues between them. As a result there was not enough time to consider different alternatives. However it is the researcher's subjective opinion that in the first 30 minutes team B did

not truly collaborate but tried to work in the traditional process, it was in the last 20 minutes that all the team members agreed to one design solution.

Researcher: What is the downside to this process?

Architect B "initially *the planning was very haphazard…that was a problem. We didn't plan on which material to use, we have lots of material options… so the question was which material should be used to make it look better and to make it stand…after a while we forgot about aesthetics and worked towards meeting the requirements…that resulted in using paper columns and paper bases…"*

Refer to the appendix for pictures and cost estimate of Team B's wineglass holder.

Focus Group Interview with Team D

Participants: Architect D, Contractor D, Civil Engineer/Estimator D

It is the researcher's observation that Team D collaborated from the beginning, worked on concepts, and weighed the results of each option they generated, produced alternatives and worked without any arguments or tensions between team members.

Researcher: How did you manage with time?

Estimator D *"….1 hour is totally enough…we spent around 40 minutes on the design, because building it does not take much of time…we finished it in 20 minutes".* **Architect D** *"If we had more time then we could have definitely come up with a better product…because it is only one hour we didn't really think of many options…coz we were concentrating on finishing the project in that 1 hr…if we had more time then we would have come up with more alternatives, but having more time doesn't necessarily*

mean a better design....we made decisions along the way…because of the time constraint we didn't really come up with a holistic design."

Researcher: How about team dynamics?

Supporting the researcher's observation on the team dynamics **Architect D** commented "*I mean...everybody was coming up with solutions...So as a team we worked really well..."*

Researcher: What is the downside to this process?

In spite of finishing, the project on time Estimator B voiced out that *"though we spent more than half amount of time on planning…but if we started with drawings, we could have come up with alternatives…I feel designing directly with the materials is a haphazard way of starting the project".*

Architect D supported this statement by concluding that "*There was no purely design base in this experiment…because there is no time...we first have to start on paper.*"

Refer to the appendix for pictures and cost estimate of Team D's wineglass holder.

Survey Interviews – Telephone Interviews

Sutter Health Cathedral Hill Hospital

Location - San Francisco, California

CHH is a 555 bed, 912,000 Square feet acute care health facilities for women and children located in San Francisco, CA. (Rybkowski 2009).

Client – California Pacific Medical Center

Architect - Smith group

Engineering - Degenkolb

General Contractor - Boldt Company

Lean consultants and researchers

The following discussion was part of the telephone interview conducted with one of the architects, VA from the architectural firm, smith group associates.

Researcher: What are the Challenges and constraints of TVD?

VA "The *planning was a subset to architecture. TVD was mainly not as concrete because we were dealing with space and. we were given the total gross square footage and at the time the estimate was based on the square footage, once we established the massing..TVD in terms of its program and in terms of space…in my opinion did not affect our planning as much and again at that time it was based on square footage...Now it might be based on something else"*

"*The challenge was really meeting the square footage that was established for us. And that was the target for us because the cost depends on cost .I can't imagine that there were any constraints, other than confirming the square footage that were established …the more area we added to the building..The more is the cost..We tried to balance the program and be as efficient as possible with the area*

Researcher: Working in a team, how are the team dynamics?

In a new process there's always going to be a learning curve as long as everybody is committed to learn and understanding the project…it is hard, there must be some frustrations but all in all I think a lot of the figuring things happened early on the project which I think is sensational for the project. Contractors are not being used to a part of this process, in some cases architects had to get in to more details , maybe there

was some discomfort in the very beginning but that's again part of the learning process. Over all it was a good experience.

Researcher: What might be the motivation to be part of TVD?

VA "*The contract is a big factor in how we work…but the better way to deliver a project is to meet the cost and that is value to the client…the contract made the difference in the way we worked…a new way of adding value to the project"*

Researcher: What is the downside to this process?

VA "I don't think we have been in this process long enough to see if this is the downside but in my opinion TVD only work if you bring the more unknown to known..you want to bring down the cost only to increase the cost later because of some other factors..If you don't know your stuff early then TVD won't be showing reduction in costs..."

Sutter Medical Castro Valley Hospital

Location - San Francisco, California

Sutter Health is one of the nation's leading not-for-profit networks of community-based health care providers, with over 60 facilities in Northern California including hospitals, cancer centers, long-term care centers, research institutes, and home health and hospice centers

Project Details

SMCV is a 130-bed hospital, which will replace the current Eden medical center in California **.**It is a $320 million project that is fully funded by Sutter Health

Owner - Sutter Health

Architect - Devenney Group

General Contractor - DPR Construction

Mechanical and Plumbing Design - Capital Engineering

Following is the telephone conversation with CD , the project manager for SMCV project

Researcher: Is cost a negative constraint?

Yes...it is... Mainly it's getting the team to use budget as a constraint on design and so it's something that always present in the minds of the team from when they start that one big difference from traditional delivery ....it's the difference mind set of the team that makes the difference…

Researcher: What about the time factor?

No, we still have the date by which the project needs to be finished…so we have to stick to the time. we take the pre construction phase much more seriously…we had a validation phase …conceptually it won't be possible to do the project for the money the owner was thinking of…so yeah we spent about 3 or 400 thousand dollars…on a 2 month effort to verify that…its very critical phase. Often these things are established to the…And that could be one of the problems. So we spent about 2 months of the time on the concepts to verify that the budget is realistic

Researcher: Working in cross-functional teams, how are the team dynamics?

Yes there were some problems between companies...Because what we are asking them to do is very different from traditional project delivery...so its requires a different focus and a different set of behaviors…i think primarily we have to get comfortable with sharing unfinished concepts with team members…so what they call sharing information often

and early…that not traditional. People tend to develop...Which is sort of interesting...Coz they are not really finished…it's a

Researcher: What is the downside to this process?

The potential downside is that I think it takes full engaged team, full engaged owner is aware that it is difficult, its difficult because hospitals and big scale projects a, they are tricky things, it takes a lot of work, it's nothing about delivery models, its just working hard ,people working hard in the right direction.

Cardinal Glennon Children's Hospital,

Location: St.Louis, Missouri

Project Details:

The project is a 138,000 sft $45.6 million children's hospital expansion consisting of a surgical suite, a 60 bed Neonatal intensive care unit (NICU) , a central sterile unit, 10 surgical suites,10-bay post anesthesia recovery rooms

Owner: SSM healthcare

Architect: Christner Inc.

Builder: Alberici Constructors,Inc

Core team –owner, architect, engineer, builder, lean partners who has a stake in the incentive pool

Following is the telephone conversation with TVL, the architect from the architectural firm Christner Inc. TVD phase did not exist for this project as the decision to implement integrated project delivery (IPD) was taken after the design was finalized.

Researcher: How are the team dynamics?

"…we knew each other's well as managers…we were in the habit of helping each other out instead of being advisories... the lessons learned here form the phase I project , development above the design and also the cost model …will be implemented for the phase 2 project"

Researcher: Working with cross-functional teams, how are the team dynamics?

TVL "Umm…the architects, engineers, contractors have all worked together in the phase 1 project and everybody behaved well in the phase 1…we are quite accustomed to working with the construction team, constructability look at cost estimation…what IPD did to us is it really gave us is that to bring members in the team representing architectural design, engineering design and constructability….and really get things well figured out ..so the latter part of the construction documents phase…there was a team that meet every Friday morning to do co-ordination between architects engineers and contractors

Here was the incentive…because of the arrangements of the contract..Nobody would benefit if there was miss co-ordination on the site. Because the contractor was not be allowed to claim change order and it would certainly waste labor and therefore run out of costs…everyone has an incentive to make sure the coordination was a as perfect as we could that and the team responded well to that challenge and put together a construction document that was particularly for the NICU that was very complicated…we had about 28,000 sft of ceiling space ,a very complicated ceiling space that does not have a single re route space or a change order…that's because the team has an incentive to work together not because of the contract language…

Providing incentives – motivation factor

The word I would like to use here is the Alignment – umm…ahh…we had very good alignment with all the team members because of the incentive…let me explain…we had a control estimate…the incentive arrangement created good alignment

Researcher: What are the challenges to this process?

TVL "*One of the challenges we have is to help the client understand cost for instance we can reach a very tight waiting room say about 20sft per seat ...we can a much more gracious waiting room with 30 sft per seat which is probably more like what those people have in mind and it takes a more square footage to house the whole thing...so it's a value decision for the client to make..so that's one dimension of value ...and then within that waiting room whether it is 20 sft per seat or 30sft per seat...we can making choices about the amenities that are available..type of finishes, furniture…quality of furniture and really have to make decisions about both of those dimensions…how large in terms of quality and how high in terms of quality…*

Delivering more is doesn't necessarily better."

Researcher: What are the downsides to this process?

TVL "*Not quite sure…one is that if you find that the team member is not performing …you don't have the isolation of the conventional contracts…The whole team can be effected and so the management team has to be willing to act very quickly...that's not typical..Typical is people will go on and on and on trying to work out the situation…in this arrangement you really don't have the luxury of time..You have to perform or you have to make decisions to replace them or whatever you have to do*

The second downside is that…the method we use to construct the incentive …and get alignment along the team members require that the owner accept a degree of risk that most institutions are not willing to accept or believer that they can manage…we have an extraordinary owner in this case who was very confident and the ability to manage the risk that they were willing to take on…and give the benefits from it...most institutional clients are not willing to take on that kind of risks and therefore it is an example that can be very hard to replicate on other project.

St. Clare Health Centre

Location - Fenton, Missouri

The project is a 43,000-sft urban replacement hospital. 154 bed inpatient tower, 85,00sft medical office building and 75,000 sft ambulatory care center.

Owner: SSM healthcare

Architect: HGA architects

Builder: Alberici Constructors

The core team with senior representation of the owner, architect, engineers and builders met weekly to collaboratively discuss issues and make the more difficult decisions.

Following is the telephone conversation between the researcher and HGA architects and TG, project manager from the Alberici constructors.

Two architects from HGA architects were present for the telephone interview

Researcher*:* Working in a team, how are the team dynamics?

Architect 1*" This is not the first time we worked on TVD, we worked on the Sutter health project."*

Architect 2 *" Its positive experience…the main concept of the IPD is to work in team and collaborate with each other and truly work as a team…if we don't trust each other then what's the point of doing IPD…"*

Architect 1*"We worked with people who are familiar with the process…who have worked with us before…that made it a good experience."*

Architect 2 *"We had a good working relationship."*

Researcher: Is Cost a constraint to designing?

Architect 1*"Cost is the biggest constraint…cost scope and schedule."*

Architect 2*" It's not just the cost…its coming up with best solutions…it could be several different solutions…they all may cost similar to each other…have to weigh the pros and cons of each options,…the best option often look at the life cycle cost it may not be the initial cost that you are looking at it…,may not be the cheapest solutions...it may be the next to the most t expensive solution…but it may have the much longer durability to it… Yeah from the architects perspective it's not mainly on the shoulder of the architect but it's on the whole team…you know in the traditional process it may have been…but in this process the team benefits Umm…you know by helping the architect…You know…come up with right design and be efficient and resolve…you know…the issues within the target value design. Just because it costs less or costs more...it does not necessarily mean that it is more aesthetic. The most expensive solution is not always the best…that our job to find solutions…What fits and hopefully within the budget".*

Researcher*:* What is the motivation?

Architect 2*"There are several different reasons...one reason being the contractual requirements.Everybody has something to gain or to lose collectively…we don't have that "competent against each other, whereas now…everybody is really working with each other to find the most effective solution.*

Researcher*:* What is the downside to this process?

Architect *1*"*The amount of pre construction fees…that the owner has to put out initially for this process. The pay back is that in construction it's going to be less change orders and problems and then there this time , team members to get together regularly…weekly, monthly …that's the downside. I think that's the process of target value design…design together…people back and redesign…"*

Following is the interview with TG, involved in the TVD process as the CM from the Alberici contractors for the St.Clare project.

Researcher: Working in a team, how are the team dynamics?

TG " I don't think there were any tensions involved in the project *We went through structural and MEP drawings, we had the in-house estimators…we had very good results from the architecture and the structural department…but the electrical and mechanical systems were where we struggled the most…because our specialty contractors doing mechanical and electrical estimating…between reviewing conceptual estimating…draft development of design, we found in the estimate they generated we found that ...there were gaps because not all the work designed …that's part of the learning process.*

Researcher: *What are the challenges?*

I think sometimes it's hard for specialty contractors that don't often participate in the preconstruction process…to get in to the mindset of the global scope rather than what's drawn on the documents as the design develops, there's more scope that continuously added to the documents and we as managers have to make sure that those scopes are fully understood that they don't get fixed in the estimation process..

Researcher: What is the motivation to work on such project?

It definitely not the incentive pool, its most definitely not the newness of the process…its owner's desire that want to have the right level of expertise on the design as well as the construction side …putting the effort to provide the best value and the best cost at the earliest phase of the project..I think what motivates

Researcher: Is cost a constraint?

There is constant pressure…Schedule pressure and cost pressure to keep the costs down. There were continually cost and time pressures... It can be stressful, it can cause conflict but most of the times it helps in finding solutions to our client.

I think that's because specialty contractors, architects, owners they have different perspectives but the conflicts are never personal.

IRB Approval Form

TEXAS A&M UNIVERSITY
DIVISION OF RESEARCH AND GRADUATE STUDIES - OFFICE OF RESEARCH COMPLIANCE

1186 TAMU, General Services Complex 979.458.1467
College Station, TX 77843-1186 FAX 979.862.3176
750 Agronomy Road, #3500 http://researchcompliance.tamu.edu

Human Subjects Protection Program Institutional Review Board

DATE: 12-May-2010

MEMORANDUM

TO: GOTTIPATI, UDAYA N
77843-3578

FROM: Office of Research Compliance
Institutional Review Board

SUBJECT: Initial Review

Protocol Number:	2010-0301
Title:	Evaluating the Challenges of Target Costing in the Construction Industry
Review Category:	Expedited
Approval Period:	12-May-2010 **To** 11-May-2011

Approval determination was based on the following Code of Federal Regulations:

45 CFR 46.110(b)(1) - Some or all of the research appearing on the list and found by the reviewer(s) to involve no more than minimal risk.
---
(7) Research on individual or group characteristics or behavior (including, but not limited to, research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices, and social behavior) or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation or quality assurance methodologies.

(Note: Some research in this category may be exempt from the HHS regulations for the protection of human subjects. 45 CFR 46.101(b)(2) and (b) (3). This listing refers only to research that is not exempt.)

Provisions:

This research project has been approved for one (1) year. As principal investigator, you assume the following responsibilities

1. **Continuing Review:** The protocol must be renewed each year in order to continue with the research project. A Continuing Review along with required documents must be submitted 30 days before the end of the approval period. Failure to do so may result in processing delays and/or non-renewal.
2. **Completion Report:** Upon completion of the research project (including data analysis and final written papers), a Completion Report must be submitted to the IRB Office.
3. **Adverse Events:** Adverse events must be reported to the IRB Office immediately.
4. **Amendments:** Changes to the protocol must be requested by submitting an Amendment to the IRB Office for review. The Amendment must be approved by the IRB before being implemented.
5. **Informed Consent:** Information must be presented to enable persons to voluntarily decide whether or not to participate in the research project.

This electronic document provides notification of the review results by the Institutional Review Board.

VITA

Name: Udaya Naidu Gottipati

Address: 3137 TAMU, Langford Building A, Room 422,
Department of Construction Science, College of Architecture,
Texas A&M University, College Station, Texas 77843-3137

Email Address: udayagottipati@gmail.com

Education: B.Arch., Jawaharlal Nehru Technological University,
School of Planning & Architecture, 2006