DEVELOPMENT AND TESTING OF SIMULATION (GAME) TO ILLUSTRATE BASIC PRINCIPLES OF INTEGRATED PROJECT DELIVERY AND TARGET VALUE DESIGN: A FIRST RUN STUDY

A Thesis

by

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ABSTRACT

This research is focused on developing a simulation (game) that will help explain the basic principles of Integrated Project Delivery (IPD) and Target Value Design (TVD).

The transfer of knowledge about Lean principles is currently limited and there is a need for teaching materials in this field. The Lean Construction community believes that teaching lean principles through games or simulations is very effective. This study is focused on developing a simulation that explains the basic principles of IPD and TVD. After study of current literature related to IPD, TVD and Lean simulations, this game was developed and then tested on construction professionals and students. Test results from a first run study showed that the simulation helps to explain some principles of IPD and TVD. However further study is needed to ensure that those who engage this simulation confidently understand key principles of IPD and TVD.

DEDICATION

Dedicated to my family

ACKNOWLEDGEMENTS

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Lastly, I would also like to express my deepest appreciation to my parents, wife, and all of my family for their support.

NOMENCLATURE

AIA	American Institute of Architects
CIAC	Construction Industry Advisory Council
CII	Construction Industry Institute
CURT	The Construction Users Roundtable
DBB	Design Bid Build
IFMA	International Facility Management Association
IPD	Integrated Project Delivery
LCI	Lean Construction Institute
LPS	Last Planner ™ System
P^2SL	Project Production Systems Laboratory
PPC	Percent Planned Complete
PPC	Project Partnering Contract
ROI	Return on Investment
TC	Target Costing
TVD	Target Value Design
VA	Value Analysis
VE	Value Engineering

TABLE OF CONTENTS

LIST OF FIGURES

Page

Page

Page

LIST OF TABLES

1. INTRODUCTION

Smith et al. (2011), in their research titled "Lean and Integrated Project delivery" states, "The construction industry is unsafe, inefficient, fraught with errors and litigation." Waste created by design flaws, poor planning, and flaws in material supply systems is significant, and many researchers are studying about waste in the construction industry (Formoso et al., 1999). Forbes and Ahmed (2011, page 25) mention that the US Department of Commerce reported from 1990 to 2000 the increase of productivity in the construction industry was far less than that of other industries. It was about 0.8%, whereas for other industries it increased by 2%. However, the writer does not seem to be convinced by the Department of commerce report. Teicholz (2004) found in his study that the productivity of the construction industry is declining when measured by contract dollars of new construction work per hour. Figure 1 shows an average decline of about 0.59% per year, whereas other nonfarm industries are increasing by 1.77% per year. But there are some exceptions in the construction industry as well. Forbes and Ahmed (2011) wrote about the waste created from inefficiencies in labor and material control, which increases the cost by about 25 - 50%. Smith et al. (2011) mentions that 49.6% of the time spent in construction may be considered wasteful.

Waste is perceived by different researchers in different ways. Taiichi Ohono defined waste as, "non-value adding activity" **(**Liker, 2004, page 30). Formoso stated that, "waste should be defined as any losses produced by activities that generate direct or indirect costs but do not add any value to the product from the point of view of the client" (Formoso et al., 1999; page 328). Fernandez-Solis (2012) described about 22 case studies done among similar projects; he found that the projects were chaotic but still claimed to be completed within budget and on time. However, an analysis of Percent Planned Complete (PPC) showed that the average PPC was only 62%, and the main reason for not doing the promised work was "unclear information." This also shows how waste is embedded in projects. These issues of productivity and waste will ultimately affect the project as a whole because the owner must pay for inefficiencies, which impoverishes the potential value of the final product. Bossink et al. (1996) found in his research that the material waste in the construction industry of Netherland was about 9% of the total construction materials procured**.**

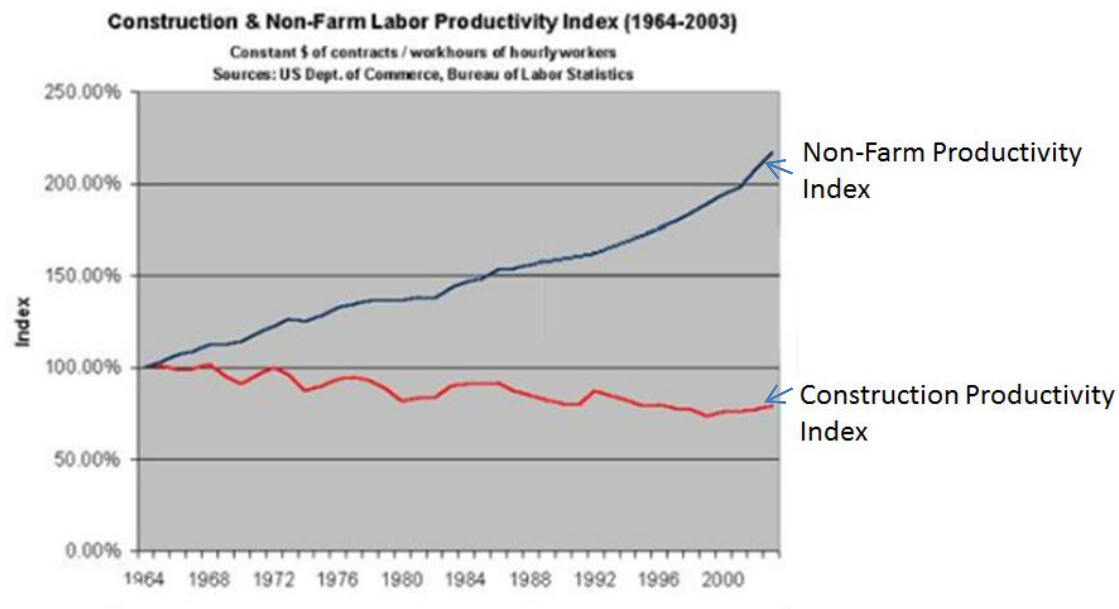


Figure 1. Labor productivity index for US construction industry and all non-farm industries from 1964 through 2003

Adapted from Forbes (2011, page 25), and Teicholz (2004).

Traditional project delivery systems like Design Bid Build (DBB), separates different parties in the project. Stake holders hesitate to invest in technologies that improve productivity because they don't see value in long-term investment (Teicholz, 2004). Projects are becoming more complex and they require more resources. Errors, omissions, and incomplete drawings result in change orders that increase the project cost (Lydon, 2011).

The Lean Production System works by eliminating various types of waste. Continuous improvement is the path it follows to achieve that goal (Lee et al., 1999). Glenn Ballard, one of the developers of Target Value Design (TVD), claims that projects implementing TVD are completed about 19% below the market price and strive to reduce waste (Ballard, 2009). “TVD is a management practice that drives design to deliver customer values, and develops design with in project constrains” (Ballard, 2009, slide 2). Some architects feel that reducing cost may affect the aesthetics of building, but this is not always true. Rybkowski (2011) studied the effect on aesthetics of product due to TVD and found that aesthetics is not compromised due to TVD.

TVD is not just about target costing, it goes beyond that to establish a link between the three milestones, namely expected cost, allowable cost, and target cost (Ballard and Morris, 2010). Hal Macomber in 2009 gave a presentation at the UK Lean conference where he talked about foundational TVD practices: owner’s engagement, difference in traditional and TVD design process, and importance of collaboration (Macomber, 2009). TVD was researched and created by the Lean Project Consulting, Inc. Company formed by Greg Howell and Glenn Ballard and later joined by others. The term was first used for the Sutter Health Project (Macomber, 2009).

Like TVD and Target Costing (TC), researchers are also working on Integrated Project Delivery (IPD). Smith (2011) mentions about our buildings becoming more complex in every aspect, but implementing integrated process have helped to increase productivity and value for the client. IPD strives towards addressing the problems in construction industry; waste, inefficiency and complicated relation between the involved parties (Ghassemi and Gerber, 2011). IPD benefits from the experience of all the parties to achieve the best result and higher value for the owner. It reduces waste and increases efficiency throughout the project. It also helps to complete the project in less time (Carbasho, 2008). IPD has a vision of a seamless team of professionals coming together with a mutual responsibility and achieving the owner’s goal (Thomsen, 2011). IPD brings all parties together earlier in the project, and collaboration reduces waste in design and allows sharing data among teams, designer, and constructor, eliminating barriers and increasing productivity in construction (Lydon, 2011).

From the above discussion we can understand the importance of TVD and IPD and how implementing these principles will help to reduce waste in the Construction Industry. It will not only help financially but will also help to preserve our environment.

2. PROBLEM STATEMENT

TVD and IPD are becoming key processes with the Lean Construction community. Despite its importance, current knowledge transfer is either oral or has to be formalized. Some Universities like the University of California Berkeley, Texas A&M University, Michigan State University, and the University of Florida are offering courses on Lean construction (Wandah, 2012). Some books, and also many research papers including case studies, have been published on the topic. The Associated General Contractors of Metro DC also organizes training session on Lean Construction (AGC, 2012). The Lean Construction Institute (LCI) is spread all over USA, and LCI chapters also organize seminar and training sessions to educate professionals about Lean. Still the gap exists between the industry and knowledge of Lean Construction. There is a need of training for Lean techniques, and continuous improvement about Lean cannot be achieved without training (Sacks et al., 2009). Vishal Porwal, a Texas A&M graduate, found from his study about the Last Planner ™ System (LPS) of production control that the lack of training was one of the challenges in implementing and using LPS in construction projects (Porwal, 2010).

Continuous improvement and LPS are parts of lean construction like TVD and IPD. Therefore, the findings of Porwal's (2010) and Sacks's (2009) research can be assumed valid for TVD and IPD as well. For the industry people to fully understand the process and adopt IPD and TVD, we should develop teaching materials that suit them. This study was focused in developing and testing a simulation that helps to explain the basic principles of TVD and IPD.

3. RESEARCH GOAL AND OBJECTIVES

3.1 Goal

The purpose of this study is to develop a simulation in order to explain the basic principles of TVD and IPD to construction students and professionals. The goal of this study is to prove that the developed simulation is useful in understanding the basic principles of TVD and IPD. The results from this study are helpful in determining other teaching modules of lean construction.

3.2 Objectives

The first objective of my study was to find materials available in IPD and TVD; this helped me to understand the current state. Secondly, I visited some projects applying IPD and TVD and interacted with project members. Learning the process and member's experiences to get firsthand knowledge was important. Studies about teaching Lean effectively also helped me in my study. Teaching TC with figures was more effective than just lectures, and the participants learned even more with effective figures than the ineffective ones (Hullum, 2010). "Evidence suggests that students' design and problem-solving abilities are improved in courses that use active and collaborative learning" (Johnson et al., 2012, paragraph 8). Boersema (2011) describes the benefits of teaching Lean through games. Following these studies, my main objective was developing a simulation that is simple and easy to understand.

4. LITERATURE REVIEW

4.1 Integrated Project Delivery

In 2007 the American Institute of Architects (AIA) National and the AIA California Council published the Integrated Project Delivery (IPD) Guide. The Guide defines IPD as a:

> "Project delivery approach that integrates people, systems, business structures and practices into a process that collaboratively harnesses the talents and insights of all participants to optimize project results, increase value to the owner, reduce waste, and maximize efficiency through all phases of design, fabrication, and construction" (AIA 2007, page 2 and Wang, 2008, page 6).

Table 1. Comparison between conventional and IPD systems

Adapted from AIA (2007)

Traditional Process		IPD Process
Traditional Project Delivery like (DBB) is based on needed or minimum necessary basis.	teams	IPD is assembled early and it is composed of key project stakeholders.
DBB is controlled, hierarchical and the knowledge and information is gathered as needed.	process	IPD is concurrent and multi-level and information is open and shared with the trust and respect from stakeholders.
DBB is individually managed and transferred to the greatest extent possible.	risk	IPD is collectively managed and shared appropriately.
DBB is pursued individually and minimum effort is expected for	compensation/ reward	IPD is value based and team success is tied to the project

Table 1 Continued.

Traditional Process		IPD Process
maximum return and it is usually first cost based.		success.
DBB is usually paper-based, two dimensional and analog.	communications/ technology	IPD is digital based, virtual and building Information Modeling (3, 4 and 5) dimensional
DBB encourages unilateral effort; allocate and transfer risk.	agreements	IPD encourages and promotes multi-lateral and open sharing collaboration.

4.1.1 Principles of Integrated Project Delivery

Cook et al. (2007) in its Guide book covers different issues regarding IPD.

a. Mutual respect and trust
b. Mutual benefit and reward
c. Collaborative innovation and decision making
d. Early involvement of key partners
e. Early goal definition
f. Intensified planning
g. Open communication
h. Appropriate technology
i. Organization and leadership.

4.1.2 Building an Integrated Team

Ghassemi and Gerber (2011) found from their study the following characteristics of IPD projects:

a. Early involvement

b. Share risk reward
c. Multi-party contract
d. Collaborative decision making
e. Liability wavers
f. Jointly developed goals

Figure 2 shows the differences in team formation of the traditional delivery process (DBB) and IPD process. As the parties come together in the early stage of the project, they have a better chance of contributing their input early in the project, which will help to reduce waste. Even agencies are consulted from the beginning in IPD so that reworks are reduced. In Figure 3 the Macleamy curve also shows how the input in the early stage will help to impact cost and functionalities rather than at a later stage. As the time passes the change will result in wasted time and money. Input of all the concerned parties at the earlier stage will save time and money later.

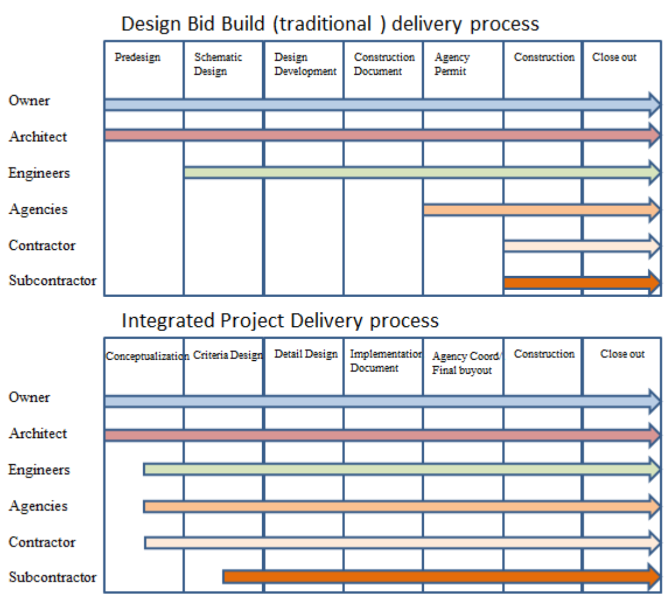


Figure 2. Comparison of traditional and IPD system, team formation

Redrawn and adapted from Cook et al. (2007)

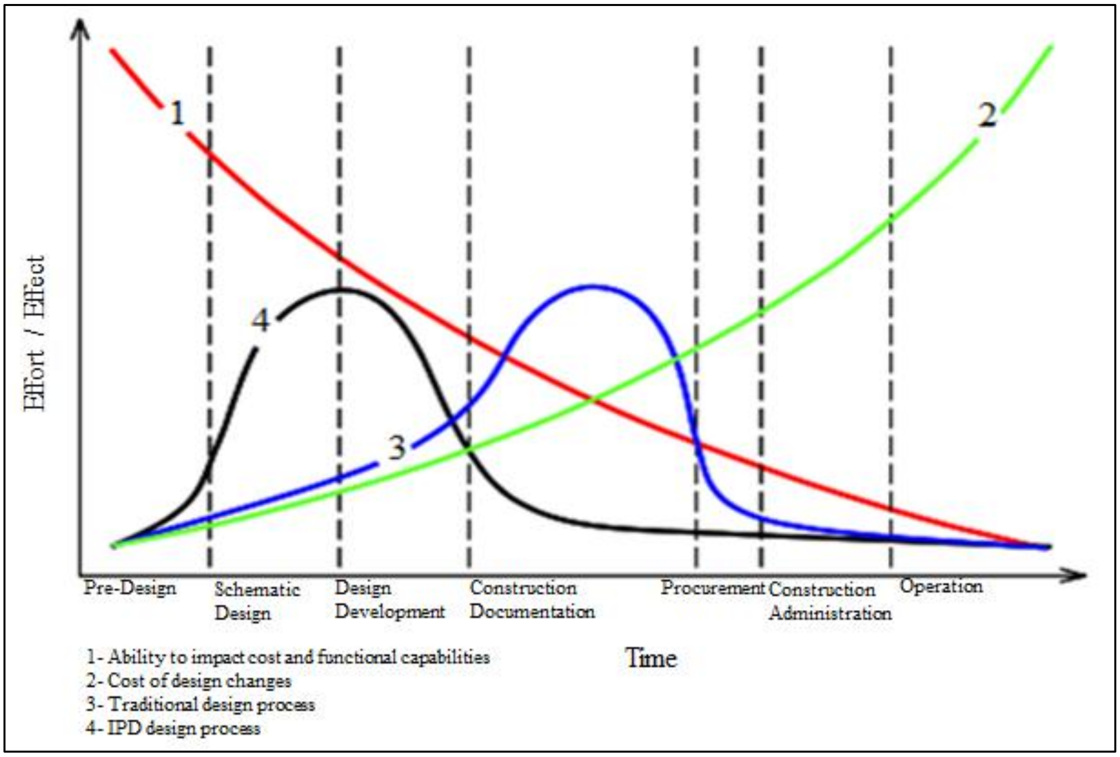


Figure 3. Macleamy curve

Adapted from CURT, (2004)

4.1.3 Contracts in Integrated Project Delivery

Matthews and Howell (2005) talk about two types of contracts in IPD:

a. Transactional contracts

b. Relational contracts

In transactional contracts, an exchange of goods takes place, whereas in a relational contract the contract is done among all the parties involved in the project for smooth running of the project. Smith et al. (2011 page 6) states, "Relational contracts create a collaborative system with shared responsibility for managing and sharing risk and incentives tied to the amount of value generated by the end product."

Smith et al. (2011) also mentions the various IPD contracts in practice today, the countries where they were developed and used, and the year in which they were developed:

a. Alliancing Agreements used in Australia, Finland, and UK, developed in UK
b. PPC (2000) and PPC (2000) Internationally used, developed in UK
c. Integrated Form of Agreement for Lean project Delivery used and developed in USA
d. Consensus DOCS300 used and developed in USA
e. AIA C191-2009 Standard Form Multi-party Agreement for IPD used and developed in USA

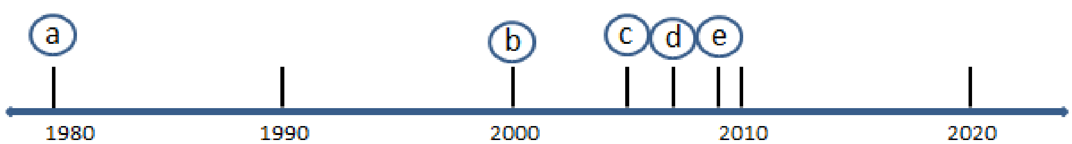


Figure 4. Time line of IPD contracts

4.2 Value Engineering (VE)

Value Analysis (VA) started in the USA around 1940 during World War II. A shortage of raw materials and labor forces forced the American companies to apply cost cutting techniques. General Electric was a pioneer in implementing VA, but the name Value Engineering was not applied until later (Dell'Isola, 1973). "Value Engineering (VE) is a systematic, interdisciplinary examination of factors affecting the cost of a product so as to devise means of achieving the specified purpose at the required standard of quality and reliability at the target cost" (Cooper and Slagmulder, 1997, p. 129). The Department of Defense has used VE in their projects since 1954 (Dell'Isola, 1973). America emerged as a winner in World War II and a new consumer economy made American companies forget about VE and implement a different system. Whereas Japan, after World War II, was looking for new efficient systems, so they adopted VE from American companies and developed it to suit their needs (Rooster and Johnson 2011).

4.3 Target Costing

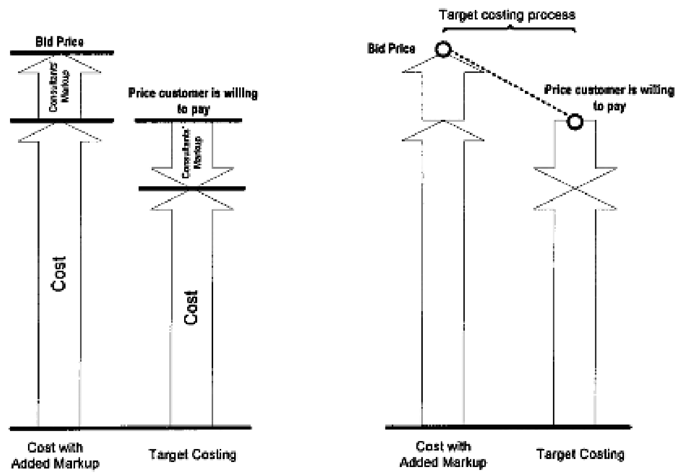
Target Costing (TC) was developed by the Japanese. They adopted the simple idea of Value Engineering from the Americans and developed the profit making management system. About 80% of the Japanese manufacturing industry currently uses target costing (Ansari et al. 1997).

Ansari defines Target Cost as "the allowable amount of cost that can be incurred on a product and it stills earn the required profit from that product. It is a market driven costing system in which cost targets are set by considering customer requirements and competitive offerings" (Ansari et al. 1997). In the same way, Clifton defines Target Costing as a "disciplined process for determining and realizing a 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" (Clifton et al. 2004, page 1). Figure 5 shows how the conventional method of setting out cost is different from Target Costing.

Target cost = competitive market price – Target profit Ansari et al. (1997).

4.3.1 Cooper's Target Costing Triangle

Cooper describes Target Costing with a three-sided approach. Figure 6 shows the triangle where customer, product designer, and supplier are the three corners of the Target Costing Triangle. The customer puts competitive pressure on the product designers and suppliers through market driven costing to deliver the product for his needs. Product level Target Costing focuses on the designer's creativity to reduce the cost of the product to the target level. Value Engineering is used to decrease cost while maintaining the customer's value, whereas component level Target Cost keeps pressure on the supplier's creativity to reduce the cost of the components.



In cost with added markup: Cost + Consultants Markup = Bid price

In Target Costing: Price Customer is willing to pay – Consultants Markup = Cost

Figure 5. Comparison between Cost with additional markup and Target Costing

Rybkowski (2009) Reprinted with permission

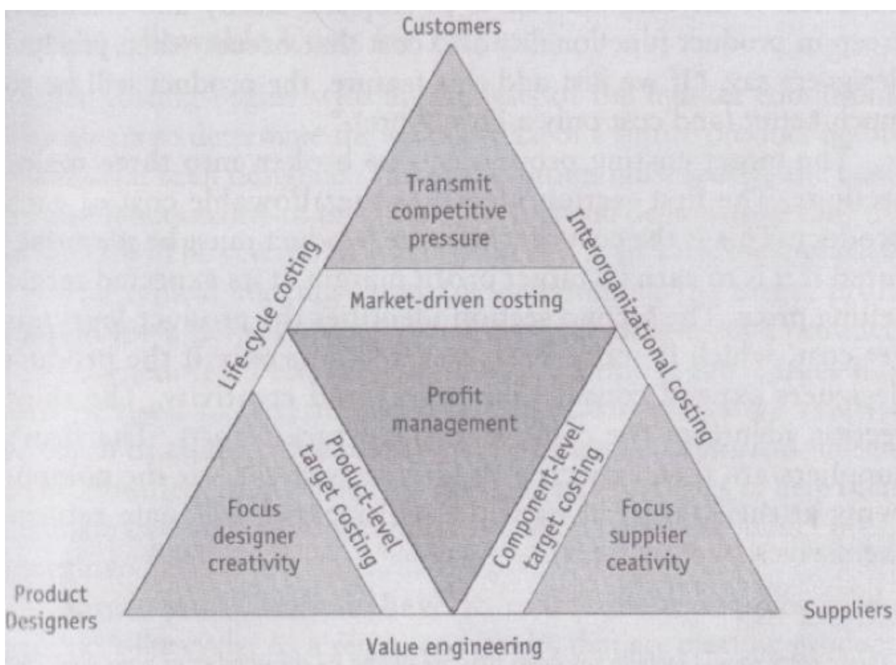


Figure 6. Target Costing Triangle

Reprinted from Cooper (1997)

4.3.2 *Clifton's Four Step of Target Costing*

Clifton (2004) describes the Target Costing process in four steps. The first step is to identify the product; market study and research will help to identify the product customer's need. The second step is to set the Target Cost. This is also dependent on the customer and how much they are willing to pay for the particular product. Designers work creatively together with other departments to produce the product defined by the market and the cost the customer wants. This is a stage of achieving the Target Cost. Finally after the product has been introduced, competition continues and then the challenge is to maintain the cost by continuous improvement (Clifton et al. 2004). Figure 7 shows Clifton's process of Target Costing.

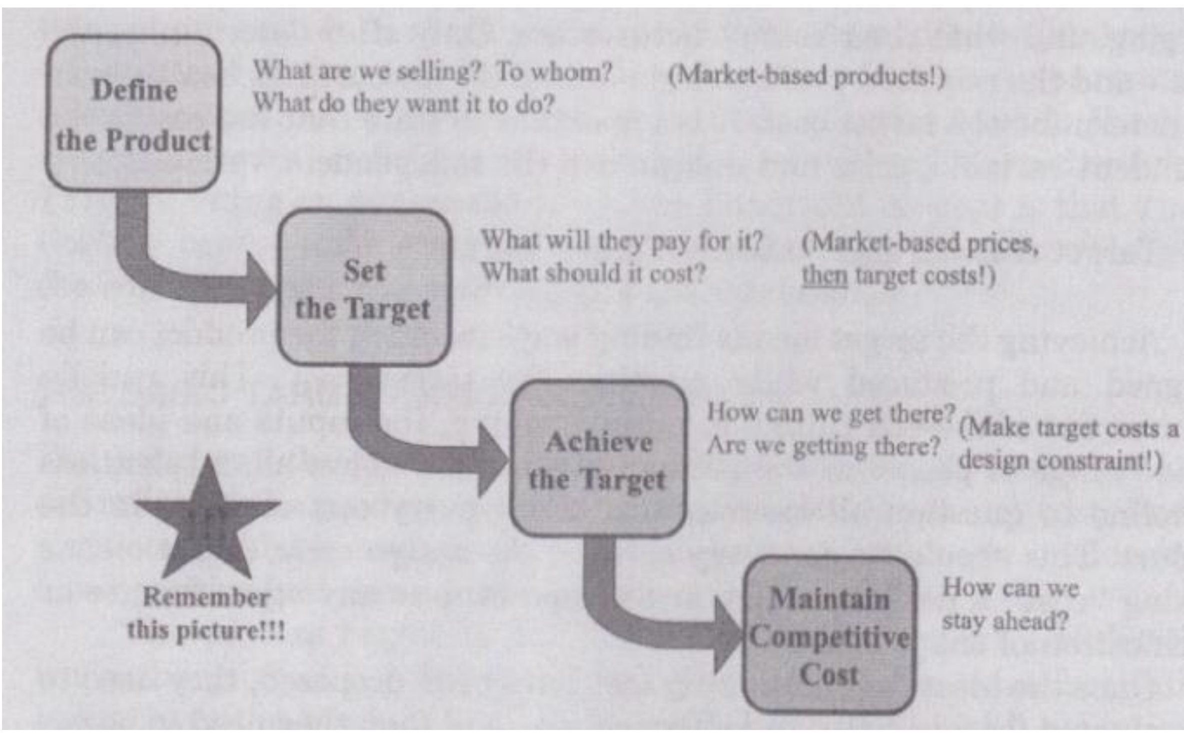


Figure 7. The fundamental questions at each step in Target Costing

Clifton's Target Costing process

Reprinted from Clifton (2004)

4.3.3 Comparison of Target Costing and Cost-Plus Approaches

Ansari et al. (1997) compared a regular practice of the Cost plus model with Target Costing model. This will make a clear distinction between the two processes of costing.

Table 2. Comparison of Target Costing and Cost-Plus Approaches

Adapted from (Ansari, 1997)

Cost Plus	Target Costing
In Cost Plus, Market is not considered while planning cost.	In Target Costing, market consideration is the prime focus of cost planning.
Price is the main factor which determines the cost.	Cost is the main factor which determines the price.
Waste and inefficiencies should. be considered for cost reduction.	Design plays the key role in cost reduction.
Customer does not interfere with the cost reduction.	Customer takes an active part in cost reduction.
Single department is responsible for cost reduction.	Multiple department works together to manage cost.
Suppliers get involved at the end.	Suppliers are involved early.
Initial price for the customer is minimized.	Ownership cost is minimized.
There is little or no involvement of value chain cost planning	There is involvement of the value chain cost planning.

4.3.4 Subdividing the Target Costs

When the Target Cost of the overall product is very low, some subsystems may be at the lowest practical price and further reduction is not possible. All subsystems work together for the same project goal. Figure 8 shows that there is a difference in the scope of work between the two conditions, though the cost reduction objective is same. This shows that the systems might sometimes have to sacrifice their scope of work for the sake of the whole project.

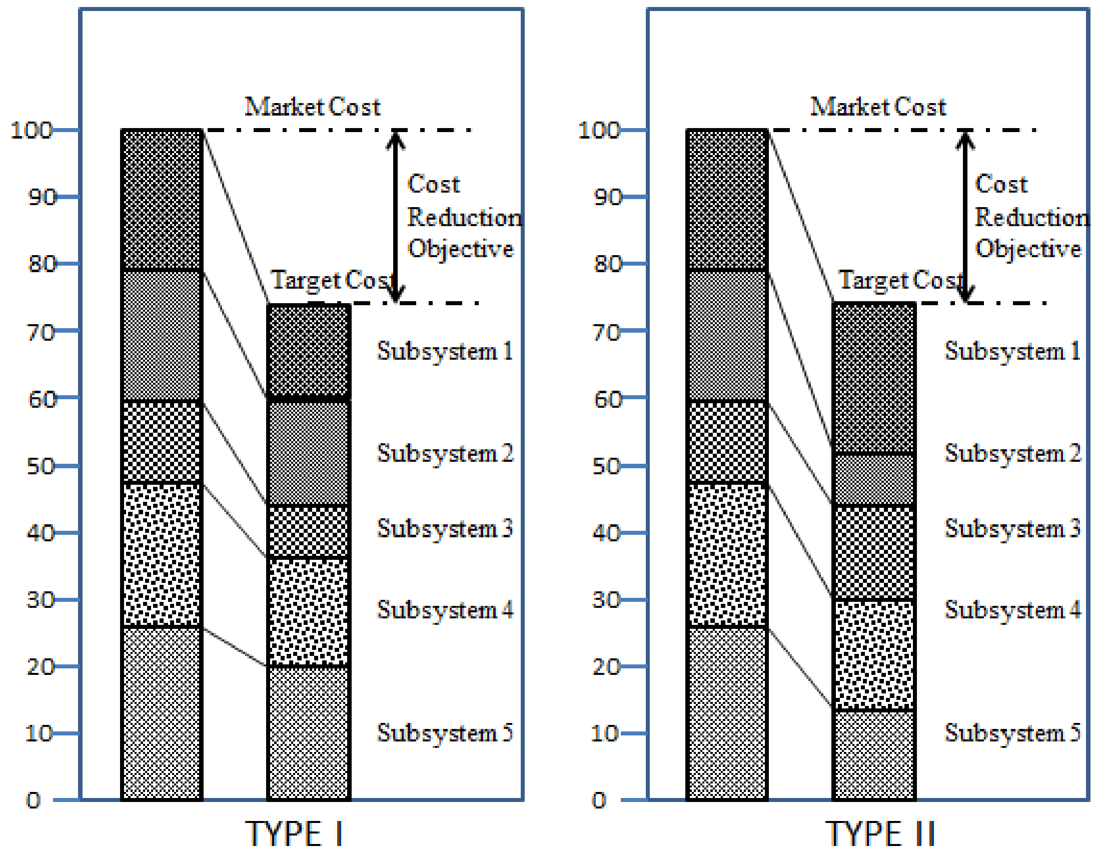


Figure 8. Subdividing the target cost into subsystems

Adapted from Clifton et al. (2004) and Rybkowski, (2009)

4.4 Target Costing in Construction

Ballard (2007, page 1) defines Target Costing in the construction industry as "the practice of constraining design and construction of a capital facility to a maximum cost. It is an appropriate practice for all clients with financial constraints (maximum available funds or minimum ROI requirements) that a capital facility project must meet in order to be considered successful by that client".

Table 3. Main difference between Normal practice and Target Costing

Ballard (2007) Reprinted with permission

Normal Practice	Target Costing
What do I want?	What am I trying to accomplish?
What will it cost me?	What is that worth to me?
Can I afford it?	What can I afford to pay to get it?
	What can I expect to pay? Is expected cost less than or equal to allowable cost?

4.4.1 Key Features of Target Costing in Construction

Ballard (2007) in his presentation described 9 main features of Target costing:

a. The client has the responsibility of evaluating the business case and deciding if he will fund it for the feasibility study.

b. Each of the key members participates in the feasibility study, and if the results are positive they will deliver the project.

c. In the process, the client also becomes an active member and participates actively throughout the project.

d. The team needs to produce a detailed budget aligned with the scope during the study.

e. All team members are responsible for understanding the business case and stake holder's values.

f. All partners must agree never to exceed the target cost.

g. Members must understand the cost implications in design options since designers design according to the cost guidelines.

h. Designers and cost modelers work together in each design step.

i. The Last Planner ™ system helps to manage and coordinate the actions of all the team members.

4.4.2 When Target Costing can be Applied in Construction

Ballard and Reiser (2004) mention three different situations when target costing can be applied in construction:

a. Where the client has a limited amount of money and wants to invest to the extent that all investment creates value.

b. When the service provider needs to commit to fixed price guaranteed maximum fixed price.

c. When the developer wants the target production cost to generate profit.

4.5 Target Value Design

Glenn Ballard, who is one of the developers of the Target Value Design (TVD), states that "TVD is a management practice that drives design to deliver customer values, and develops design with in project constrains" (Ballard, 2009, slide 2).

4.5.1 Brief History in Development of Target Value Design

Target Value Design is the result of continuous improvement from Value Engineering to its current form today. Various articles and books talk about its development in the following steps:

a. American Companies, especially GE, used VE in their product designs during World War II around 1940.

b. Toyota adopted the VE model from the Americans and developed it into a profit planning tool called Target Costing during 1960.

c. Manufacturing Industry became familiar with Target costing at the end of the 80s and early 90s and implemented it in the manufacturing industry.

d. Construction industry also started implementing target costing in their projects after its success in the manufacturing industry since mid-90.

e. Greg Howell and Glenn Ballard developed target costing as the Target Value Design to suit the construction industry in 2004. The term was first used for the Sutter Health Project.

These steps are graphically inserted into Figure 9.

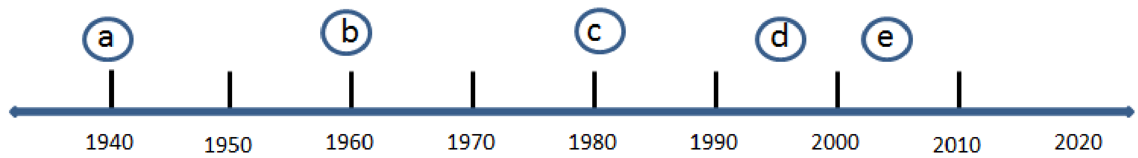


Figure 9. Development of Target Value Design a Historical Perspective

4.5.2 Different Levels of Cost Related to Target Value Design

There are different levels of cost that are related to TVD. Figures 10 and11 shows the relationship between various costs in TVD.

Rybkowski defines Market Cost as “the benchmark cost; it consists of the cost per square foot that would be expected for comparable constructed projects” (Rybkowski, 2009, page 130).

Ballard defines Allowable Cost as “the amount a client is able and willing to spend to get what they need to accomplish their purposes or ends” (Ballard, 2010, page 3).

Ballard defines Expected Cost as “the forecasted or estimated cost of the project, initially based on benchmarking against similar facilities” (Ballard, 2010, page 3).

Ballard defines Target Cost as “the cost is what the team commits to deliver, sometimes contractually and sometimes ‘only’ morally, and is typically set below the Expected Cost in order to spur innovation beyond current best practice” (Ballard, 2010, page 3).

Generally, Allowable Cost> Expected Cost> Target Cost (Ballard, 2010).

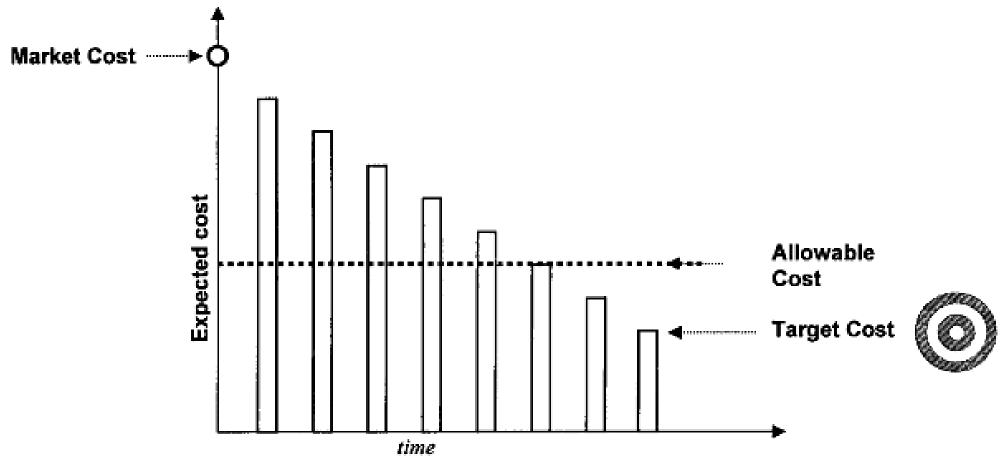


Figure 10. Explanation of different costs

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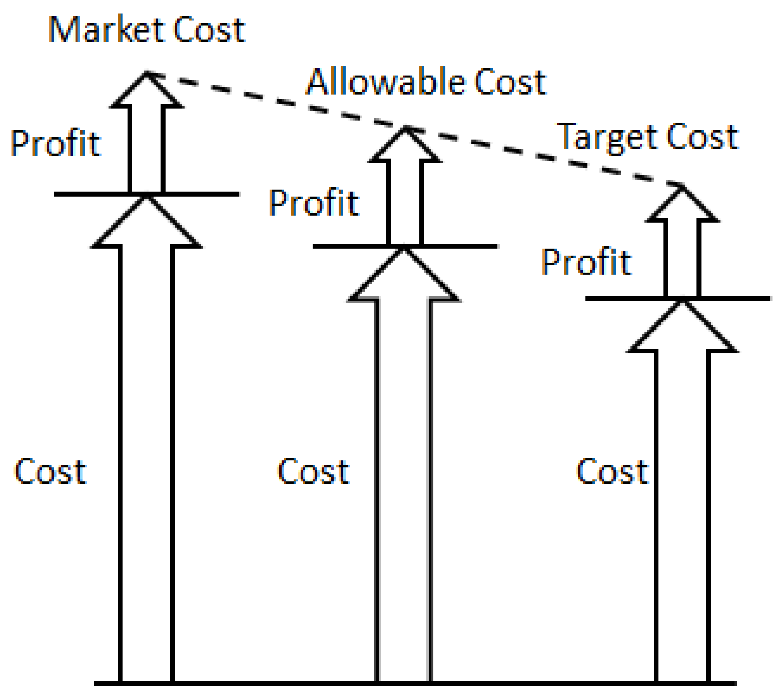


Figure 11. Explanation of different costs (A)

Adapted from Rybkowski (2009)

4.5.3 Ballard's Explanation of Target Value Design Process

Glenn Ballard, one of the developers of TVD, explains the TVD process in five steps:

a. Develop project business plan,
b. Validate the project business plan,
c. Set Targets for values and conditions of satisfaction,
d. Steer design to targets and
e. Steer construction to targets (Ballard, 2011).

Figure 12 explains Ballard's TVD.

4.5.4 Benchmarks for Target Value Design

Ballard and his research team at P^2SL have developed the benchmark for TVD from their experiences and studies in different projects. This benchmark is derived from projects related to healthcare and educational facilities, and for this reason some changes might be required for other kinds of projects.

a. The customer has the responsibility of developing and evaluating the project business case and deciding whether or not to fund the feasibility study. They can decide that based on the project's allowable and market cost.
b. Based on what the customer is able and willing to pay to get life cycle benefits, the business case is derived. This is most likely created from an operation model with the specification of an allowable cost. The business case also specifies the financing constraints and whether the customer has the necessary fund for the investment required to obtain the life cycle benefits.
c. All the key members, such as designers, constructors, and customer stakeholders are involved in the feasibility study and will deliver the project if the findings are positive.
d. Feasibility includes knowing what is wanted and the constraints; such as cost, time, and location. The project progresses to funding if alignment is achieved or if it looks like it can be achieved during the project.

e. A detailed budget and scheduled aligned with the scope of and quality of the project is developed from the feasibility study.

f. Each and every customer is considered an important member of the team. Therefore, all team members must understand the business case and the goals and values of the stakeholders.

g. A contract is used to align the team member's goals and the project objectives.

h. All the team members agree upon the rule that cost and schedule target cannot be exceeded and only the customer has the power to change the target cost, quality, schedule, or scope.

i. The team members discuss the design alternatives such as change in the cost, quality, or schedule before the major investment of design time.

j. Members of the team collaborate during cost estimation and budgeting and the last planner system is used to coordinate the action of the team members.

k. Targets are set as stretch goals and target scope and cost are allocated to cross functional TVD teams.

l. Frequently the cost estimates need to be updated by the TVD team.

m. Meetings between teams should be held weekly or as needed at a co-location (Ballard 2011)**.**

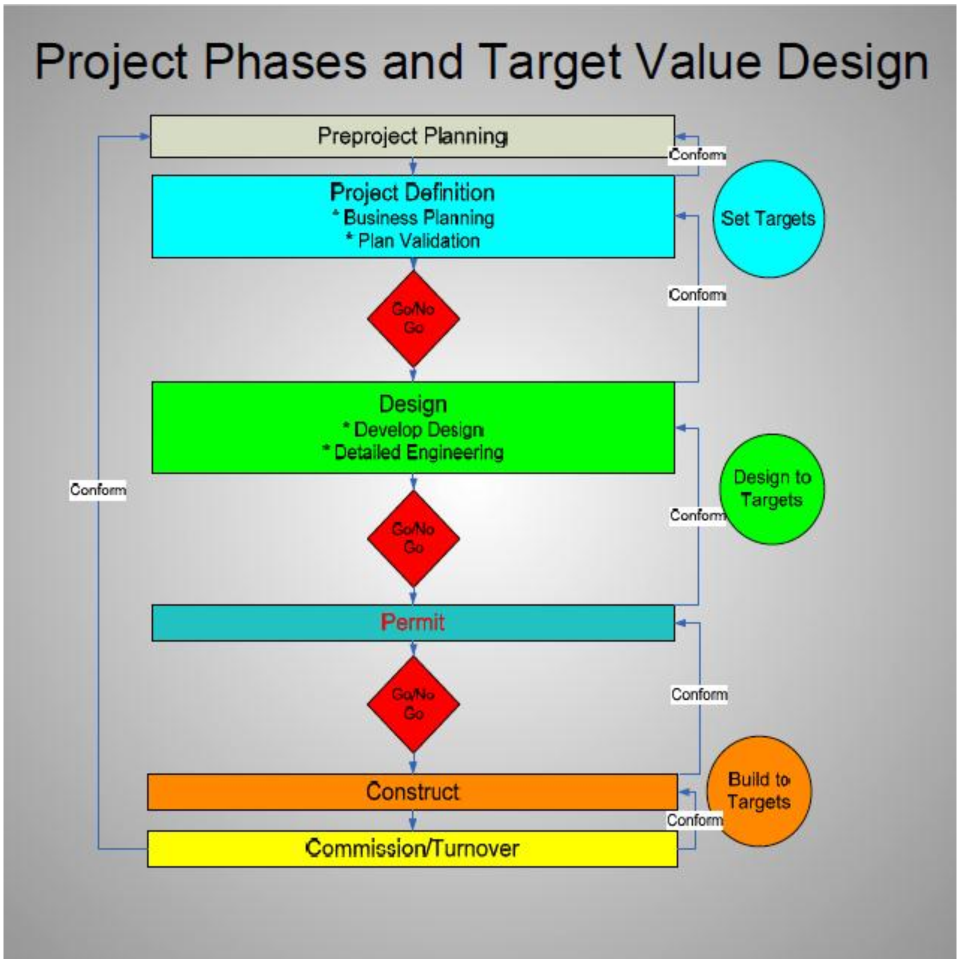


Figure 12. Ballard's Target Value Design process

Ballard (2009) Reprinted with permission

4.5.5 Difference in Communication between Co-location and without Co-location

Co-location is a process where all the team members come together in one place and work together for that particular project. It can be very important when we talk about making decisions collaboratively. This will help to understand the problems each team member is facing and such problems can be solved with joint effort by all the team members. Figure 13 and 14 shows how co-location helps to reduce time in making decisions. If co-location is not at all possible then frequent meetings between the team members is suggested.

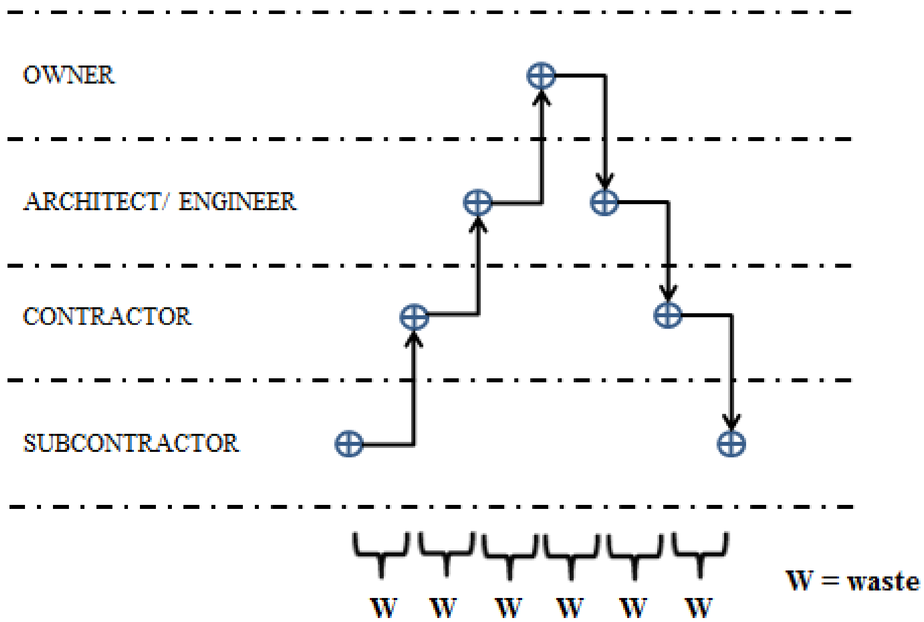


Figure 13. Communication without co-location

Adapted from Rybkowski (2010)

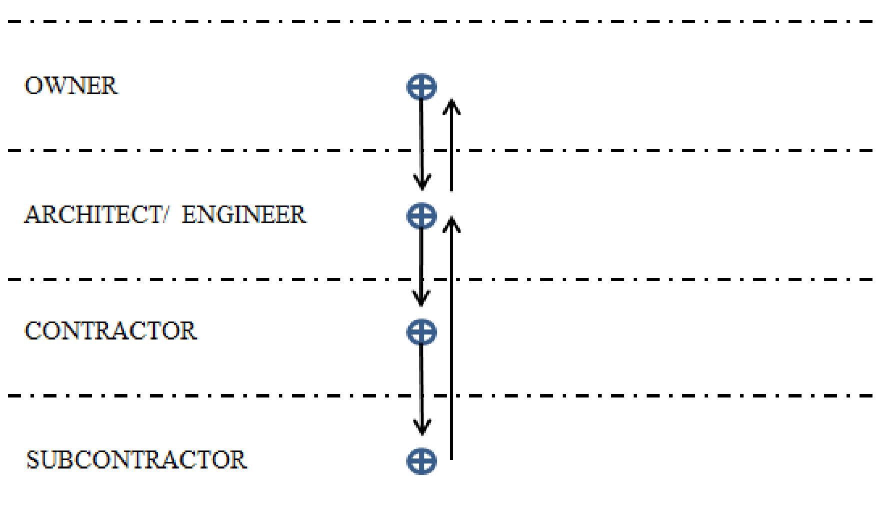


Figure 14. Communication with co-location

Adapted from Rybkowski (2010)

4.5.6 Risk Pool

Profits of all the parties are put aside in a risk pool to motivate all the team members. Figure 15 explains how profit is kept in risk pool. All team members work really hard together to safeguard their profit and to earn more bonuses at the end of the project. The client releases all the funds agreed to earlier as and when required, but he/she holds the profit of all the parties. This profit remains as a guarantee with the client from all the parties to deliver a project as promised.

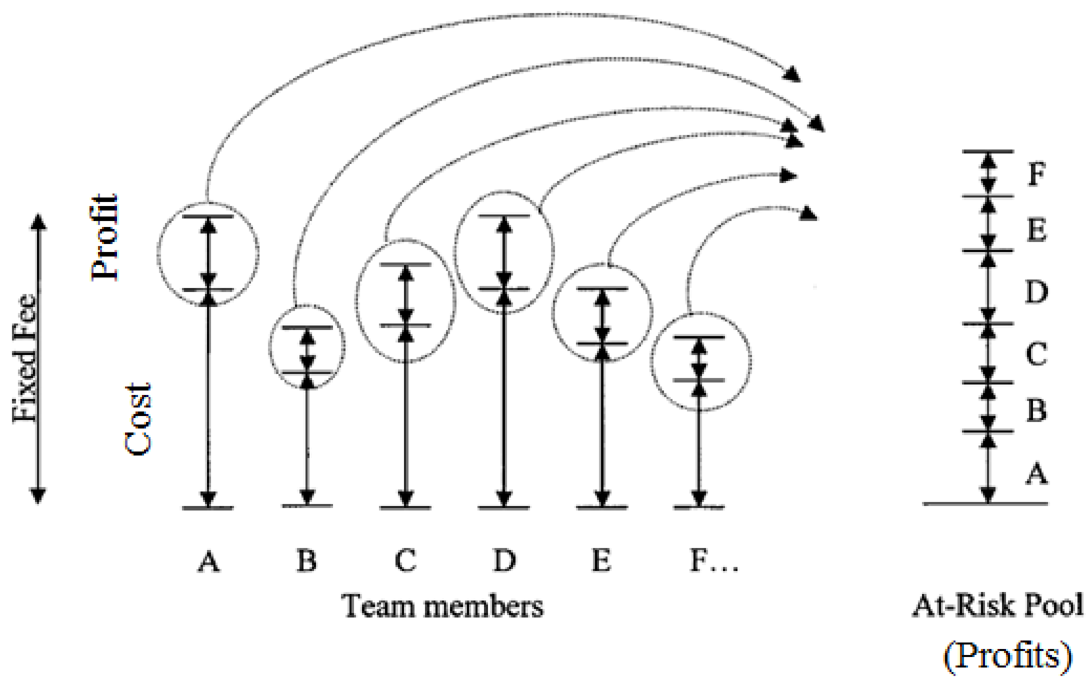


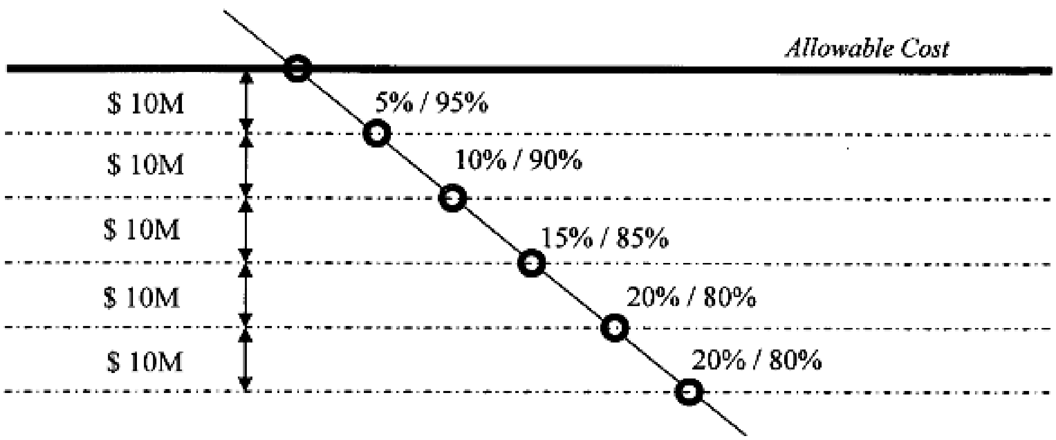
Figure 15. Remunerative fee structure

Risk pool created to motivate team members achieve more.

Adapted from Rybkowski (2009)

4.5.7 Profit Share beyond Allowable Cost

Team members promise to complete the project within the allowable cost, but the owner promises to give extra profit to team if project is completed below the allowable cost. Figure 16 is an example that shows profit sharing with respect to saving. It is very difficult, and requires extra effort, to save money beyond the allowable cost, so the owner promises to give extra profit to the team if they achieve further savings. The percentage of profit share continues to increase as the savings increases.



X/Y where X is profit share of construction team and Y is profit share of owner.

Figure 16. General remunerative structure beyond allowable cost created to motivate team members achieve more.

Rybkowski (2009) Reprinted with permission

4.6 Simulations

Literatures suggest that games have been used as the most effective means to teach and gain knowledge I have some examples to prove the above statement. We have been playing games since our childhood; it starts from our mother's lap and continues towards the big stadiums. In the same way, the Lean community also prefers to use simulations to explain its principles.

Today, most of the school age kids are attracted towards computer games. So, this craze of computer games is being utilized by professionals to attract young people towards this field. Initially, they start by playing games and later enter into designing. While designing games they learn about more advanced topics like programming (Overmars, 2004). Lectures and projects were used to teach software engineering, but these two systems are not adequate to explain all its aspects. To solve this problem an “educational card game” has been designed that explains the process that are not taught well in lectures and projects (Baker et al., 2004)

Lean simulations were first designed to suit the manufacturing industry, and now, due to its benefits, the Lean process is expanding in many other fields. Researchers working in these fields are trying to change these games or to invent a new one to suit their particular industry. The healthcare industry is also adopting Lean, and games are being developed for healthcare as well (Popovska et al. 2008). Gilbertson et al. (2006) mentions various simulations that are being used for leadership development trainings. “Interactive computer graphics and games are power tools that can be used in the educational process” (Clua et al., 2006, page 1). In the same way, Carron et al. (2008, page 24) states in their research that “we have demonstrated through examples how educational games are relevant to providing students with a dynamic and pleasant learning platform.”

Seven benefits of teaching lean through simulation

a. Simulations demonstrate Lean principles in action;
b. Games involve your audience;
c. Games are perfect team building activities;
d. Simulations are small and flexible;
e. Games are confidence builders;
f. Test real processes with simulations first; and
g. Give yourself a break (Boersema, 2011).

Table 4. List of some Lean Games and its Details

TOPIC	SIMULATION	ORIGINATION OF GAME	SUMMARY OF RULES	OBJECT OF SIMULATION
IPD	RED BEAD GAME	DR. DEMING	Pick the beads with the supplied tray with 30 degree angle	To show how the flaws are embedded in the system (Rooster and Johnson, 2011).
IPD	MAROON & WHITE GAME	Smith and Hullum 2011	The goal of this game is to score as many points as possible. Choosing one color from M & W, who chooses W gets 100, M gets 0 but if both choose M will get 50 each and If both choose W will get 0. Scores will be added and discussed what participants felt.	To show the importance and benefit of trust. How trust are broken for personal benefits. Leadership quality can also be explained by this game (James smith personal communication 01/04/, 2012).

Table 4 Continued.

TOPIC	SIMULATION	ORIGINATION OF GAME	SUMMARY OF RULES	OBJECT OF SIMULATION
IPD	MARSHMALLOW CHALANGE	PETER SKILLMAN	Make a tallest tower possible to hold marshmallow on top of it.	To explain the importance cooperation, prototyping matters, diverse skill matters, incentives magnify outcome (Wujec, 2010).
IPD	ALIGNMENT SIMULATION	CII	Survey sheet is distributed with statements and the participants will give point according to how strongly they agree or disagree with the statement. All the scores will be added, plotted and the result is distributed to all partners.	This will help team members understand the alignment situation of the team members (Fish et al. 2005).

4.7 Integrated Project Delivery and Target Value Design in Facility Management

According to International Facility Management Association (IFMA), "Facility management is a profession that encompasses multiple disciplines to ensure functionality of the built environment by integrating people, place, process and technology." People perceive the facility manager as a person responsible for fixing the broken services of the building, but their scope is far beyond that. They not only make sure that the regular repairs and maintenance are done properly and on time, but also make plans to run the facility swiftly and smoothly. They have to be proactive and think ahead of time.

Facility Managers are the people who come into the picture at a very early stage of the project, even before the Architects and Designers. In an existing business, when management thinks of extending a complex or space, the first person they will discuss this project with is the facility manager. The facility manager has a greater role in choosing the appropriate department for investment. He/she is also responsible for moving the project forward smoothly. Generally, the facility manager is the owner's representative in the project and most of the meetings, and acts as a bridge between the client and construction team. The facility manager's role is not limited to deciding about new projects, but also has to see which department needs investment and then talk with the management to allocate funds.

During our guest lectures in facility management class, some of the speakers talked about the ratio of constructing a building and maintaining it over its life time. Figure 17 shows that the ratio is 15% construction cost to 85% maintenance cost of the building during its life (personal communication with Valerian Miranda, 01/2012). So, it is very important when and how we invest our money. Spending some extra money upfront may be beneficial in the long run.

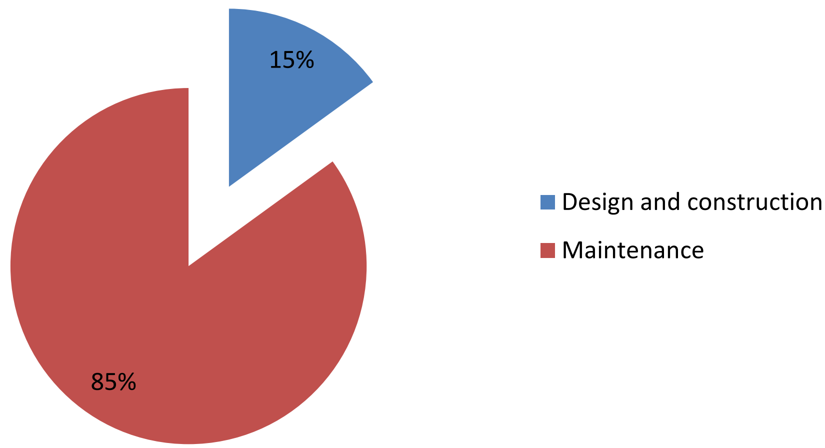
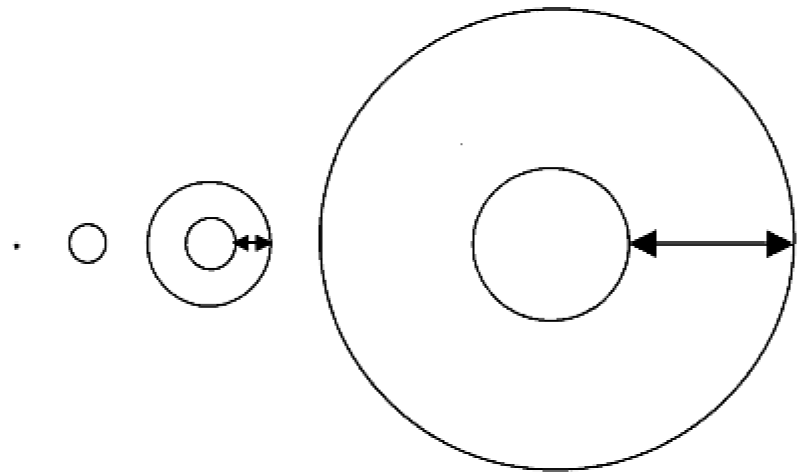


Figure 17. Percentage breakdown of design construction and maintenance of a building.

As discussed before, the construction industry is full of waste and it needs fixing. Our buildings are becoming more complicated day by day and if we continue to follow along a line as we are doing today, it will get worse. I want to share one proverb: "How to eat an elephant? One bite at a time." Implementing lean might be one bite in eating up a gigantic problem of waste.



Design cost	Construction cost	Maintenance & building operating costs	Business operating costs
0.1	1	5	200
0.1	1	1.5	15

Figure 18. Ratio of cost of owning and using a building.

Rybkowski (2009) Reprinted with permission

Researchers working in Lean construction feel that implementing lean principles will reduce waste. As discussed earlier, implementing IPD helps in reducing waste, "They accelerate projects while minimizing risk and improving quality. It is no accident that most IPD projects are fast-tracked" (Burkhalter, 2011, paragraph 5). In addition, implementing TVD has saved up to 19% of market cost (Ballard, 2009). While attending conferences related to Lean, people talk about upfront cost in implementing IPD and TVD. "The major downside, at least financially, with the IPD process is that more inter-disciplinary coordination and effort is required up front so IPD will appeal to owner-operators such as long-term developers and facilities mangers and not so much to commercial developers" (Bard, 2010, paragraph 9). Facility managers get involved with their projects as they are used and maintained for a long time. It is not like developers who develop and go away. Figure 18 shows that the design cost of the project is only "0.1" while other costs are far higher. So investing in upfront meetings to save bigger costs later makes sense for the sake of the project and for society as a whole.

It is very important that facility managers learn IPD and TVD. Being closest to the owner, facility managers have great influence in the project and they can play a role in convincing owners to implement IPD and TVD. Without knowing IPD and TVD and their benefits, facility managers will not be able to advocate for it. The Lean community thinks that implementing IPD and TVD will be easy if owners are convinced of its benefits and they take a lead (personal communication with Dr. Rybkowski, 01/2011).

Today, facility managers have an increased challenge to maintain their facilities than ever before. In addition to all other conditions, facility managers also face the problem of budget cuts. Some companies have a policy to cut down the maintenance budget every year. Clear Lake Regional Medical Center is one of them (personal communication Sayed Ali, 01/2012). When faced with a financial crunch, TVD can be a solution to that problem.

I hope that by playing this game, one will be forced to think about IPD and TVD.
I have discussed earlier about the lack of teaching materials and the value of teaching Lean through games. From the above discussions, we can say that the benefits of IPD and TVD are not limited to contractors and designers, but are also important to facility managers who have a bigger role in the project.

5. SIGNIFICANCE OF THIS STUDY

Vishal Porwal, a Texas A&M graduate, found in his study that there is a need of training to implement Last planner (Porwal, 2010). In the same way, Sacks (2009) also discussed the need for teaching Lean techniques. TVD and IPD are Lean techniques, and similar to Last Planner. Therefore, the findings of Porwal's and Sacks's research can be assumed valid for TVD and IPD as well. The Construction Industry Advisory Council (CIAC) awarded a grant of $25,000 in 2010 to develop a lean guide book.

From the above discussion, we have explained the significance of this study. Responses from participants after playing the game explained how effective the game is in clarifying the principles of TVD and IPD.

6. RESEARCH METHODS

6.1 Understanding Target Value Design and Integrated Project Delivery

Understanding IPD and TVD was very important for this research, available materials regarding IPD, TVD, and Lean simulations were studied. Figure 19 describes the research methods associated with the development and testing of the game. To prepare myself to better understand the state of the art IPD and TVD in industry, I attended series of workshops including:

a. IPD Workshop, offered by DPR Construction, Austin (Sept 2010).
b. Secrets of Last Planner revealed, offered by Linbeck and TD Industries, LCI Dallas (Dec 2010).
c. IPD assured workshop offered CIMA, Dallas (June 15 and 16 2011).
d. Presentation on Push vs. Pull, offered by Texas A&M Lean Lab, Implementing 5'S, experience of TD Industries, LCI, Houston (July 2011).
e. Additionally I observed IPD being implemented on actual construction project on pre- construction meetings. Cooks Children Hospital, Dallas. (Dec. 14, 2011) and (May 23, 2012).
f. Workshop on Lean, IPD, TVD and Last Planner, offered by Lean Lab Texas A&M to PENROS, Springs, Colorado. (April 26-28, 2012).

6.2 Design Simulation for Integrated Project Delivery and Target Value Design (Tower Game)

After studying available materials regarding IPD and TVD and some of the games available, the next step was developing a game that will help construction professionals understand the basic principles of IPD and TVD. This simulation explains the basic principles of IPD and TVD and its process. This is a modified version of the original game called "Marshmallow Challenge." In the original game, the focus is to make the tower as tall as possible with cooperation from all the team members, whereas in this format the focus is to build a tower using different materials for a particular requirement.

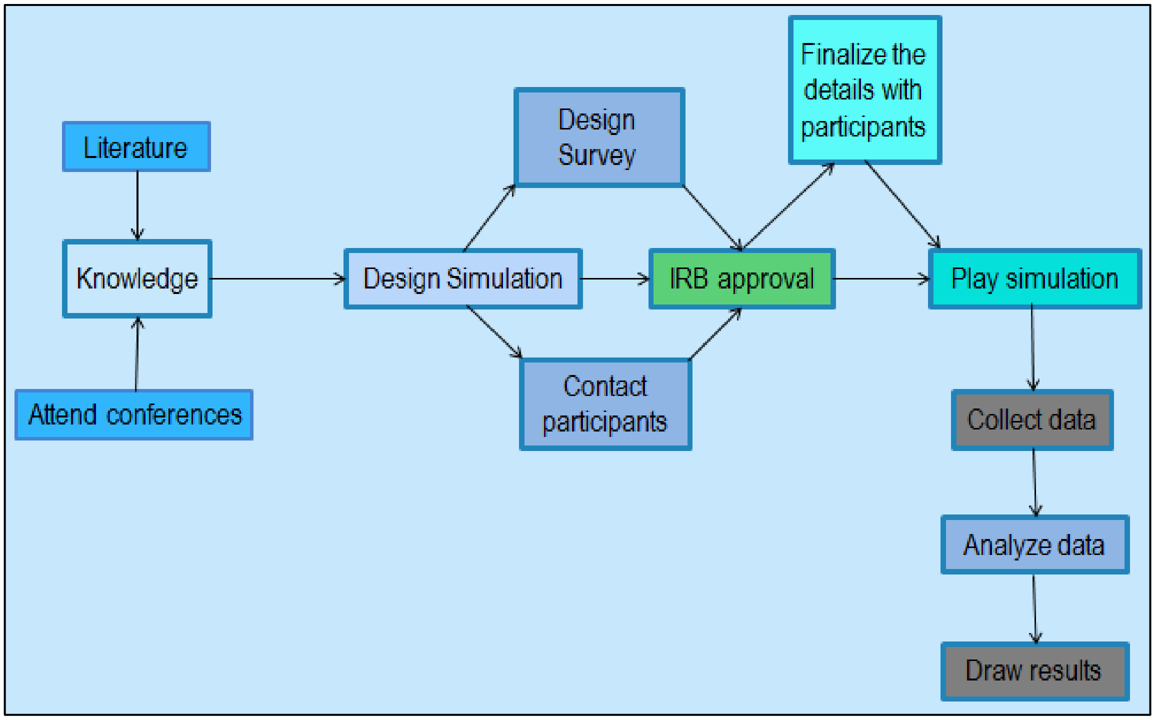


Figure 19. Research Methods

6.2.1 The Game

Rules and steps of the game

The simulation is played in two rounds; one representing traditional Design Bid Build (DBB) process and second representing IPD process.

Round one (traditional Design Bid Build format)

This round is played in traditional Design Bid Build format. Owner, design team and construction team are placed at different places as shown in the Figure 20. Design process, approval process and construction process are also similar to what we do in DBB.

Setting up a room

The room is set up as shown in figure below; all members of the construction team are at different locations.

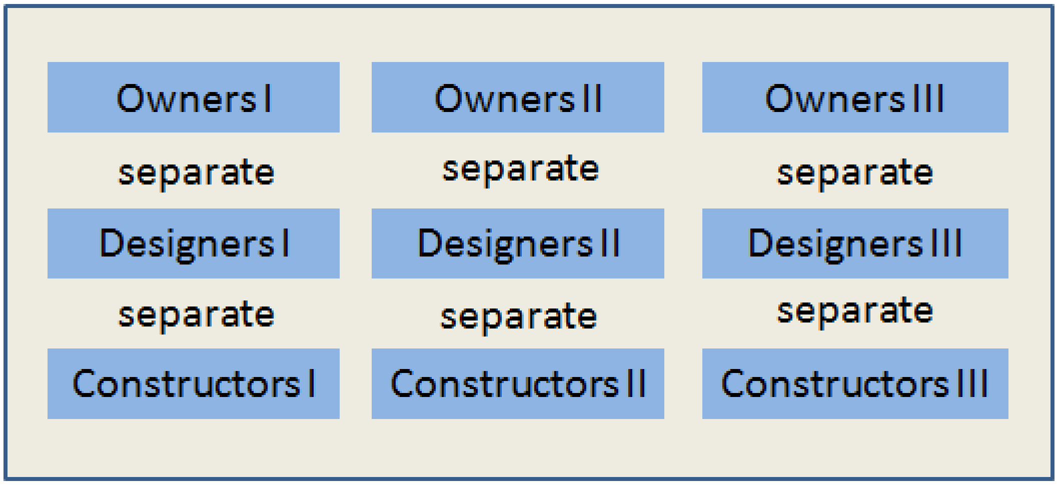


Figure 20. Setting up a room for simulation (round one)

Task

The following is a summary of the task, as given to the participants.

a. From the members in your group, form the following teams:
- Owner team
- Design team
- Construction team:
    - Horizontal member supplier
    - Vertical member supplier
    - Tape supplier

Your client wants you to design and build a tower that is 2’-0” tall which is capable of holding a marshmallow on top. The tower should be built with the supplied materials as shown in Figure 21.

Figure 21. Picture showing materials supplied to make tower

Figure 22 is an example of Design Sheet I that was distributed to the participants with these instructions.

Design I: Team: _______ Time of completion (design): ________ Time of completion (construction): ________

Request for information (how many times):__________

Client wants to build a 2'0" high tower to hold Marshmallow (use following materials and give specifications in the drawing)

Spaghetti (9" long)
Coffee stirrers (4" long)
Straw (7" long)
Skewers (11" long)
Paper tape

Figure 22. Example of design sheet I

(to be supplied to participants)

The following additional information is shared with the participants with regard to the requirements:

a. Your tower must be mobile (i.e. don't tape it to the table).
b. Your tower cannot be more than 2" out of plumb (measured at the marshmallow)
c. Note the time of completion of design as well as construction.
d. After construction of tower is complete, find out the cost of the tower in the supplied costing sheet.

Figure 23 is an example of Costing Sheet I.

Design I: Team:______________

	Name	Unit cost	Hor. Supplier		Ver. Supplier		Tape Supplier		Total Cost
			No.	Cost	No.	Cost	No.	Cost	
1	Spaghetti	$ 1.00							
2	Coffee mixture	$ 5.00							
3	Straw	$ 2.00							
4	Skewer	$ 3.00							
5	Paper tape per joint	$ 0.50							
6	**Cost of supplier**								
7	Profit 10%								

Figure 23. Example of costing sheet for design I
(to be supplied to participants)

Lastly, participants are asked to calculate the various costs with the following parameters.

- Market Cost is the average cost of all the towers currently built
- Allowable Cost is calculated by deducting 15%-20% from market cost.
- Target Cost is set by team members; here all participants work to set the target.

Round two (IPD form)

This round is played in IPD format. Client, design team and construction team members are at same places as shown in Figure 24. Design process, approval process and construction process are also similar to what we do in IPD, all done with the consent of the team members.

The following instructions are given to the participants for Round Two.

“Now that you have set the Allowable Cost and Target Cost, let’s try again. Design and build a 2’-0” tower to the same specifications as before. DESIGN AND CONSTRUCTION TEAMS SHOULD WORK TOGETHER AS A SINGLE TEAM THIS TIME.”

Setting up a room

The room is set up for second round as shown in Figure 24 below.

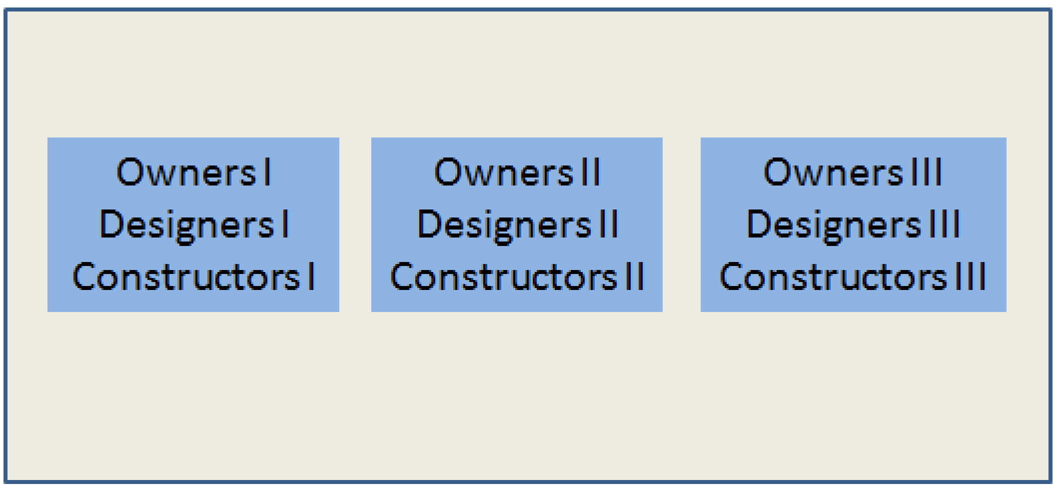


Figure 24. Setting up a room for simulation (round two)

Figure 25 is an example of design sheet II.

Design II: Team: ________ Time of completion (design): ________ Time of completion (construction): ________

Request for information: __________

Instructions:
Client wants to build a 2'0" high tower to hold Marshmallow, Designer will draw a model in this sheet (use following materials and give specifications in the drawing)

Spaghetti (9" long)
Coffee stirrers (4" long)
Straw (7" long)
Skewers (11" long)
Paper tape

Figure 25. Example of design sheet II

(to be supplied to participants)

Figure 26 is an example of the cost information for the second game.

Design II: Team:____________

	Name	Unit cost	Hor. Supplier		Ver. Supplier		Tape Supplier		Total Cost
			No.	Cost	No.	Cost	No.	Cost	
1	Spaghetti	$ 1.00							
2	Coffee mixture	$ 5.00							
3	Straw	$ 2.00							
4	Skewer	$ 3.00							
5	Paper tape per joint	$ 0.50							
6	**Cost of supplier**								
7	Profit 10%								

Figure 26. Example of costing sheet for design II

(to be supplied to participants)

The following information was shared with the participants regarding their task.

- Design a tower, calculate the cost, and if it exceeds the Allowable Cost, redesign it to lower the total cost.
  - If your estimate is below Allowable Cost build the tower (see how close you can come to your target cost)
- Your tower must be mobile (i.e., don't tape it to the table)
- Your tower cannot be more than 2" out of plumb (measured at the marshmallow)
- Set your own design time and construction time and note if the work is completed within the estimated time.

6.3 Selecting Participants for this Research

This research aimed to test the effectiveness of the game with different people involved in the construction industry, mainly students and professionals. The simulation was played between two groups. Group I were students of Acme Engineering College and Group II were professionals.

The steps for selecting participants of Group I was:

a. Sent email to the Department head of the Acme Engineering College, Architecture Department explaining the details about the research.
b. Department head put notice regarding research and asked the interested students and faculty to take part in research.
c. From among the students and faculties present in the hall, 24 participants including student and faculty took part in research.

The steps for selecting participants of Group II were:

a. Sent emails to company heads explaining the details regarding the research.
b. Company secretary sent an email to all employees to participate who are interested.

c. From among the professionals who came to participate, 24 people volunteered to take part in the game.

7. RESULTS

7.1 Description about the Participants who Took Part in Research

This research was carried out in Nepal with two groups, one from the Acme Engineering College and other from the construction profession. All together 48 participants participated in this research, 24 of which were students. From the discussion with the participants it was clear that they had never heard about Lean Construction, IPD and TVD. The following is a description of the fields of expertise of the professionals.

Developer	1
Architect/Designer	6
Engineer	9
General Contractor	3
Supplier	1
Architect/Designer/Engineer	1
Engineer/General contractor	2
Architect/Designer/G. Contractor	1

Table 5 summarizes the years of experience of the construction professionals in the construction industry. The majority had been in the field 5 to 15 years.

Table 5. Experience in the construction industry

Less than 5 yrs.	5-10 yrs.	10-15 yrs.	More than 15 yrs.
5	7	8	2

7.2 Data and Pictures

Simulations were played in two rounds. Figures 27 and 28 are the pictures of towers which were built by the participants in one game. Figure 29 shows the different levels of cost in two games. Design sheets and costing sheets of one simulation is in the Appendix section. After playing games, participants answered the questions regarding the effectiveness of the game in explaining the basic principles of IPD and TVD. Data collected from the response were then entered into excel sheet for analysis.

Team Blue Team Red Team White

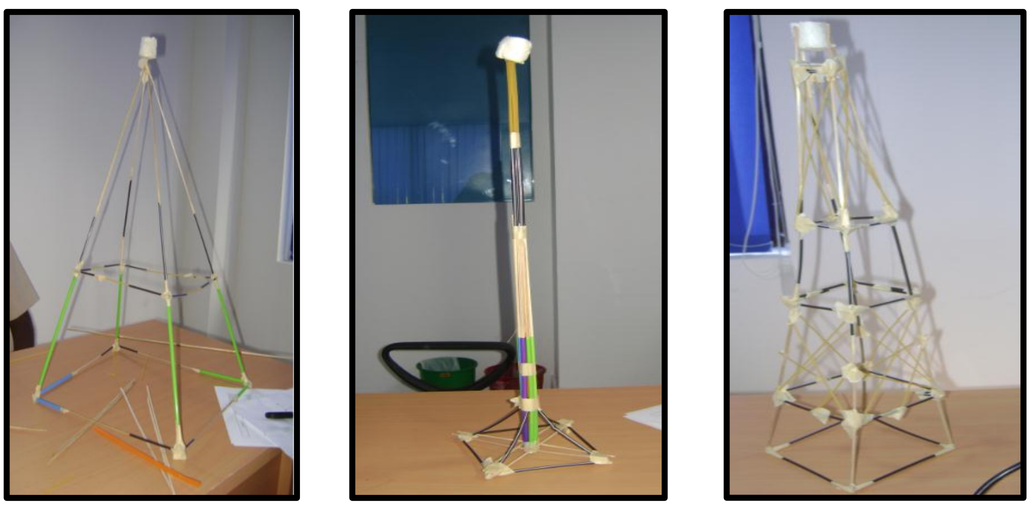


Figure 27. Model of tower build in traditional format of the game

Team Blue Team Red Team White

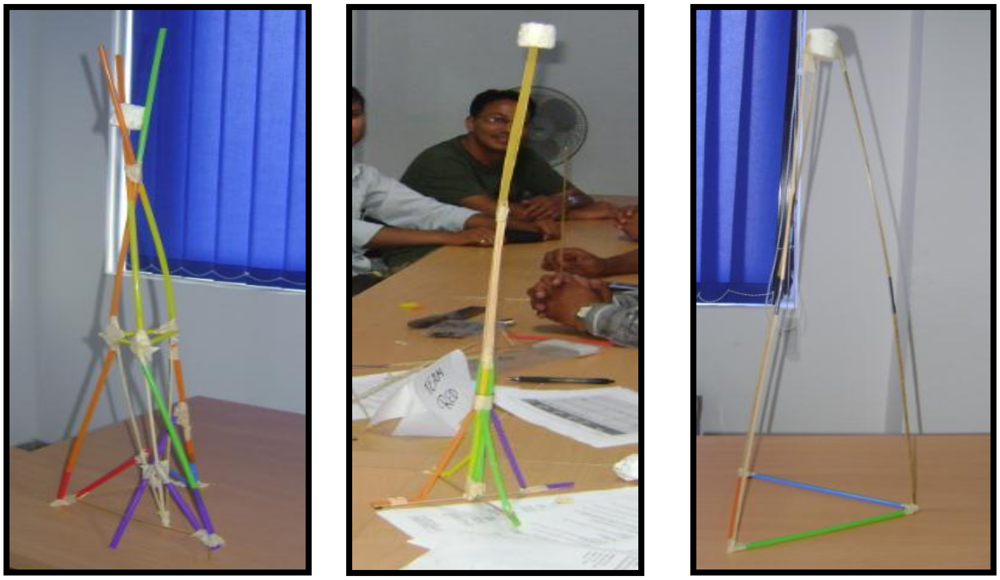


Figure 28. Model of tower build in IPD format of the game

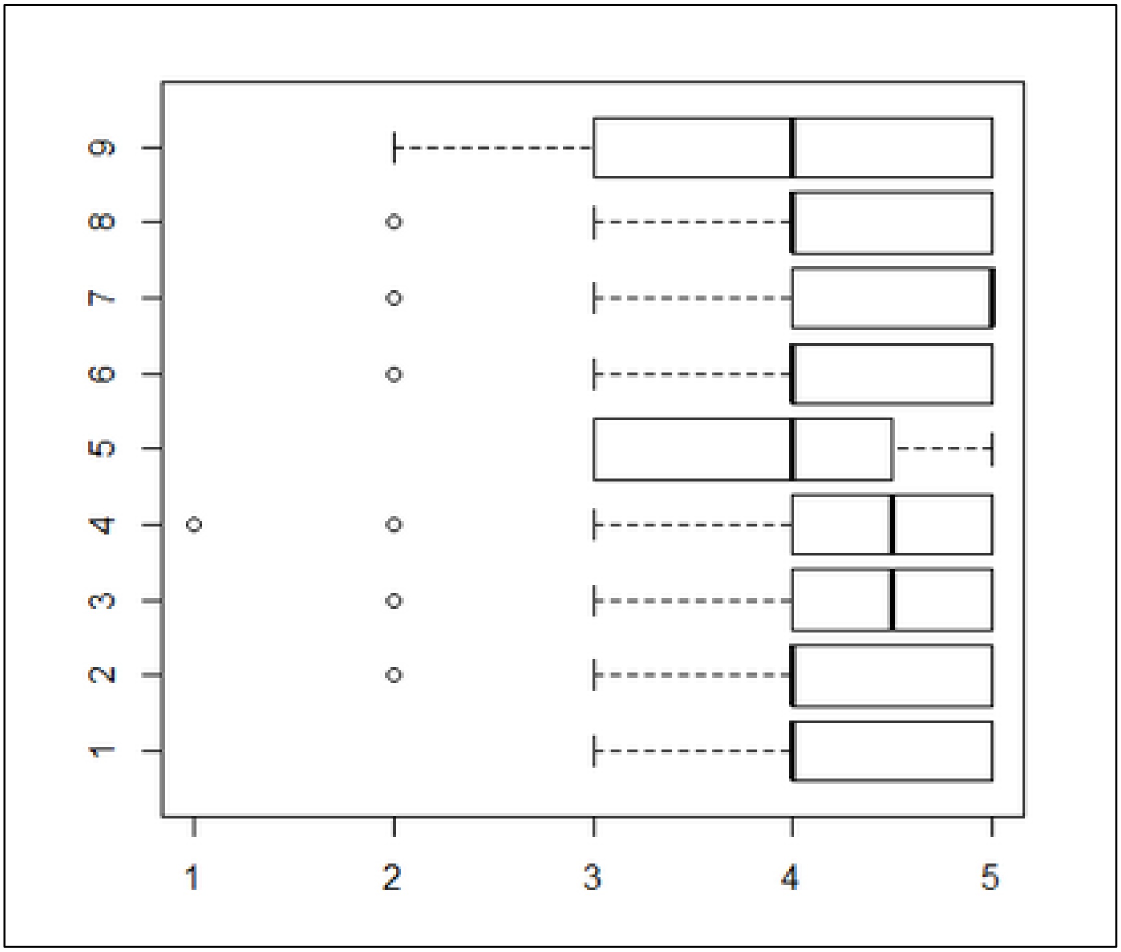
TEAMS	COSTS
A	$80.00
B	$118.00
C	$239.5
Average cost	$145.83
Allowable cost 20% less	$116.66
Target cost	$60.00

TEAMS	COSTS
Red	$91.5
White	$140.5
Blue	$99.0
Average cost	$110.33
Allowable cost 20% less	$88.26
Target cost	$50.00

Figure 29. Different levels of cost of towers

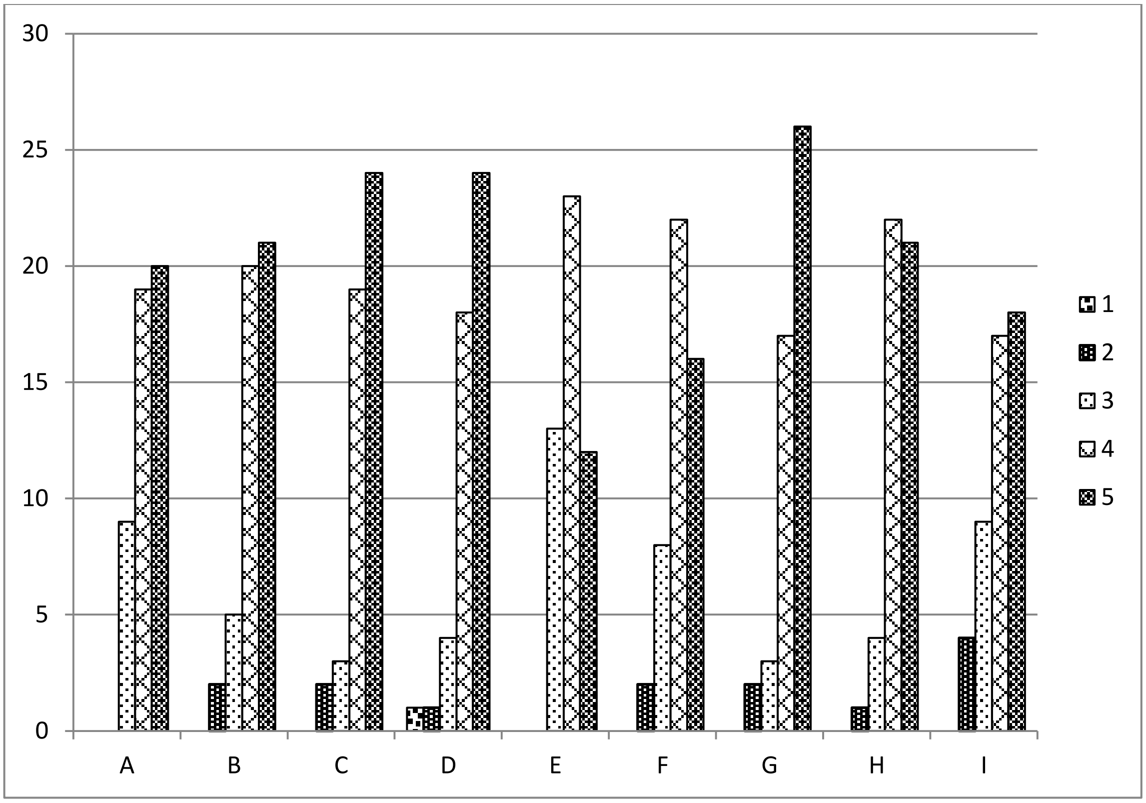
Figure 30, which is a box-and-whisker plot of responses about IPD, shows the median value and participants' responses using percentiles. From this figure, we can say that all of the questions are in the 25th percentile at "4" except two. This means more than 75% of the respondents' chose option "4" or above (i.e. above 75% of the respondents believed that the game was either "slightly effective" or "very effective"). Of these two questions, "Organization and leadership" and "early goal definition" are within the 25th percentile at "3" and median at "4" (i.e. more than 50% of the participants for these two questions chose "4" or "5"). More than 50% of participants believed that the game was either slightly effective or very effective.

Figure 31 is a histogram that shows how participants responded to the questions regarding the principles of IPD. Here we see that most participants believed "open communication," "early involvement of key partners," and "collaborative innovation and decision making" were explained very effectively in the game. Participants showed mixed results for other principles



1. Mutual respect and trust
2. Mutual benefit and reward
3. Collaborative innovation and decision making
4. Early involvement of key players
5. Early goal definition
6. Intensified Planning
7. Open communication
8. Appropriate technology
9. Organization and leadership

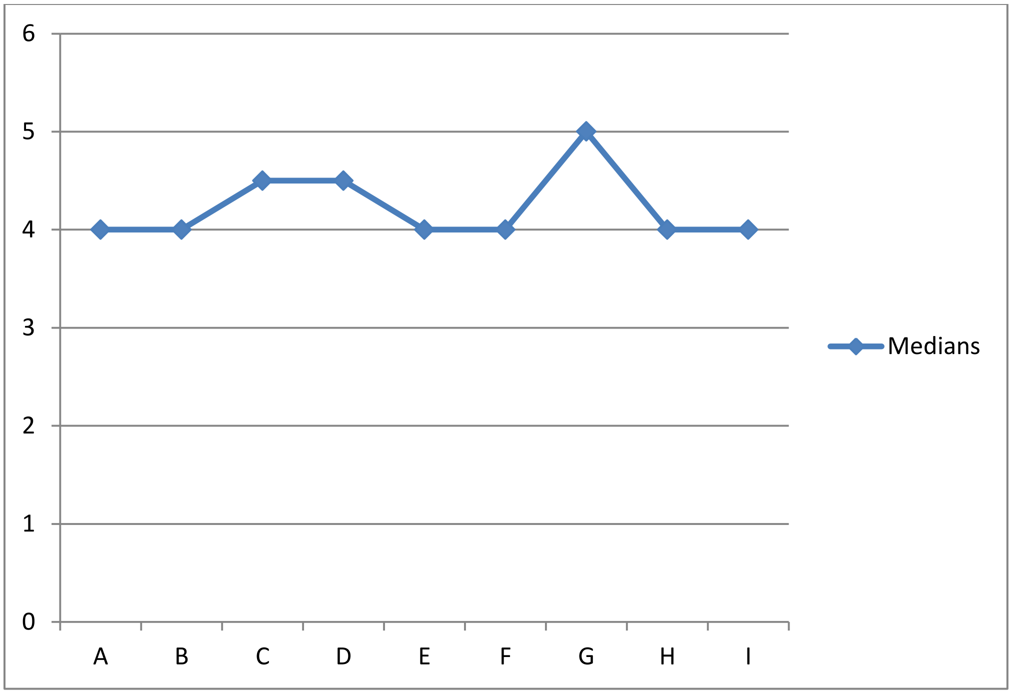
Figure 30. Box and whisker plot showing participant's response to the questions about IPD



A. Mutual respect and trust
B. Mutual benefit and reward
C. Collaborative innovation and decision making
E. Early involvement of key players
F. Early goal definition
G. Intensified Planning
H. Open communication
I. Appropriate technology
J. Organization and leadership

Figure 31. Histogram showing participants' response to the questions about IPD

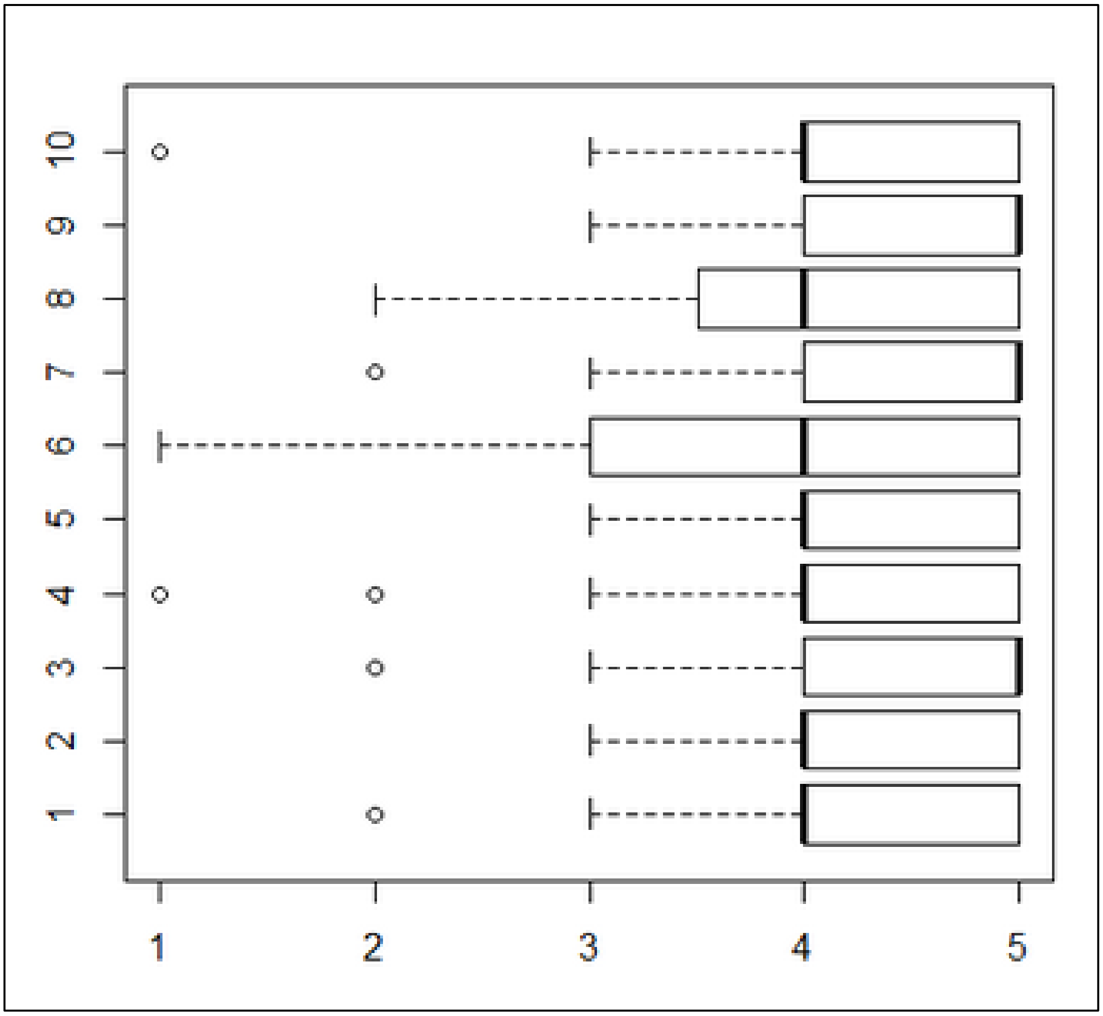
Figure 32 shows the median for each question.



A. Mutual respect and trust
B. Mutual benefit and reward
C. Collaborative innovation and decision making
E. Early involvement of key players
F. Early goal definition
G. Intensified Planning
H. Open communication
I. Appropriate technology
J. Organization and leadership

Figure 32. Medians of participants' response for IPD

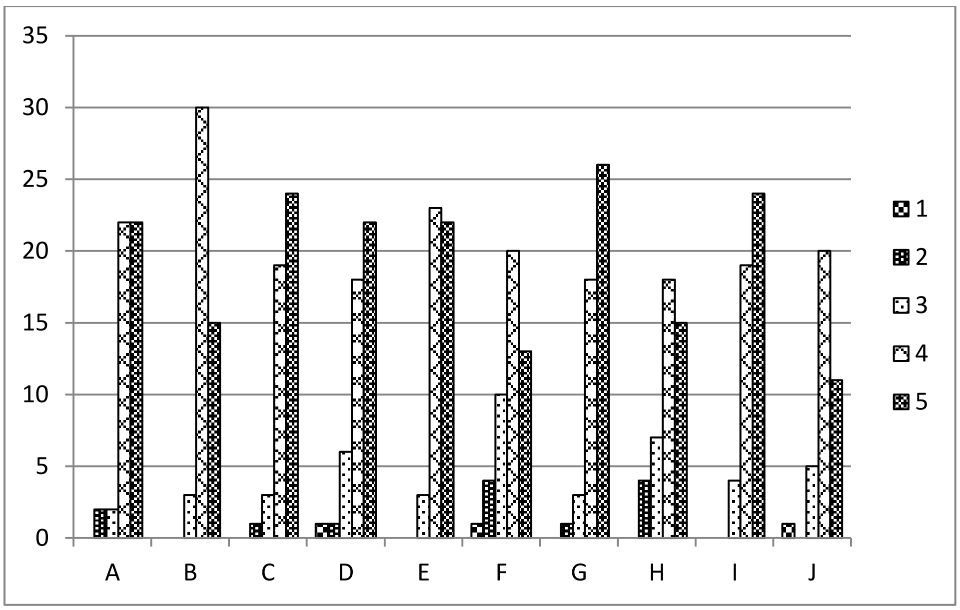
Figure 33, a box-and-whisker plot of responses, illustrates where different percentiles lie. In TVD, all of the questions have the 25th percentile as option "4" except for two. This means that more than 75% of the participants believed that the game was either slightly effective or very effective in explaining the principles of TVD. Of these, two are "The Last Planner" and "cost and schedules targets cannot be exceeded and only the customer can change the scope."



1. Project business case
2. Feasibility study
3. Client is an active member of the team
d. Understanding the values of customer
e. Relational contracts between parties
6. Costs and schedule target cannot be exceeded and only customer can change scope
7. Continuous estimating and budgeting collaboration among team members
8. The Last Planner
9. Frequent update of estimates among teams
10. Co-location

Figure 33. Box and whisker plot showing participants' response to the questions about TVD

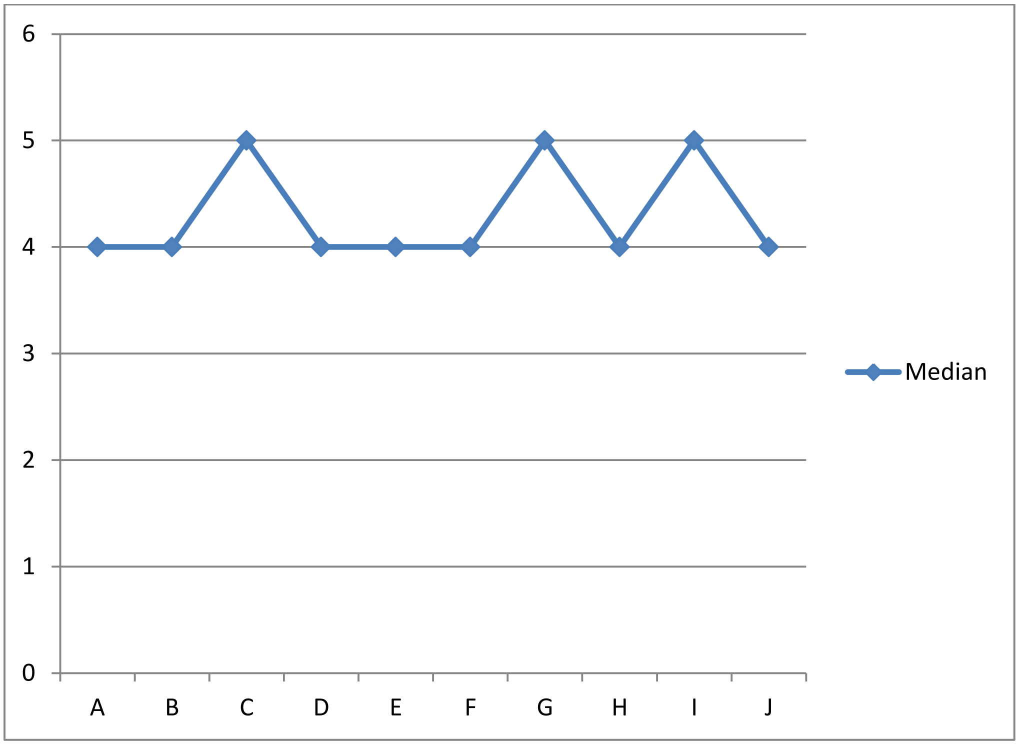
In the same way, Figure 34, which is a histogram, shows the participants' responses regarding TVD. The maximum number of participants chose "feasibility study" as slightly effective (i.e. approximately 30 participants). Concerning "continuous estimating and budgeting through collaboration among team members," more than 26 participants believed that this principle was explained very effectively in the game. For other principles, we see that most of the participants chose either "slightly effective or very effective."



A. Project business case
B. Feasibility study
C. Client is an active member of the team
D. Understanding the values of customer
E. Relational contracts between parties
F. Costs and schedule target cannot be exceeded and only customer can change scope
G. Continuous estimating and budgeting collaboration among team member
H. The Last Planner
I. Frequent update of estimates among teams
J. Co-location

Figure 34. Histogram showing participants' response to the questions about TVD

Figure 35 shows the median for each question.



A. Project business case
B. Feasibility study
C. Client is an active member of the team
B. Understanding the values of customer
C. Relational contracts between parties
F. Costs and schedule target cannot be exceeded and only customer can change scope
G. Continuous estimating and budgeting collaboration among team members
H. The Last Planner
I. Frequent update of estimates among teams
J. Co-location

Figure 35. Medians of participants' response for TVD

Table 6 addresses the responses to the question regarding different cost levels in TVD. For these kinds of data, The Kruskal-Wallis chi-squared test can be used for analysis, but some assumptions are made. We assume that all the answers were from different people and no one answered 2 questions. This test is to see whether the medians are equal or not. From figure 36, which shows the result of Kruskal-Wallis test for IPD, we see that one or more medians has a significant difference. From Figures 37, which shows the result of Kruskal-Wallis test for TVD, we see that one or more medians has a significant difference.

Table 6. Response for question regarding different cost levels in TVD.

Correct	Wrong	No answer
21	24	3

```
IPD:

       q1               q2              q3              q4              q5       
 Min.   :3.000   Min.   :2.00   Min.   :2.000   Min.   :1.000   Min.   :3.000  
 1st Qu.:4.000   1st Qu.:4.00   1st Qu.:4.000   1st Qu.:4.000   1st Qu.:3.000  
 Median :4.000   Median :4.00   Median :4.500   Median :4.500   Median :4.000  
 Mean   :4.229   Mean   :4.25   Mean   :4.354   Mean   :4.312   Mean   :3.979  
 3rd Qu.:5.000   3rd Qu.:5.00   3rd Qu.:5.000   3rd Qu.:5.000   3rd Qu.:4.250  
 Max.   :5.000   Max.   :5.00   Max.   :5.000   Max.   :5.000   Max.   :5.000  
       q6              q7              q8              q9       
 Min.   :2.000   Min.   :2.000   Min.   :2.000   Min.   :2.000  
 1st Qu.:4.000   1st Qu.:4.000   1st Qu.:4.000   1st Qu.:3.000  
 Median :4.000   Median :5.000   Median :4.000   Median :4.000  
 Mean   :4.083   Mean   :4.396   Mean   :4.312   Mean   :4.021  
 3rd Qu.:5.000   3rd Qu.:5.000   3rd Qu.:5.000   3rd Qu.:5.000  
 Max.   :5.000   Max.   :5.000   Max.   :5.000   Max.   :5.000  


	Kruskal-Wallis rank sum test

data:  ipd
Kruskal-Wallis chi-squared = 16.0212, df = 8, p-value = 0.04208
```

$P < 0.05$. So, we can reject null.

Medians are not equal and one or two medians have significant difference between them.

q1. Mutual respect and trust

q2. Mutual benefit and reward

q3. Collaborative innovation and decision making

q4. Early involvement of key players

q5. Early goal definition

q6. Intensified Planning

q7. Open communication

q8. Appropriate technology

q9. Organization and leadership

Figure 36. Krusal-Wallis test result for IPD.

```
TVD:

       q1               q2               q3               q4               q5       
 Min.   :2.000   Min.   :3.00   Min.   :2.000   Min.   :1.000   Min.   :3.000  
 1st Qu.:4.000   1st Qu.:4.00   1st Qu.:4.000   1st Qu.:4.000   1st Qu.:4.000  
 Median :4.000   Median :4.00   Median :5.000   Median :4.000   Median :4.000  
 Mean   :4.333   Mean   :4.25   Mean   :4.404   Mean   :4.229   Mean   :4.396  
 3rd Qu.:5.000   3rd Qu.:5.00   3rd Qu.:5.000   3rd Qu.:5.000   3rd Qu.:5.000  
 Max.   :5.000   Max.   :5.00   Max.   :5.000   Max.   :5.000   Max.   :5.000  

       q6               q7               q8               q9              q10       
 Min.   :1.000   Min.   :2.000   Min.   :2.00   Min.   :3.000   Min.   :1.000  
 1st Qu.:3.000   1st Qu.:4.000   1st Qu.:3.75   1st Qu.:4.000   1st Qu.:4.000  
 Median :4.000   Median :5.000   Median :4.00   Median :5.000   Median :4.000  
 Mean   :3.833   Mean   :4.438   Mean   :4.00   Mean   :4.426   Mean   :4.081  
 3rd Qu.:5.000   3rd Qu.:5.000   3rd Qu.:5.00   3rd Qu.:5.000   3rd Qu.:5.000  
 Max.   :5.000   Max.   :5.000   Max.   :5.00   Max.   :5.000   Max.   :5.000  


        Kruskal-Wallis rank sum test

data:  vtd
Kruskal-Wallis chi-squared = 23.7566, df = 9, p-value = 0.004703
```

$P < 0.05$. So, we can reject null.

Medians are not equal and one or two medians have significant difference between them.

q1. Project business case

q2. Feasibility study

q3. Client is an active member of the team

q4. Understanding the values of customer

q5. Relational contracts between parties

q6. Costs and schedule target cannot be exceeded and only customer can change scope

q7. Continuous estimating and budgeting collaboration among team member

q8. The Last Planner

q9. Frequent update of estimates among teams

q10. Co-location

Figure 37. Krusal-Wallis test result for TVD

7.3 Participant’s Comments

In addtion to all the materials regarding this simulstion I would also like to mention about some comments given by two participants.According to one participant,“IPD is the best” and according to another,“Great game and addressing the cost when choosing products”. These are few examples of the comments from the participants. Many participants also gave suggestions during the discussion session.

8. DISCUSSION

After playing the game, participants answered questions regarding its effectiveness in explaining the principles of IPD and TVD. Questionnaire responses were collected using Likert scales; therefore, qualitative analysis can be used for this kind of research. In the Results section, a detailed description about the participant's responses was shown using a histogram and box-and-whisker plot.

Results of these responses are quite encouraging because most of the participants believed that the game was either slightly effective or very effective. Some of the participants believed that some principles were not explained well in the game, which is true. It is quite surprising that some principles of TVD that I thought were not explained in the game earned a higher response (e.g. "The Last Planner" which is not explained properly, earned a median value of "4").

For the question regarding different costs involved in TVD, only 21 participants of 48 answered it correctly and 3 did not respond. In response to the questions regarding definitions, very few gave an acceptable answer.

Here, I would also like to mention that whenever we play lean simulations, generally we improve in the later half . So, there might be questions if the improvements seen are due to the learning curve . In this game, we play an IPD format in second round so one might doubt if it is also due to the learning curve. For me I was also testing TVD so I had to play in the same forrmat. In future if we only wish to test principles of IPD and to prove that improvement is not due to learning curve, game can be played in reverse format i.e. IPD format first and see the response from the participants.

In order to confidently say which principles are explained well in this game, we might have to play it five or six times and study the results. Improvements can always be made during this process.

8.1 Positive Aspects of the Simulation

a. During the discussion session, participants talked about the benefits of IPD and some of them even commented “IPD is the best.”

b. During the discussion session, participants believed that reducing costs would not affect aesthetics and towers built during the IPD format were beautiful.

c. When two or more teams play, teams compete to reduce costs as in real life.

d. In comments, many participants wrote that cooperation could be seen in the game.

8.2 Things that can be Improved in the Simulation

a. During discussion, some participants suggested that we should provide the estimate sheet with the design sheet in a traditional round as well; I agree that this will create a situation that is fair.

b. Examining and analyzing the responses, I believe that some terms should have been explained properly to the participants. I believe that they might have become confused with some of the terms.

c. After examining the game, I realized that we could add string in the supplied material so that there are choices between the tape and the string. Presently, we have only one option.

d. While playing the game in the traditional format, Architects, Owners and Contractor should be separated and the Facilitator should strictly tell them to fill out the “request for information” and “completion time.” During the discussion session, going through this will help participants think about the value of cooperation.

e. During the IPD session, I noticed that instead of designing and then constructing, they were doing it in reverse. To avoid this, materials may be collected after the first round then again supplied once the design is complete.

f. From the responses of the participants, I realized that it was difficult to form a proper definition; this needs to be addressed.

9. CONCLUSION

IPD and TVD are becoming more prevalent. It is a challenge to produce trained professionals. In this thesis, the researcher focuses on achieving a goal of delivering a game that will help in learning the processes of TVD and IPD.

The game was played in two locations in Nepal with 24 participants in each location and they were divided into three groups. After playing, participants answered a set of questions regarding the game. Data were collected using Likert scales leading to interpretation using comparisons of medians and percentiles.

Histograms and box-and-whisker plots are effective for interpreting non parametric data. Data showed that the game was effective in explaining some principles of IPD and TVD but the results are unsatisfactory because participants gave higher scores to the questions that were not related to the game. While responses for IPD were quite satisfactory, response for TVD were not nearly so.

Another tool to analyze non parametric data is the Krusal-Wallis Rank Sum test and some other paired tests. But they require underlying assumptions, which are not relevant to this study. Even though some assumptions were made, test was done with Krusal-Wallis Rank Sum test. The analysis shows that the medians are not equal, which means that the medians are spread. Medians with higher grade responses show that the participant believed that those principles are explained effectively in the game.

Principles of IPD having higher medians

a. "Open communication" had a median score of "5."
b. "Early involvement of key partners" had a median score of "4.5."
c. "Collaborative innovation and decision" had a median score of "4.5."

Principles of TVD having higher medians

a. "Client is an active member of the team" had a median score of "5."

b. "Continuous estimating and budgeting through collaboration among team members" had a median score of "5."

c. "Frequent update of estimates among teams" had a median score of "5."

Results from IPD data are satisfactory but TVD is somewhat unsatisfactory. Because of time constraint, only a first run study was completed; further studies may be done to determine greater effectiveness.

a. Following the above suggestions this game can be played up to five or six times and the participant's response will tell how effective the game is.

b. Game can also be played in reverse format i.e. IPD in first round to prove that improvement is not due to the learning curve.

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APPENDIX A

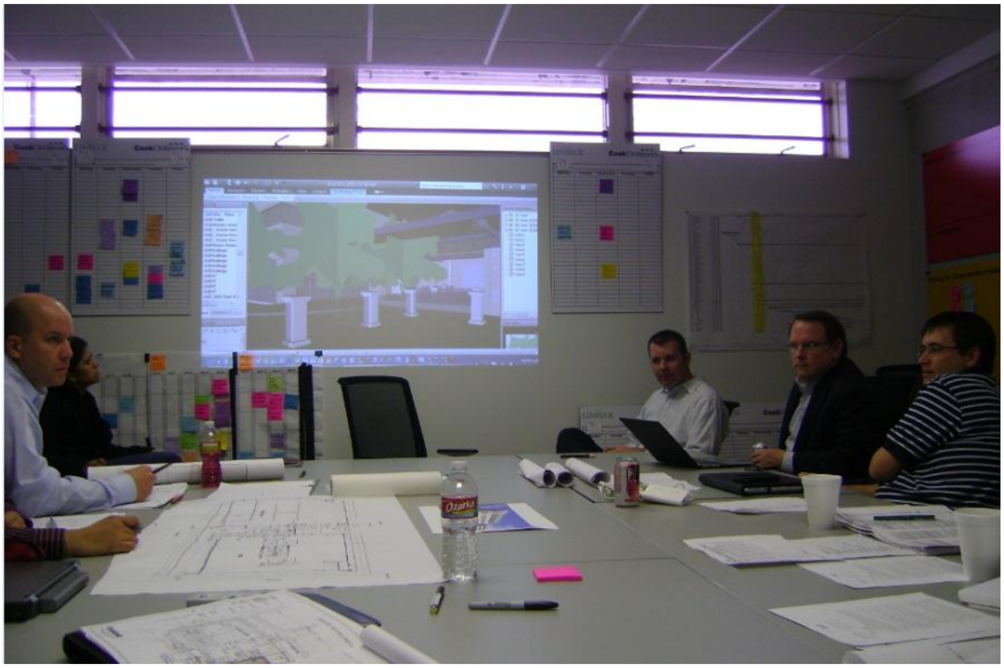


Figure 38. BIM Presentation at big room meeting, COOK's Children Hospital

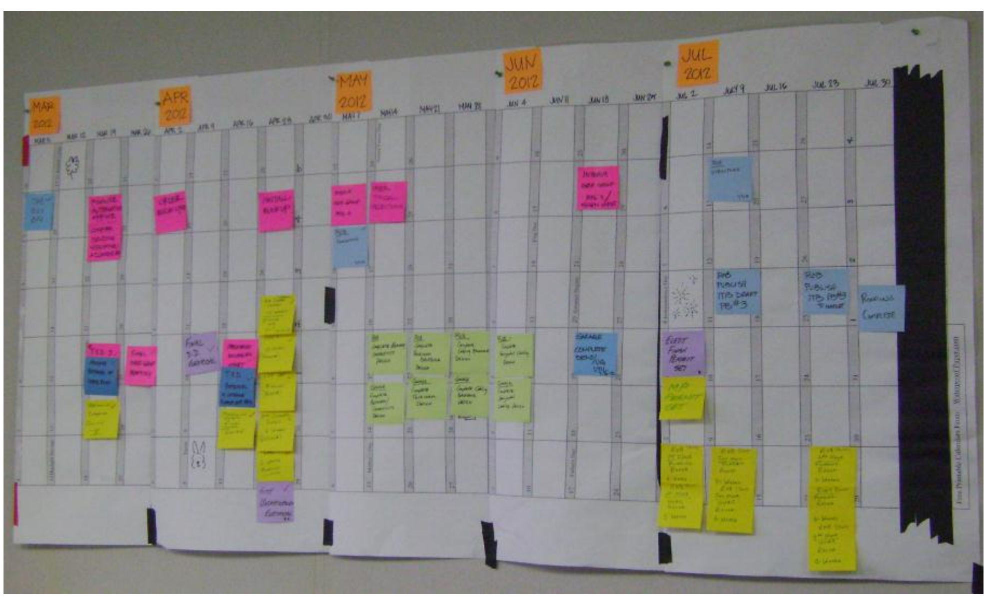
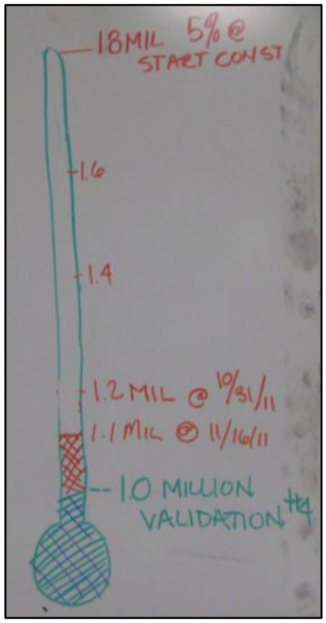
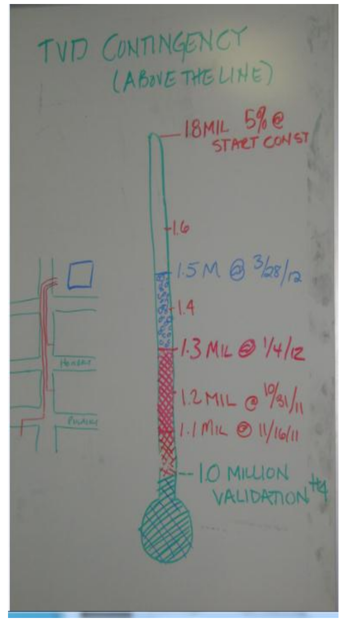


Figure 39. Example of schedules



14 December ,2011



23 May, 2012

Figure 40. Target Cost and achieved saving.

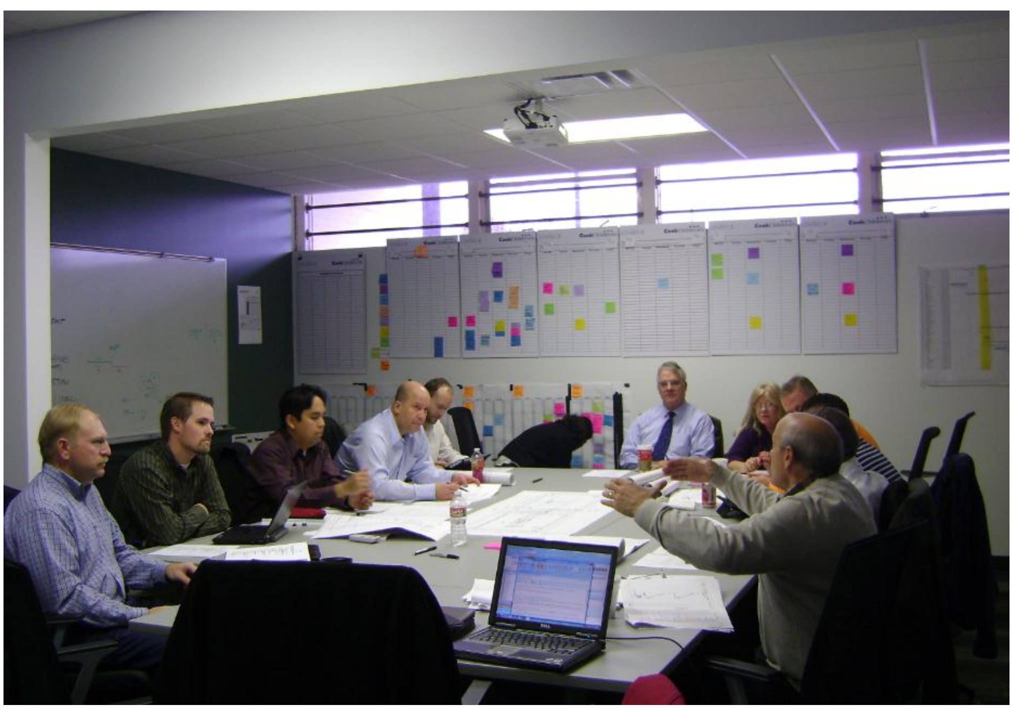
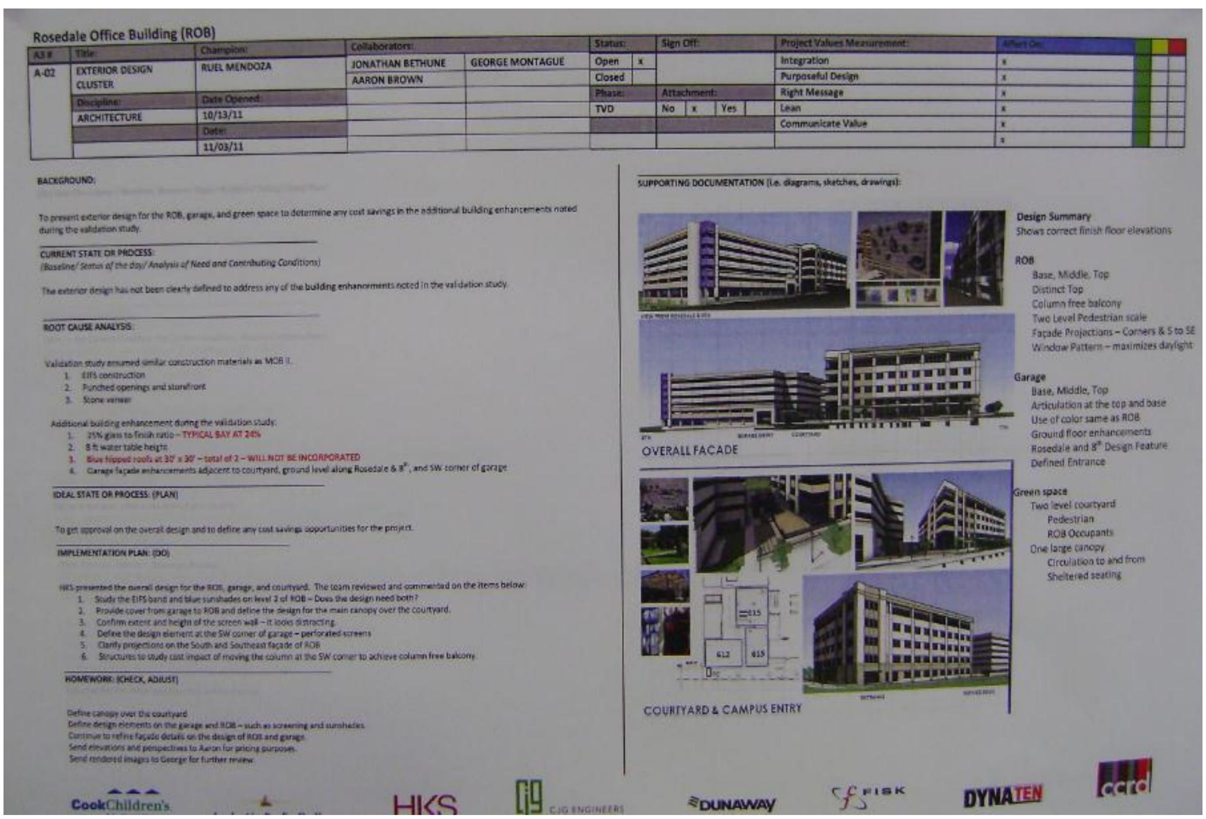


Figure 41. Picture of core shell group meeting

Figure 42. A3s on display



Rosedale Office Building (ROB)

A3 #	Title:	Champion:	Collaborators:		Status:		Sign Off:	Project Values Measurement:	Affect On:
A-02	EXTERIOR DESIGN CLUSTER	RUEL MENDOZA	JONATHAN BETHUNE	GEORGE MONTAGUE	Open	x		Integration	x
			AARON BROWN		Closed			Purposeful Design	x
	Discipline:	Date Opened:			Phase:		Attachment:	Right Message	x
	ARCHITECTURE	10/13/11			TVD		No x Yes	Lean	x
		Date:						Communicate Value	x
		11/03/11							x

BACKGROUND:

To present exterior design for the ROB, garage, and green space to determine any cost savings in the additional building enhancements noted during the validation study.

CURRENT STATE OR PROCESS:
(Baseline/ Status of the day/ Analysis of Need and Contributing Conditions)

The exterior design has not been clearly defined to address any of the building enhancements noted in the validation study.

ROOT CAUSE ANALYSIS:

Validation study assumed similar construction materials as MOB II.
1. EIFS construction
2. Punched openings and storefront
3. Stone veneer

Additional building enhancement during the validation study:
1. 25% glass to finish ratio – TYPICAL BAY AT 24%
2. 8 ft water table height
3. Blue hipped roofs at 30' x 30' – total of 2 – WILL NOT BE INCORPORATED
4. Garage façade enhancements adjacent to courtyard, ground level along Rosedale & 8th, and SW corner of garage

IDEAL STATE OR PROCESS: (PLAN)

To get approval on the overall design and to define any cost savings opportunities for the project.

IMPLEMENTATION PLAN: (DO)

HKS presented the overall design for the ROB, garage, and courtyard. The team reviewed and commented on the items below:
1. Study the EIFS band and blue sunshades on level 2 of ROB – Does the design need both?
2. Provide cover from garage to ROB and define the design for the main canopy over the courtyard.
3. Confirm extent and height of the screen wall – it looks distracting.
4. Define the design element at the SW corner of garage – perforated screens
5. Clarify projections on the South and Southeast façade of ROB
6. Structures to study cost impact of moving the column at the SW corner to achieve column free balcony

HOMEWORK: (CHECK, ADJUST)

Define canopy over the courtyard
Define design elements on the garage and ROB – such as screening and sunshades
Continue to refine façade details on the design of ROB and garage
Send elevations and perspectives to Aaron for pricing purposes
Send rendered images to George for further review

SUPPORTING DOCUMENTATION (i.e. diagrams, sketches, drawings):

OVERALL FACADE

COURTYARD & CAMPUS ENTRY

Design Summary
Shows correct finish floor elevations

ROB
- Base, Middle, Top
- Distinct Top
- Column free balcony
- Two Level Pedestrian scale
- Façade Projections – Corners & S to SE
- Window Pattern – maximizes daylight

Garage
- Base, Middle, Top
- Articulation at the top and base
- Use of color same as ROB
- Ground floor enhancements
- Rosedale and 8th Design Feature
- Defined Entrance

Green space
- Two level courtyard
  - Pedestrian
  - ROB Occupants
- One large canopy
  - Circulation to and from
  - Sheltered seating

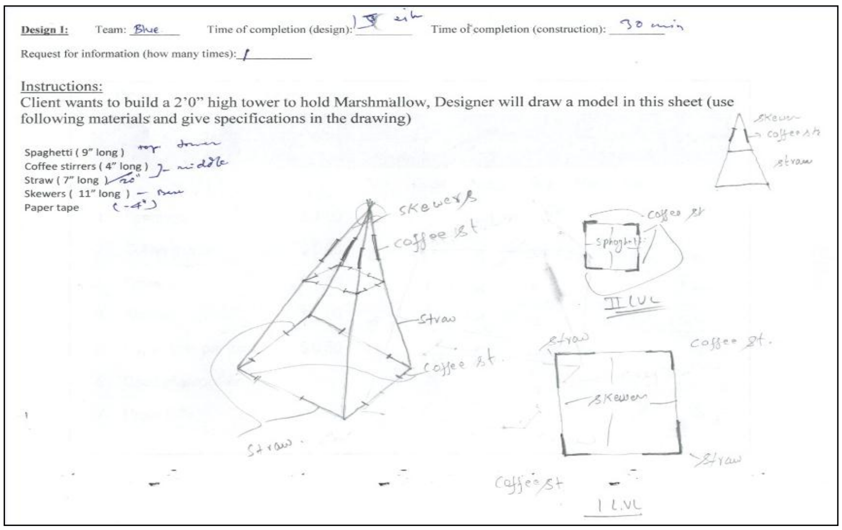
CookChildren's HKS CJG ENGINEERS DUNAWAY FISK DYNATEN ccrd

Figure 43. Example of A3 on display

APPENDIX B

Design Sheets and Costing Sheets

Blue Team



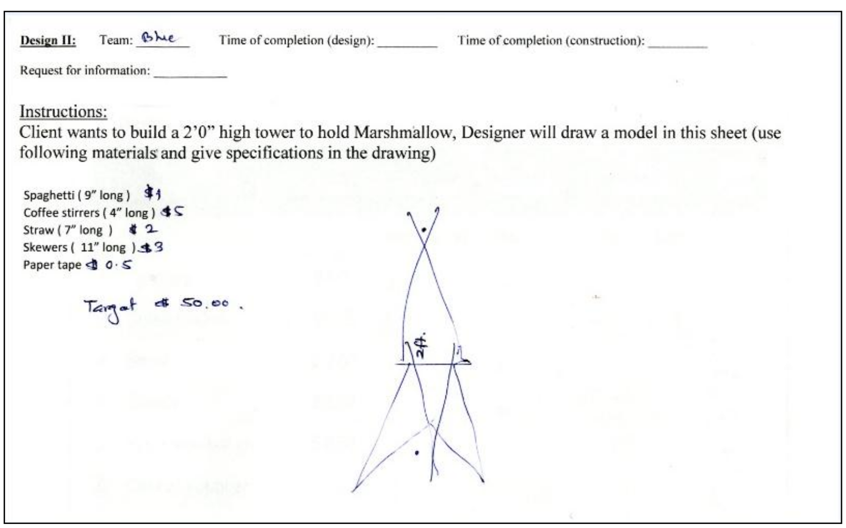
Design I: Team: Blue Time of completion (design): 15 min Time of completion (construction): 30 min

Request for information (how many times): 1

Instructions:
Client wants to build a 2'0" high tower to hold Marshmallow, Designer will draw a model in this sheet (use following materials and give specifications in the drawing)

Spaghetti (9" long) top down
Coffee stirrers (4" long) middle
Straw (7" long) 20"
Skewers (11" long) base
Paper tape

Figure 44. Design sheet I of Blue Team



Design II: Team: Blue Time of completion (design): ________ Time of completion (construction): ________

Request for information: __________

Instructions:
Client wants to build a 2'0" high tower to hold Marshmallow, Designer will draw a model in this sheet (use following materials and give specifications in the drawing)

Spaghetti (9" long) $1
Coffee stirrers (4" long) $5
Straw (7" long) $2
Skewers (11" long) $3
Paper tape $0.5

Target $50.00.

Figure 45. Design sheet II of Blue Team

Design I: Team: Blue

	Name	Unit cost	Hor. Supplier		Ver. Supplier		Tape Supplier		Total Cost
			No.	Cost	No.	Cost	No.	Cost	
1	Spaghetti	$ 1.00	2	2	–				4
2	Coffee mixture	$ 5.00	6	30	4	20			50
3	Straw	$ 2.00	2	4	4	8			12
4	Skewer	$ 3.00	4	12	4	12			24
5	Paper tape per joint	$ 0.50	~~13~~	~~7.5~~	~~5~~	~~2.5~~	18		9
6	**Cost of supplier**								99
7	Profit 10%								9.9
									108.9

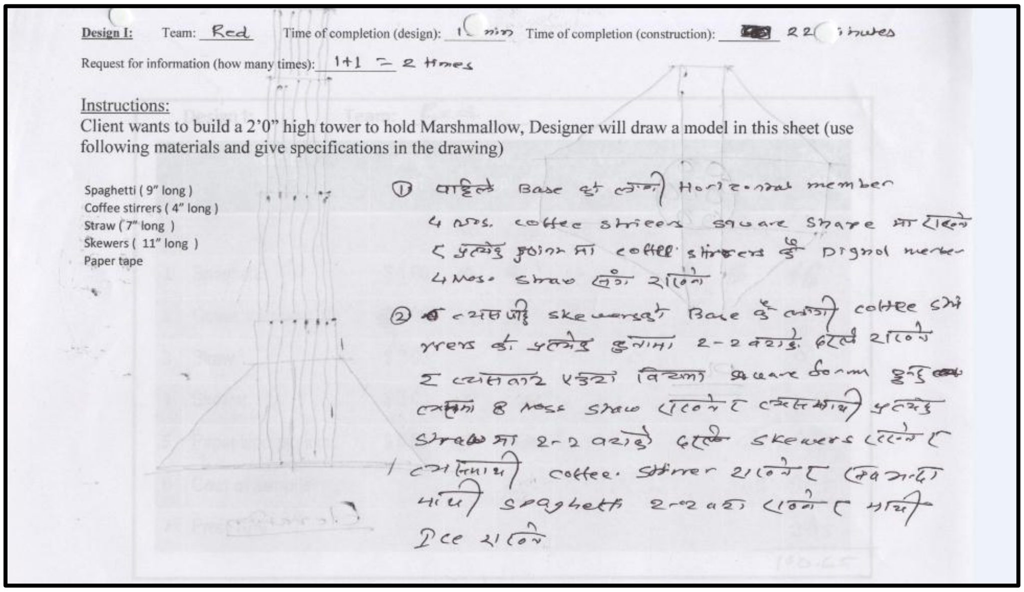
Figure 46. Costing sheet I of Blue Team

Design II: Team: Blue

	Name	Unit cost	Hor. Supplier		Ver. Supplier		Tape Supplier		Total Cost
			No.	Cost	No.	Cost	No.	Cost	
1	Spaghetti	$ 1.00	3			3			3
2	Coffee mixture	$ 5.00							
3	Straw	$ 2.00	1	2	12	24			26
4	Skewer	$ 3.00			3	9			9
5	Paper tape per joint	$ 0.50					11	5.5	5.5
6	**Cost of supplier**								43.5
7	Profit 10%								

Figure 47. Costing sheet II of Blue Team

Red Team



Design I: Team: Red Time of completion (design): 1 min Time of completion (construction): 22 minutes

Request for information (how many times): 1+1 = 2 times

Instructions:

Client wants to build a 2'0" high tower to hold Marshmallow, Designer will draw a model in this sheet (use following materials and give specifications in the drawing)

Spaghetti (9" long)
Coffee stirrers (4" long)
Straw (7" long)
Skewers (11" long)
Paper tape

Figure 48. Design sheet I of Red Team

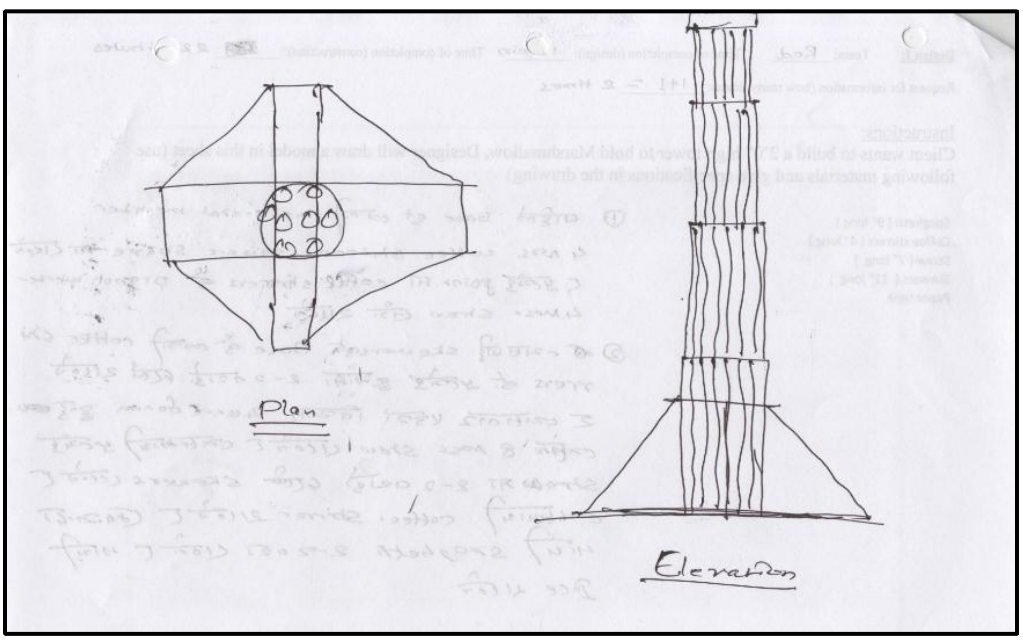


Figure 49. Design sheet I (A) of Red Team

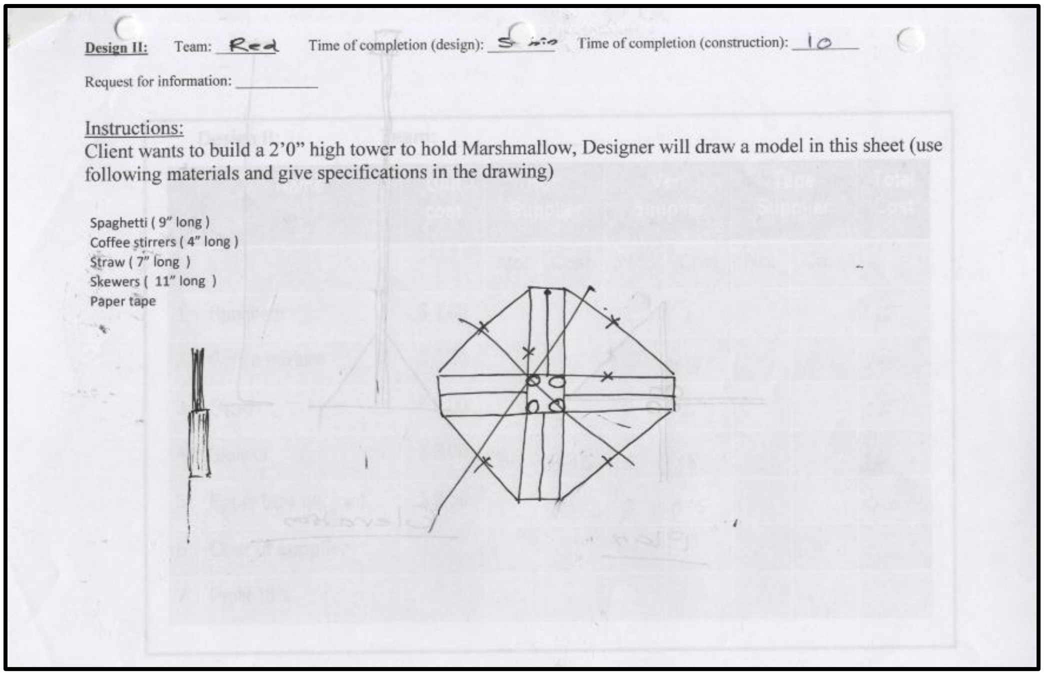


Figure 50. Design sheet II of Red Team

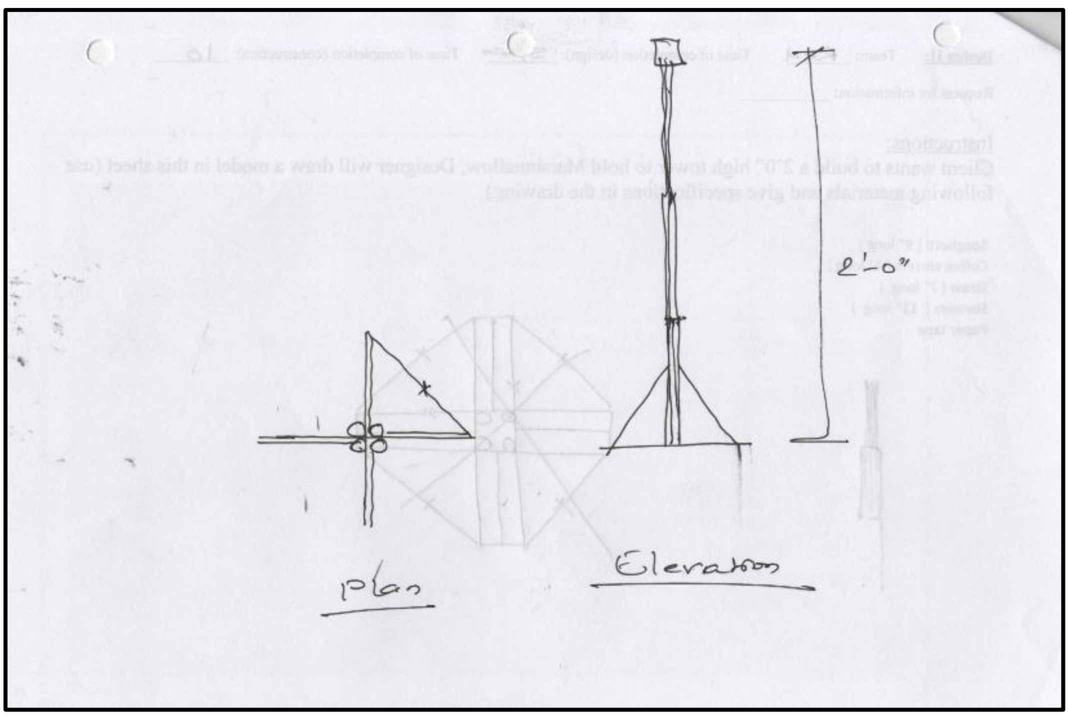


Figure 51. Design sheet II (A) of Red Team

Design I: Team: Red

	Name	Unit cost	Hor. Supplier		Ver. Supplier		Tape Supplier		Total Cost
			No.	Cost	No.	Cost	No.	Cost	
1	Spaghetti	$ 1.00	[illegible]	[illegible]	16	16	8	8	18
2	Coffee mixture	$ 5.00	7	7	8	8			15
3	Straw	$ 2.00			8	8			8
4	Skewer	$ 3.00	16	48					48
5	Paper tape per joint	$ 0.50	[illegible]	[illegible]			9	4.5	4.5
6	**Cost of supplier**			55.5		32		4.5	91.5
7	Profit 10%								9.15
									100.65

Figure 52. Costing sheet I of Red Team

Design II: Team:

	Name	Unit cost	Hor. Supplier		Ver. Supplier		Tape Supplier		Total Cost
			No.	Cost	No.	Cost	No.	Cost	
1	Spaghetti	$ 1.00			6	1			6
2	Coffee mixture	$ 5.00			3	15			~~15~~
3	Straw	$ 2.00			8	2			16
4	Skewer	$ 3.00	~~2~~	~~34~~6	6	18			24
5	Paper tape per joint	$ 0.50			8	0.5			4.0
6	**Cost of supplier**								
7	Profit 10%								

Figure 53. Costing sheet II of Red Team

White Team

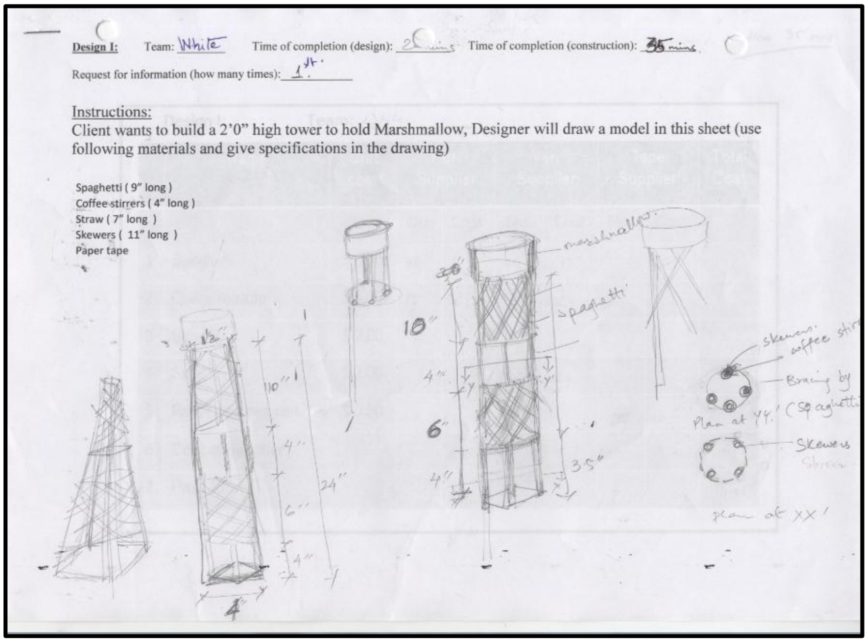


Figure 54. Design sheet I of White Team

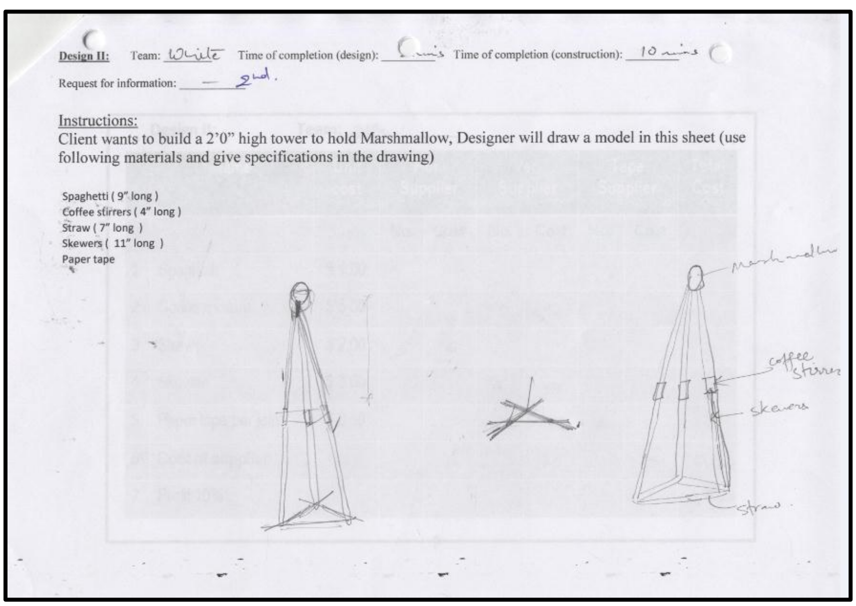


Figure 55. Design sheet II of White Team

Design I: Team: White.

	Name	Unit cost	Hor. Supplier		Ver. Supplier		Tape Supplier		Total Cost
			No.	Cost	No.	Cost	No.	Cost	
1	Spaghetti	$ 1.00	13		13.	13.			
2	Coffee mixture	$ 5.00	13	65	4	20.			
3	Straw	$ 2.00							
4	Skewer	$ 3.00			8	24			
5	Paper tape per joint	$ 0.50					37	18.5	
6	**Cost of supplier**			65		57		18.5	140.5
7	Profit 10%								14.05

Figure 56. Costing sheet I of White Team

Design II: Team: White.

	Name	Unit cost	Hor. Supplier		Ver. Supplier		Tape Supplier		Total Cost
			No.	Cost	No.	Cost	No.	Cost	
1	Spaghetti	$ 1.00							
2	Coffee mixture	$ 5.00			1	5			
3	Straw	$ 2.00	3	6					
4	Skewer	$ 3.00			6	18			
5	Paper tape per joint	$ 0.50					6	3	
6	**Cost of supplier**			6		23		3	32
7	Profit 10%								3.20

Figure 57. Costing sheet II of White Team

Pictures from the games

Figure 58. Students ready to take part in game

Figure 59. Designer busy designing a tower

Figure 60. Construction team busy constructing a tower

Figure 61. Estimating cost of tower.

Figure 62. Towers built in traditional round

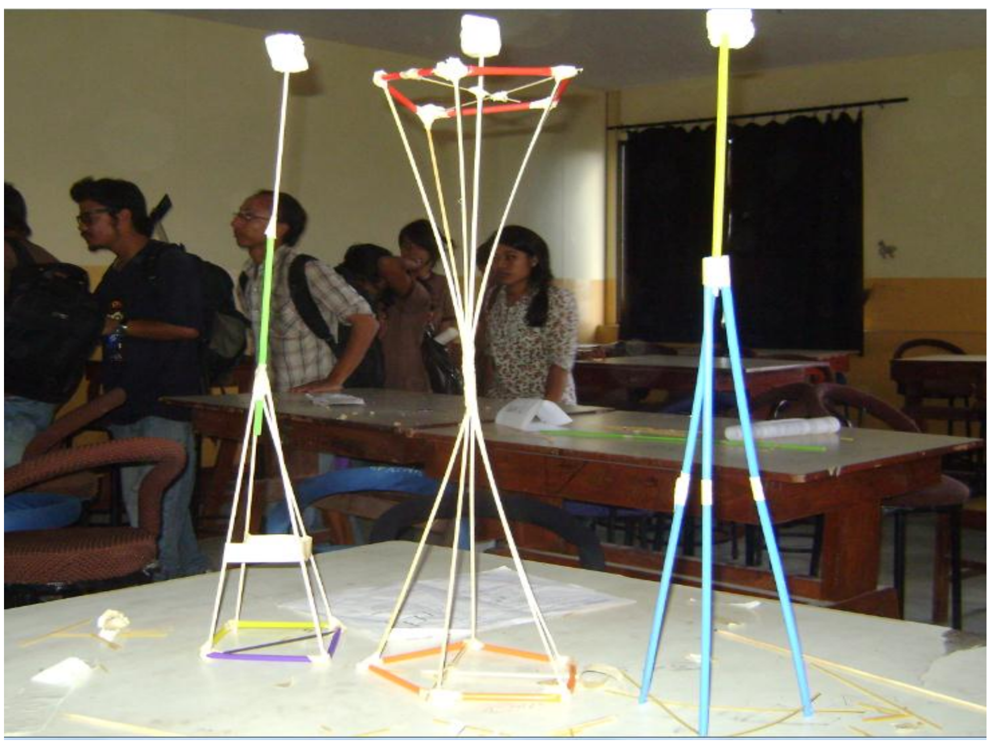


Figure 63. Towers built in IPD round

Figure 64. Team Blue with tower I

Figure 65. Team Blue with tower II

Figure 66. Team White with tower I

Figure 67. Team White with tower II

Figure 68. Team Red with tower I

Figure 69. Team Red with tower II

Raw data

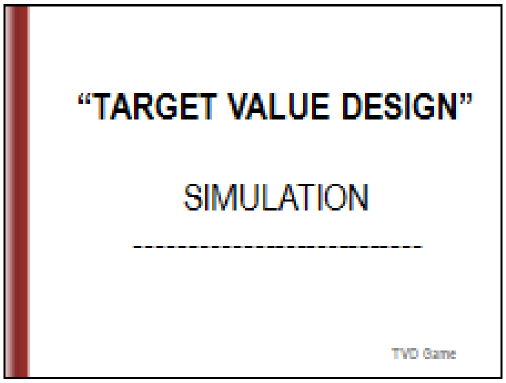
No.		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
1	**Question about I.P.D.**																																																
a	"Mutual respect and trust"	3	4	5	3	4	4	4	5	4	3	5	5	5	4	3	5	4	5	5	4	5	5	5	5	4	4	4	3	4	4	3	4	3	4	5	5	3	5	4	5	3	5	5	5	4	5	4	4
b	"mutual benefit and reward"	3	4	4	3	4	4	5	5	5	3	5	5	5	5	3	4	3	5	5	5	5	5	5	5	4	5	4	4	4	2	4	4	2	4	4	5	5	4	5	5	4	5	4	5	4	4	4	4
c	"collaborative innovation and decision making"	4	4	4	4	5	3	5	4	4	4	5	5	5	4	4	5	5	5	5	5	5	4	5	4	4	4	5	3	2	2	4	4	4	5	5	5	5	5	4	5	5	5	4	5	5	4	5	3
d	"early involvement of key partners"	5	4	5	3	5	4	4	5	5	4	4	4	5	5	4	5	5	5	5	5	5	4	5	4	5	5	5	2	1	4	4	5	3	4	5	4	4	5	5	4	3	5	4	5	5	4	3	4
e	"early goal definition"	3	4	3	3	4	4	4	4	5	3	4	5	4	4	3	4	4	4	4	3	5	3	3	5	4	4	4	4	5	4	3	4	3	5	5	5	3	4	4	3	4	5	3	5	5	4	5	4
f	"intensified planning"	4	5	5	4	5	4	4	4	4	4	4	4	5	5	3	4	4	3	3	4	5	5	5	5	5	5	4	3	4	2	3	4	4	4	4	5	4	5	2	3	3	5	4	4	5	4	3	5
g	"open communication"	4	5	2	4	5	5	5	5	4	4	4	5	4	4	5	5	5	5	5	3	5	4	3	4	2	5	4	4	5	5	4	5	4	4	5	5	5	5	5	3	5	5	4	5	5	4	5	4
h	"appropriate technology"	4	4	5	4	4	4	5	5	5	5	5	4	5	4	4	5	4	5	5	4	4	4	4	3	5	4	5	5	5	4	4	4	2	4	5	5	3	5	4	3	3	5	5	4	5	4	5	4
i	"organization and leadership"	3	4	5	3	4	4	4	5	5	3	5	2	5	4	4	5	5	5	5	4	4	5	4	5	2	5	5	3	4	3	5	4	3	4	5	5	3	5	4	2	2	3	3	5	4	4	4	4

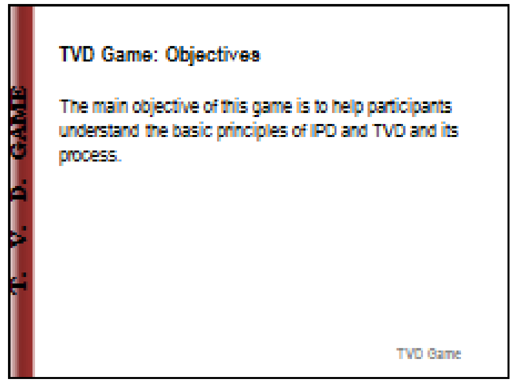
Figure 70. Raw data of IPD

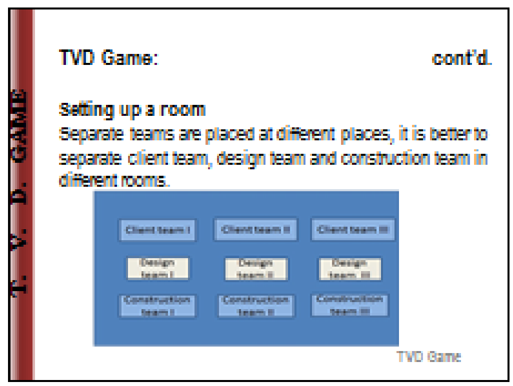
6	**Questions about T.V.D.**																																															
a	"project business case and decisions"	4	5	2	4	4	4	5	4	4	3	5	5	5	4	4	5	4	5	5	5	5	5	4	4	5	5	4	4	4	5	4	4	2	4	4	5	4	5	5	5	3	5	5	4	5	4	4
b	"feasibility study"	4	4	4	4	5	4	5	4	4	4	5	4	4	4	4	5	5	5	5	4	4	4	4	5	4	4	5	3	5	4	4	4	3	4	4	5	4	5	4	4	5	5	4	4	5	4	3
c	"client is an active member of the team"	4	5	5	4	5	4	4	5	3	2	4	4	4	5	4	5	4	4	4	5	5	5	5	3	5	5	5	4	5	5	4	5	4	5	.	5	5	4	4	4	5	4	5	5	5	4	3
d	"understanding the values of customer"	3	4	2	3	5	4	5	5	5	4	5	5	5	4	4	5	5	5	5	4	4	5	4	5	4	5	4	4	1	3	4	3	3	5	5	5	4	5	4	3	4	5	5	5	4	4	5
e	"relational contract between parties"	4	5	5	4	5	5	4	5	4	3	4	4	4	4	5	5	4	5	5	5	5	4	4	5	4	5	4	3	5	3	4	4	4	5	5	5	5	5	5	4	4	5	4	5	4	4	4
f	"costs and schedule targets cannot be exceeded and only customer can change scope"	3	4	1	4	5	3	3	5	3	4	3	4	5	5	2	2	3	4	4	4	4	4	4	3	4	4	5	4	3	5	3	2	2	4	4	4	5	5	4	3	4	5	4	5	5	4	5
g	"continuous estimating and budgeting through collaboration among team members"	4	5	2	4	5	4	4	5	4	4	4	5	5	4	4	5	4	5	5	5	5	3	4	3	5	5	4	5	5	5	4	4	3	5	5	5	4	5	5	5	5	5	4	5	4	5	4
h	"The Last Planner"	4	3	5	3	4	4	5	4	4	2	4	4	4	4	3	5	3	4	4	5	5	3	5	4	4	5	5	3	5	4	2	3	2	5	5	.	2	4	.	4	4	.	.	5	4	5	5
i	"frequent update of estimat	3	4	5	4	5	.	4	5	4	3	5	4	5	4	4	5	4	4	4	5	5	5	5	3	5	5	5	4	5	5	4	4	3	5	5	5	4	4	5	4	4	5	5	5	5	4	4
j	"co-location"	4	.	5	4	1	.	4	.	4	4	4	4	5	4	4	5	.	3	3	5	5	4	.	4	4	4	5	4	4	5	4	.	.	5	5	.	3	4	.	4	3	.	.	5	3	4	5

Figure 71. Raw data of TVD

Slides used for game







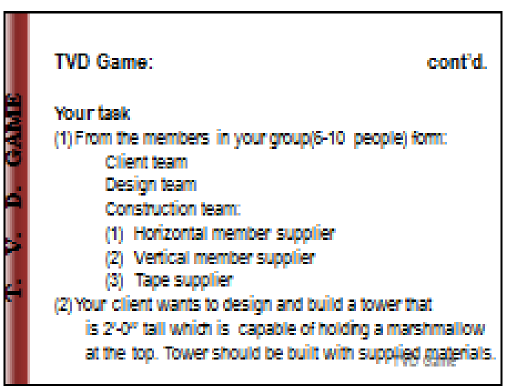
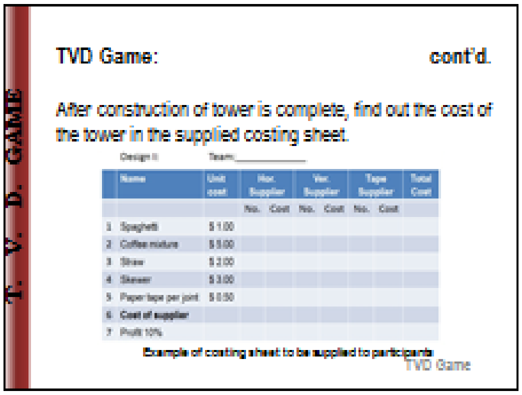
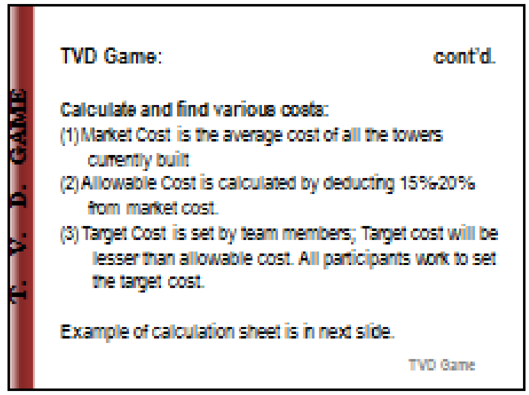
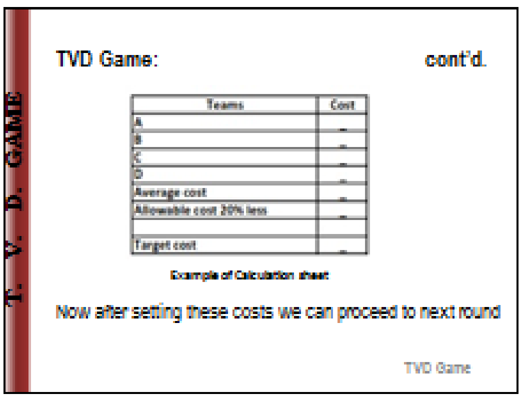
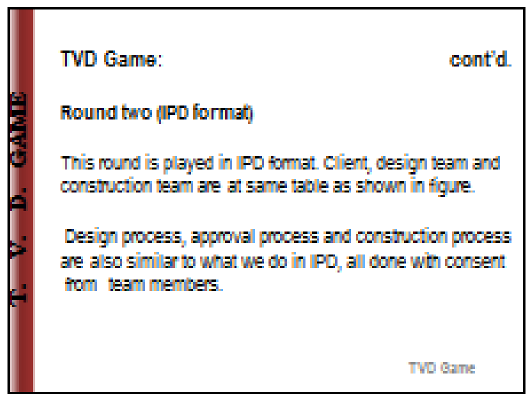


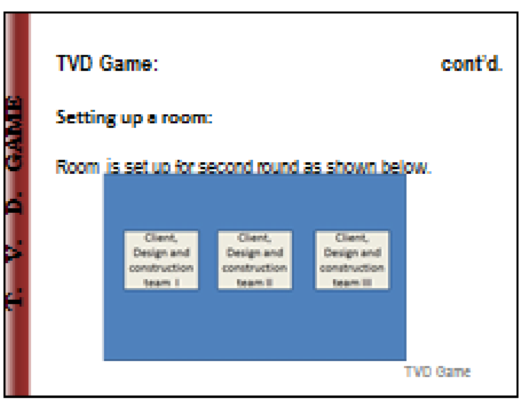
Figure 72. Slide used in game (A)











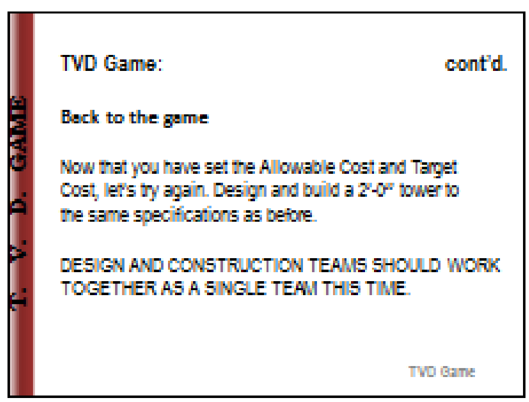
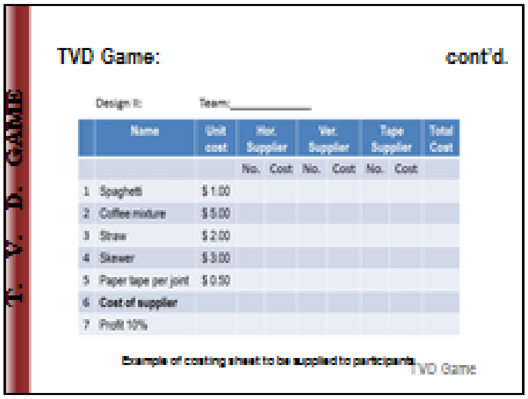
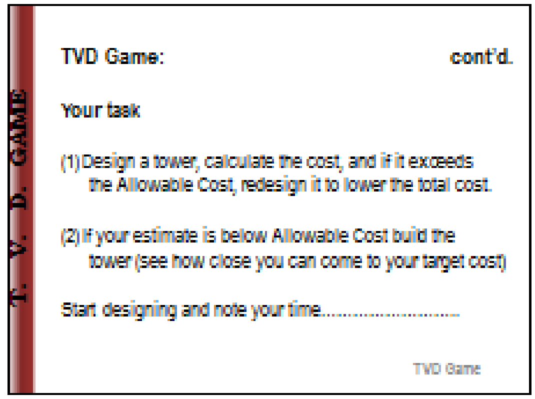
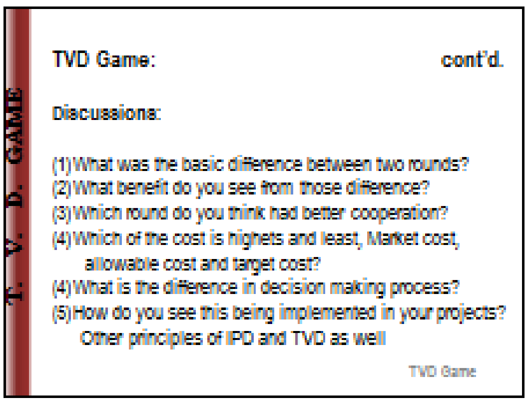


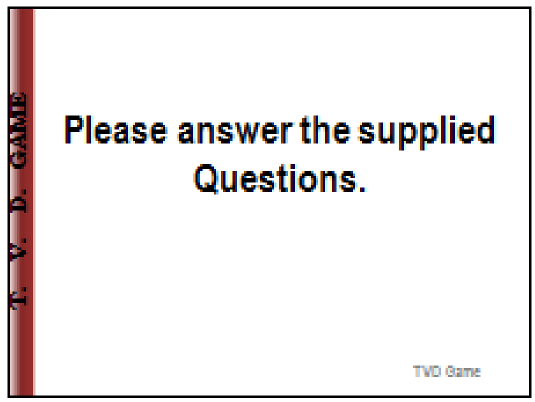
Figure 73. Slides used in game (B)



	Name	Unit cost	Hor. Supplier		Ver. Supplier		Tape Supplier		Total Cost
			No.	Cost	No.	Cost	No.	Cost	
1	Spaghetti	$ 1.00							
2	Coffee mixture	$ 5.00							
3	Straw	$ 2.00							
4	Skewer	$ 3.00							
5	Paper tape per joint	$ 0.50							
6	**Cost of supplier**								
7	Profit 10%								







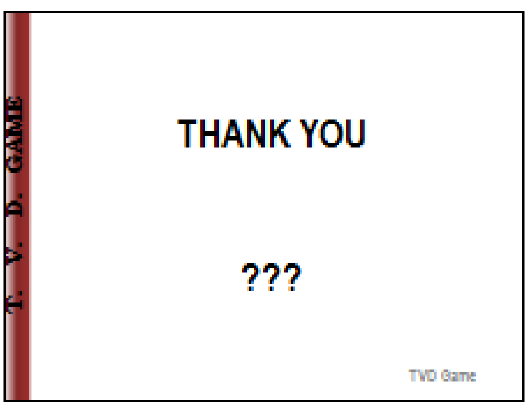


Figure 74. Slides used in game (c)

Questionnaires

Questions about IPD:

1. On a scale of 1 to 5, respond about the effectiveness of the simulation in explaining the following :

1- Not effective at all	2 - Slightly ineffective	3 - Neither effective nor ineffective	4 - Slightly effective	5 - Very effective
☐	☐	☐	☐	☐

a. On a scale of 1-5, how effective was the game in demonstrating the importance "Mutual respect and trust"?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

b. On a scale of 1-5, how effective was the game in demonstrating the importance “mutual benefit and reward”?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

c. On a scale of 1-5, how effective was the game in demonstrating the importance “collaborative innovation and decision making”?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

d. On a scale of 1-5, how effective was the game in demonstrating the importance “early involvement of key partners”?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

e. On a scale of 1-5, how effective was the game in demonstrating the importance “early goal definition”?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

f. On a scale of 1-5, how effective was the game in demonstrating the importance “intensified planning”?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

g. On a scale of 1-5, how effective was the game in demonstrating the importance “open communication”?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

h. On a scale of 1-5, how effective was the game in demonstrating the importance “appropriate technology”?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

i. On a scale of 1-5, how effective was the game in demonstrating the importance “organization and leadership”?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

Questions about TVD:

2. What is Target Cost?

3. What is Market Cost?

4. What is Allowable Cost?

5. Which of the following is generally true?

☐ Market cost > Allowable cost > Target cost

☐ Target cost > Market cost > Allowable cost

☐ Allowable cost > Market cost > Target cost

6. On a 5 scales; respond about the effectiveness of the simulation in explaining the following :

1- Not effective at all	2 - Slightly ineffective	3 - Neither effective nor ineffective	4 - Slightly effective	5 - Very effective
☐	☐	☐	☐	☐

a. On a scale of 1-5, how effective was the game in demonstrating “project business case and decisions”?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

b. On a scale of 1-5, how effective was the game in demonstrating “feasibility study”?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

c. On a scale of 1-5, how effective was the game in demonstrating “client is an active member of the team”?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

d. On a scale of 1-5, how effective was the game in demonstrating the importance of “understanding the values of customer”?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

e. On a scale of 1-5, how effective was the game in demonstrating the importance of “relational contract between parties”?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

f. On a scale of 1-5, how effective was the game in demonstrating that “costs and schedule targets cannot be exceeded and only customer can change scope”?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

g. On a scale of 1-5, how effective was the game in demonstrating the importance of “continuous estimating and budgeting through collaboration among team members”?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

h. On a scale of 1-5, how effective was the game in demonstrating the importance of “The Last Planner”?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

i. On a scale of 1-5, how effective was the game in demonstrating the importance of “frequent update of estimates among teams”?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

j. On a scale of 1-5, how effective was the game in demonstrating the importance of “co-location”?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

K. Any other comments about this simulation, give comments:

……………………………………………………………………………………………..

…………………………………………………………………………………………

………………………………………………………………………………………….

In order to better understand how to improve the simulation to suit the needs of our various participants, we would appreciate your response to the following questions.

Thank you for your help!

☐ Student ☐ Professional

If student:

☐ Undergraduate

☐ Graduate.

☐ PhD

If you are affiliated with the University, what is your major field of study?

……………………………………………………………………………

If professionals:

☐ Faculty (field :……………………………………………………)

☐ Developer

☐ Architect/Designer

☐ Engineer

☐ General Contractor

- ☐ Sub-Contractor
- ☐ Supplier
- ☐ Financial
- ☐ Insurance
- ☐ Law

Approximately what is the maximum number of years you have worked in the building and construction industry.

☐	☐	☐	☐
Less than 5 yrs.	Less than 10 yrs.	Less than 15 yrs.	More than 15 yrs.