Desmarais, Dominic, and Alves, Thais da C. L.(2024). Target Value Delivery: A Simulation Lean Construction Journal 2024 pp 41-81 https://doi.org/10.60164/ehgzibhh2 (Submitted 13 December 2023; Accepted 15 October 2024) www.leanconstructionjournal.org

Target Value Delivery: A Simulation

Dominic Desmarais[1] and Thais da C. L. Alves[2]

Abstract

Question: How can a facilitator teach the fundamental principles of Target Value Delivery (TVD) using a simulation emphasizing the importance of integrating contextual information from project partners along the value chain to establish target costs, select design solutions, and improve the delivery of value for owners?

Purpose: The purpose of this paper is to provide practitioners and academics with a simulation to help illustrate the difference between traditional siloed project delivery and an integrated approach using Target Value Delivery principles during the design phase of construction projects. The simulation was developed in response to industry practitioners who expressed the need to demonstrate the value of engaging contractors early in the delivery process and to illustrate the value they bring to the Target Value Delivery (TVD) process.

Method: The simulation presented was developed from an existing simulation, i.e., the Silo Game (Alves 2022) and the first author's experience in playing the Silo Game and contrasting it with his own experience. A literature review of similar simulations was conducted to identify gaps and improve relevancy. The Simulation was tested with practitioners for relevancy, ease of comprehension, and process outcomes.

Findings: The Target Value Delivery simulation is useful for teaching the principles of collaborative decision-making versus siloed decision-making in design. This simulation enhances the experience of participants by showing the value brought to the design process by constructors, integrating their understanding of market conditions, risks and other project contextual information.

Limitations: The simulation emulates a process based on the experiences of the first author and the structure provided by the Silo Game. The simulation goes beyond design work; it incorporates constructors' input and construction context knowledge but does not include building operators, maintenance, and decommissioning as a part of Whole Life Target Value Design (Tommelein et Ballard 2016). This paper is one additional step towards the creation of further Target Value Delivery simulations.

Implications: The simulation is documented to be broadly used to teach key principles of

[1] Director, Lean Construction, Graham Construction, 8404 McIntyre Road, Edmonton, AB T6E 6V3, dominic.desmarais@hotmail.com

[2] Professor, The Associated General Contractors (AGC) Paul S. Roel Chair in Construction Engineering and Management, Senate Distinguished Professor, San Diego State University, San Diego, CA 92182, USA, talves@sdsu.edu

Target Value Delivery and should be used to develop future simulations.
Value for practitioners: The simulation offers a hands-on and simple way to engage participants to address questions, trade-offs, and procedural elements involved in Target Value Delivery. It can be added to a training workshop or classroom.
Keywords: Target Value Delivery (TVD), Target Value Design (TVd), collaboration, integrated project delivery, value, simulation, game, Target Costing
Paper type: Full paper

Introduction

The benefits that the division of labor brings to improve a nation's productive power were suggested in the late 18th century by Adam Smith. Smith (1776) suggested that such improvements came from improved workers' dexterity, reduced workers' waste in transitions, and by focusing men on single objects. At the turn of the 20th century, Frederick W. Taylor reinforced Smith's suggestion with his Scientific Management approach. Taylor (1911) stated: "(i)t is also clear that in most cases one type of man is needed to plan ahead and an entirely different type to execute the work," thus reinforcing the ideals of labor division as specialization to increase productivity. This system worked well in the 19th century because production was simpler, contained fewer components, and was managed and executed by fewer stakeholders (Koskela 1992).

The construction industry has relied on the concepts of division of labor and responsibilities between designers and builders to organize and develop labor, reduce market risks, stabilize the supply chain, and deliver the work. Construction has been traditionally focused on conversion activities, while the focus on flow and value has been limited, reducing the effectiveness of construction (Koskela 1992). Establishing flow is the basic condition of the Toyota Production System (Ohno, 1988) and one of the tenets of lean construction. The modern challenges caused by the division of labor in terms of execution and management appear both "horizontally" (multiple workers/trades to complete a product) and "vertically" (different hierarchical levels in a production system), impacting the flow of work, decisions and instructions given to those who are part of the system. Such organizational designs, characterized by multiple layers focused on specific tasks and processes, are referred to as "silos" and "slabs" (Mintzberg 2019). The division lines are well-established, and the paradigm is reinforced by experience, legal systems, and the education system for well over a century.

In calling attention to the idiosyncratic characteristics of the construction industry and proposing alternatives to address them, Koskela (2000) suggested the use of a new production philosophy to account for three distinct elements namely, Transformation, Flow, and Value (TFV Theory), which are necessary to describe a production process. However, the decision to reject one paradigm is always simultaneously the decision to accept another, and the judgment leading to that decision involves the comparison of both paradigms with nature and with each other (Kuhn 1962). In this scenario, where construction is faced with traditional and new paradigms (TFV Theory, Lean Construction/Production), the use of serious games and simulations can be an effective way to facilitate learning, make comparisons between paradigms, and help set the stage and create a need for solutions that can be developed based on newer theories like TFV and Lean (Rybkowski et al. 2018). One way to effectively drive this change is through the development and use of hands-on simulations to promote learning of new paradigms and illustrate how they apply to construction projects (Rybkowski et al. 2021).

For the purpose of this paper, the authors are using two different terminologies to refer to a central focus of the simulation being proposed. Target Value Design (TVd) (Macomber et al., 2007) is a method adapted to construction from Target Costing to steer projects toward specific targets (Tommelein et Ballard. 2016). Whereas Target Value Delivery (TVD) is a broader approach developed to work toward a 'whole life Target Value Design' (Ballard 2011, Tommelein et Ballard. 2016).

To accomplish the purpose of describing the new simulation while relating it to previous work about the topic, the paper contains a literature review of existing simulations available for Target Value Design and Target Value Delivery and illustrates the need for creating new simulations for teaching the principles of Target Value Delivery.

The new simulation was developed using the Silo Game developed by Alves (2022). The new simulation integrates owners, designers and contractors to demonstrate their contributions to Target Value Delivery and illustrates how it can lead to better value being delivered to owners (Lean Construction Institute, 2016). It is less focused on design work and more on the Target Conditions necessary before design and the contributions of contractors in steering cost and design based on contextual irreducible uncertainties and other external conditions (Ballard 2020).

The paper initially describes the original Silo Game, followed by a discussion about Target Value Design and Target Value Delivery. Next, it addresses previous simulations that have addressed TVd or TVD simulations and explains how the new simulation was developed and how it is used. Next, the paper provides instructions on how to facilitate a workshop using the simulation alongside examples of expected outcomes. Finally, a discussion about the simulation's limitations and ideas for future research is presented.

Literature Review

The discussion presented as part of the literature review covers the basics of the Silo Game, compares Target Value Design and Target Value Delivery, and reviews other simulations about TVd provided in the literature.

The Silo Game and Integrated Design Process (IDP)

The Silo Game was introduced as an additional teaching simulation to underscore the importance of collaboration in construction. The simulation was created to offer a direct comparison between Design-Bid-Build (DBB) and collaborative project delivery models like Design-Build (DB) and Integrated Project Delivery (IPD) (Alves 2022). DBB is characterized by sequential tasks developed by the design team, which does not work collaboratively, and with participation of trades only during the construction phase. Conversely, delivery methods such as DB and IPD are known for early participation of trades collaboratively working with designers to deliver the project.

The Silo Game simulation used interdisciplinary teams and challenged them to provide a sustainable design for an environmentally conscious project. The simulation used four professional designer roles (i.e., architect, mechanical engineer, electrical engineer, and civil engineer) and compared the outcomes of their efforts in two separate rounds.

The first round mimics the design developed in silos, for instance, architects only discuss their design with other architects. The second round brings professionals from the four specialties together to develop the design and take advantage of synergies by using solutions that benefit multiple areas of interest (e.g., energy use, availability of open spaces, comfort, etc.) (Alves, 2022). The second round of the Silo Game mimics the Integrated Design Process (IDP), which is a method that originated in the 1990s for the design of sustainable buildings (Forgues and Koskela 2008, Larsson et al. 2002) and has been described as: "*A method for realizing high performance buildings that contributes to sustainable communities. It is a collaborative process that focuses on the design, construction, operation, and occupancy of a building over its complete life cycle. The integrated design process is designed to allow the client and other stakeholders to develop and realize clearly defined and challenging functional, environmental, and economic goals and objectives. It requires a multi-disciplinary design team that includes or acquires the skills required to address all design issues flowing from the objectives.*" (Knudstrup, 2004). IDP has proven successful in bringing architects and engineers together in designing better solutions. The silo game is well suited to illustrate the principles of collaborative design embodied by IDP for both the participants it contains and the connection to sustainable projects.

Target Value Design (TVd) vs Target Value Delivery (TVD)

In the Lean Construction literature, the acronym TVD has been used loosely to refer to Target Value Design and Target Value Delivery, despite evidence in the literature that these are two ways to view target value applied to construction projects. It is worth noting that the term Target Value Design (TVd) was proposed to replace Target Costing (TC), which is used in the industry at large (Macomber et al. 2007, Ballard 2011, 2012). The new terminology enabled the industry to make adaptations to the Target Cost methods to suit the Architecture, Engineering, and Construction (AEC) industry (Tommelein et Ballard. 2016). The first paper mentioning Target Value Design (TVd) in the International Group for Lean Construction (IGLC) was published by Morton and Ballard (2009). A quick review of titles and abstracts from the IGLC proceedings available at iglc.net reveals that between 2007 and 2023, 50 IGLC papers reference Target Value Design (TVd) and 26 reference Target Costing. Target Costing has remained a regular topic of publication despite the original suggestion to replace the terminology with Target Value Design (TVd) to suit the AEC industry (Pennanen et al. 2010, Tommelein et Ballard 2016, Musa et al. 2019, Narum et al. 2022). In 2010, papers started to refer to Target Value Design (TVd) as a "process" (Pennanen and Ballard 2010, Tommelein and Ballard. 2016, Alves et al., 2017).

In this context, the following definition was suggested to define the Target Value Design process: "TVD is a disciplined management practice used throughout project definition, design, detailing, construction, commissioning, and activation to assure that the facility meets the operational needs and values of the users, is delivered within the allowable budget, and promotes innovation throughout the process to increase value and eliminate waste" (Alves et al., 2017, p.19). Regarding the use of the term Target Value Delivery (TVD), the first paper available at the IGLC was published by Musa et al. (2019). The paper identifies Target Value Delivery in the Keywords section but uses "TVD" as an Acronym for Target Value Design throughout the paper. The first paper to utilize the acronym TVD to describe Target Value Delivery was published by Malvik et al. (2021).

While Target Value Design has been defined to describe the WHAT and the WHY, Target Value Delivery is intended to describe the HOW as explained by the Lean Construction Institute (LCI) (2016, p.6). However, both terms are present in the LCI publication and defined using the same acronym ("TVD") leading to confusion amongst practitioners.

In 2020, Ballard offered the following insight into the challenges related to differentiating TC, TVd and TVD: "The term *Target Value Delivery* is used instead of *Target Costing* because the cost target is but a means to value delivery. The name *Target Value Design* is also rejected because it suggests that steering to targets only occurs in design" (Ballard 2020, p.149). Using Ballard's (2020) explanation, this paper offers a simulation that departs from the use of the term Target Value Design and offers a first step towards a simulation that encompasses the concept of steering to targets both before and after the design phase thus moving closer to the Target Value Delivery ideal process.

To move past the traditional paradigm, improve flow and deliver more value, the Lean Construction community advocates for more collaborative approaches using methods focused on optimizing the whole and improving flow. Value is a major concept in the Lean Construction literature, yet it is not properly understood nor uniformly defined across the Lean Construction community (Drevland and Lohne 2023). Value has many meanings and related tenets (e.g., 'value is dependent on knowledge', 'value is context dependent', 'value is comparative', 'value is experience based'); it can be based on perception and defined by the eye of the beholder (Drevland and Lohne 2015). Despite the challenges to define value, it must be translated and operationalized by teams working in construction projects. Broad statements and rather vague comments from owners and users of a project are painstakingly translated into design and construction solutions which become physical parts of a project. Drevland and Lohne (2023, p.575) provide an abridged definition for the concept: "(v)alue is the result of an evaluative judgment of the relationship between what someone gets from an object and what they must give to obtain and use it." This suggests value brought by games and simulations to participants is also subject to such principles. Simulation games cannot be treated as a panacea, they must be externally validated, and participants need to make a cognitive connection between the lessons imparted by a simulation and its on-site application (Rybkowski et al. 2018).

Existing Games and Simulations

Game and simulations have proliferated in lean construction since the development of the Parade of Trades™ (Tommelein et al.,1999) and serve as an effective teaching mechanism in both industry and universities (Rybkowski et al. 2018) bringing lean enthusiasts together to continue to advance teaching lean using serious games, e.g., APLSO community (Rybkowski et al. 2021). Simulations related to lean construction have been steadily increasing since 2012. A systematic review of lean simulations published between 1990-2021 identified 96 games distributed amongst 52 papers (Bhatnagar et al. 2023). The review conducted by Bhatnagar et al. (2023) helped identify several papers related to simulations teaching the concepts of Target Value Design (i.e., Munankami 2012, Rybkowski et al., 2016, Devkar et al., 2019, Musa at al.,2019, Jacob et Al., 2021, Ng and Hall 2021, Kim et al. 2023), in addition to other simulations related to the topic (e.g, Alves 2022). Table 1 provides a summary of the simulations identified during the literature review.

The TVd simulations identified in Table 1 use similar processes, however, each has their own unique set of attributes to design and build a product (e.g., a condominium, a tower using marshmallows, a salad plate) considering a target cost set by the owner. The game developed by Ng and Hall (2021) uses different specialties, but it alludes to a kitchen scenario to teach participants about TVd. Except for the Silo Game (Alves 2022), which mimics the work of four design specialties designing a condominium, the simulations in Table 1 do not involve different construction specialties in design or construction.

Table 1: Comparison of TVd Simulations

Authors	Delivery	Process	Participants	Duration	Overview	Unique attributes
Kim et al. (2023)	Virtual	2 rounds	4 per team	50 min	Virtual delivery of the marshmallow game	Virtual simulation and utilization of VR headset for the delivery of the Marshmallow game.
Alves (2022)	In-Person	2 rounds	4 per team	50 min	Design narratives, design costing sheet	Sustainable design elements, real world design system information
Jacob et al. (2021)	Virtual	2 rounds	4-5 per team	90 min	Virtual instruction, tower blocks costing sheets	Geometry and unit cost of building blocks, uses RFI
Ng and Hall (2021)	Virtual	2 rounds	4 per team	na	Commercial Kitchen scenario to make parallels with construction, aim at Digital Fabrication	Design for virtual fabrication, elements of time and profit
Devkar et al. (2019)	In-person	2 rounds	4 per team	na	Design selection of building components using a BIM Model and costing information	BIM, market costs and building program
Munankami (2012)	In person	2 rounds	3-5 per team	50 min or 80 min	Use of readily available material such as spaghetti, marshmallow, straws and others to design and build a tower	Simulate costing, design and construction. Setting Market Cost, allowable cost and target cost

Thus, the simulation presented in this paper aims to fill a gap in the literature reviewed: the unique attribute of the simulation presented in this paper is the contextual information related to the trade contractors and how this information can benefit the team and owner in setting targets and extracting more value out of the process. Moreover, the simulation aims at driving change by adding value to the industry by utilizing a process that promotes the learning of the new paradigms (i.e., use of TVD and early involvement of trades) and to illustrate how it applies to construction projects as suggested by Rybkowski et al. (2021). The tangible incorporation of trade contractors early in the delivery process is still underappreciated, despite the value such participants provide as documented in the literature (e.g., Tommelein and Ballard 1997, Forgues and Koskela, 2008, Tommelein et Ballard. 2016) Yet, the adoption of this practice is slow and practitioners in industry still have difficulty to convey the message that early involvement of trades is important for successful project delivery.

The literature review reveals an interest amongst practitioners and academics in creating games and simulations to illustrate emerging concepts within the Lean Construction literature. Since the development of the TVd game by Munankami (2012), several simulations have been created to help convey the principles of Target Value Design. The development of the new paradigm, originally called Target Costing, became Target Value Design (TVd) for the AEC industry, and continued research on the application of lean concepts is now moving the practice toward Target Value Delivery (TVD). The term Target Value Design is now side-lined as the term presupposes the setting of targets during the design phase only (Ballard, 2020). The gap addressed by the simulation presented in this paper is the development of a simulation that goes beyond the design phase and incorporates participants from all phases of project delivery. This paper is a step in that direction as it shows a simulation that incorporates contractor contextual information in both a traditional delivery process such as Design-Bid-Build and a delivery process that deploys the principles of TVD.

Target Value Delivery Simulation

The simulation is played in teams of 8 or 9 participants in two rounds, depicting a traditional Design-Bid-Build (DBB) process, non-conducive to Target Value Delivery principles and reflective of the practices associated with DBB. The simulation, along with facilitator introductions, explanation of the key principles of Target Value Delivery, and group discussions is best delivered in 2 hours. The room is ideally set up with tables of 8 and the participants need to be made aware they will move tables between round 1 and round 2. The simulation is easily scalable and can be delivered in a workshop with multiple teams. It is recommended to have a facilitator for every 32 participants to ensure timely support of participants within the time allocated.

The TVD simulation was piloted with a small group in the first author's company to establish the workflow and identify major issues related to the instructions and the play. The simulation was then played in a conference with two groups in parallel: a French-speaking group with 48 attendees and an English-speaking group with 64 attendees. The author gathered feedback from participants and fellow facilitators, made some improvements, and presented the simulation one more time to a group made of academics, students, and industry participants. Following each round, there was a team debrief with the facilitators from both groups, the recording of plus/deltas and the study of the simulations data sheets. Additionally, the debrief and discussion includes the sharing of teams' results and how the sheets with information/solutions/recordings were utilized by the participants. Based on information gathered from the groups who performed the simulation, the data sheets, narratives, materials, and workflows were updated to the current form shared in this paper. Finally, the current format of the simulation was tested with a small group to validate the effectiveness of the changes.

Round 1 keeps participants working in silos, whereas Round 2 brings them together to make collaborative and inter-disciplinary decisions. However, the TVD simulation adds more reality to the Silo Game (Alves 2022) and other TVd simulations reviewed (Table 1) by introducing two distinct groups of professionals working on the problem: four design disciplines (which were present in the game) and four contractors in different specialties (which was absent in the Silo Game). Additionally, the TVD simulation adds new elements to represent the values and constraints stated by the owner (Owner's objectives), and elements related to risk and uncertainty (Owner's uncertainty). Details for each of the elements and both rounds are shared in the following sections.

Establishing Owner's objectives

Round 1 starts with the following statement form the owner:

> *You have acquired a piece of property in a mature residential neighborhood in your northern city and you intend to build a multi-key property to satisfy the shortage of rental units in the marketplace. The piece of land is on a gentle slope on a hill, near downtown and the university district. You can see the city skyline above the tree line from the property.*

Round 1 of the simulation requires the participants to have a set of objectives to guide their design selections. The objectives touch on some of the elements important for the owner and are covered in the design solutions but in a very generic and non-decisive way. This language is purposefully unhelpful to illustrate constraints a design team can face in real life and to have little to no impact on the selection amongst the various design solutions, while giving a sense of direction around what needs to be built. Considering the narrative previously shared, the following additional language is shared with participants:

- You have a 1000 Currency budget
- You want to build a minimum 25 rental units
- You are passionate about sustainability
- You want to be a green developer
- You want to be open for tenants in June
- Design to start in the new fiscal year

Owner's uncertainty

Adding more realism to the simulation, several elements of uncertainty are added to the value definition process. Such conditions on projects are used to highlight challenges owners face in the delivery of capital projects. They exist to reinforce the challenges and limitations of traditional project delivery, and the uncertainty owners can face in setting up projects and hiring teams following a traditional method. The following conditions contribute to the narrative by adding both risks and costs to round #1 of the simulation:

- Buildings in the neighborhood have installed solar panels
- You are not sure what you can afford
- You trust your hired team (1, 2, 3, or 4) to make the best design decisions for you
- You were advised to get best market value by using a traditional delivery method
- You were told tender documents would be ready in the fall

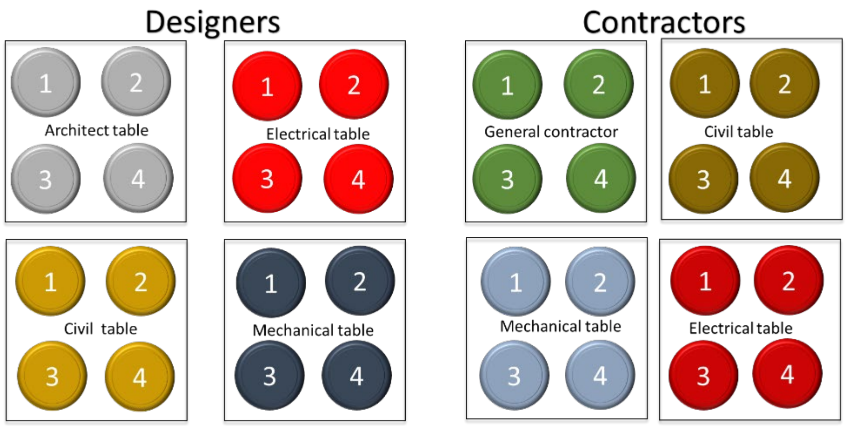


Figure 1: Round 1 Activity 1 Room logistics

Round 1 Traditional Delivery (Design-Bid-Build)

The tables are divided by design and construction disciplines, the designers are on one side of the room and the contractors on the other side of the room (Figure 1). Participants are assigned a set of sheets with their disciplines' information. Round 1 has two distinct and successive activities, the design activity (1) and the estimating activity (2). Specific instructions are given to both designers and contractors ahead of each activity to guide their efforts.

Round 1 Activity 1 - Instructions to Designers

During the design activity, each of the four design disciplines (Architect, Civil, Mechanical, and Electrical) selects one of the five design solutions in a silo. The participants are given 5 minutes to read the design solutions (Figure 2) and select the solution they believe best satisfies the owner's requirements.

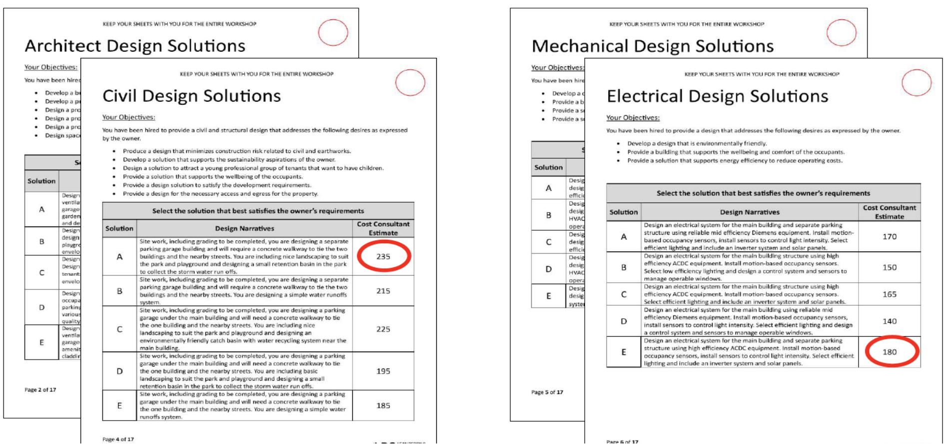


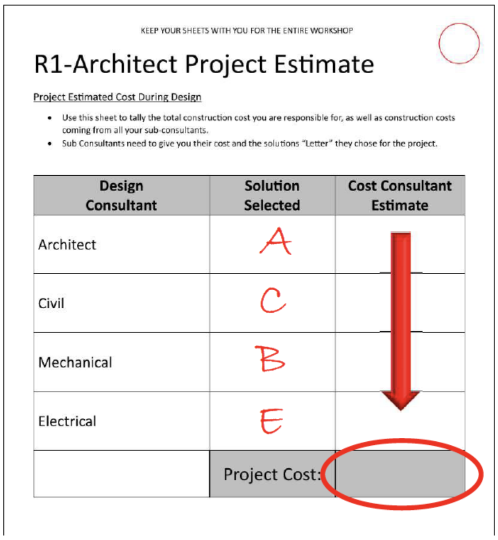
Figure 2: Round 1 Activity #1 Design Solutions

The following instructions are provided to the designers:

1. You are hired to select a solution to maximize your discipline objectives.
2. You will have 5 minutes to select a design solution for your discipline.
3. A cost consultant has given you a "market cost" for each design solution.
4. Other consultants will give their solution and associated estimate to the Architect

5. YOU ARE NOT ALLOWED TO COLLABORATE WITH OTHER TEAMS OR DISCIPLINES.
6. Keep notes of your decision-making process.

By reviewing the sheets with solutions shown in Figure 2, the mechanical, Electrical and Civil designers provide their solution selections and associated cost consultant estimates to the architects. The Architects then adds the project estimate using the information provided by the all the designers using the sheet on Figure #3.


KEEP YOUR SHEETS WITH YOU FOR THE ENTIRE WORKSHOP

R1-Architect Project Estimate

Project Estimated Cost During Design

- Use this sheet to tally the total construction cost you are responsible for, as well as construction costs coming from all your sub-consultants.
- Sub Consultants need to give you their cost and the solutions "Letter" they chose for the project.

Design Consultant	Solution Selected	Cost Consultant Estimate
Architect	A	
Civil	C	
Mechanical	B	
Electrical	E	
	Project Cost:	

Figure 3: Round 1 Activity 1 Architect Project Estimate

The simulation offers five possible alternatives for each of the four disciplines, offering a total of 625 unique combinations. In round 1, each of the solutions has a unique cost given to the designers by a "cost consultant". The distribution of potential project costs emerging out of the "design process" is illustrated in Figure 4. The simulation was played on four occasions and the design cost emerging out of the study groups varied between 985 and 1130, indicating a range of possible outcomes.

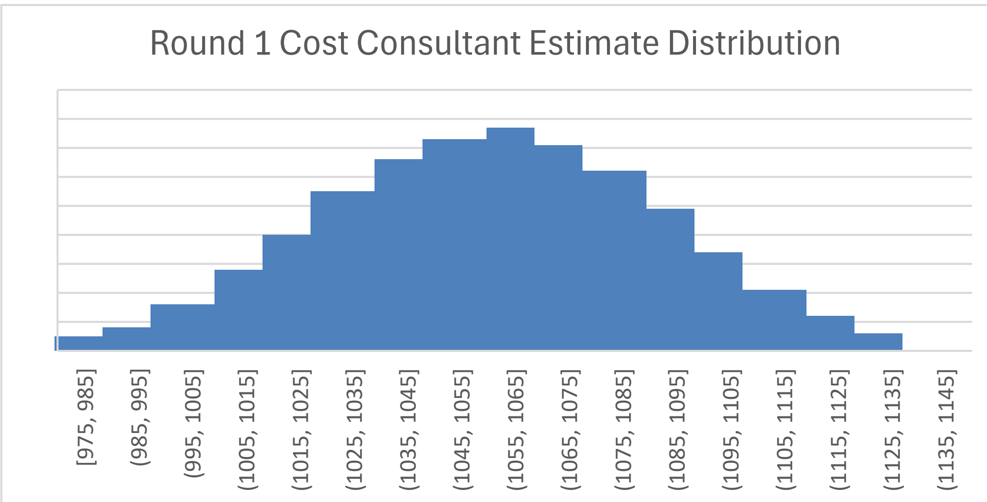


Figure 4: Round 1 Activity 1 Cost Consultant Estimate Distribution (Owner's budget = 1,000)

Round 1 Activity 1 - Instructions to Contractors

While the designers are selecting their solutions, the contractors study the information provided on their sheets in preparation for the estimating activity. The information provided to the contractor includes company specific information, cost for design elements, risks unique to their companies, assumptions, special conditions and associated contingencies. The following instructions are provided to the contractors:

1. Review the potential design solutions you might have to price.
2. Review your unique costs and private company historical data.
3. KEEP YOUR PROPRIETARY INFORMATION CONFIDENTIAL.
4. We are only reviewing design elements and potential risk while we wait.

Round 1 Activity 1 - Group Discussion, Team Design Selection

Once the Designers have selected their solution and provided them to the Architect, a unique project combination will emerge out of each team. The design combination takes the form of a 4 letters string i.e.: (B-A-C-D) as per Figure 3. The facilitator will engage the participants to record the outcome of the "design phase" for the contractors to see. Figure 5 shows the table used to compile the design information. From the test group, we can see the variety of design outcomes were selected, only team 2 and team 3 selected the same design combination. The unique combination identified by each of the teams becomes the basis for the contractors to provide an estimate in Round 1 Activity 2. The architects keep the cost consultant estimate confidential until the contractor estimates are completed after Round 1 activity 2 for comparison and discussion.

	Round 1 Activity #1				Round 1 Activity #2		Round 2	
	Solution Selected (Letters)				Cost Consultant	Contractors Estimate	TVD Outcomes	
	Architect	Civil	Mech	Elec			FTC	Added value
Team 1	A	A	D	A				
Team 2	B	D	D	A				
Team 3	B	D	D	A				
Team 4	A	A	C	A				
Team 5	C	C	D	C				
Team 6	D	D	D	D				
Team 7	A	B	C	C				
Team 8	A	C	D	B				
Team 9	A	E	C	D				
Team 10	A	C	D	A				

Figure 5: Round 1 Discuss design selection - Solutions selected

Round 1 Activity 2 - Instruction to Designers

While the contractors assemble their price, the Designers get together with their team, compare the solutions they selected and are encouraged to reflect on the outcome or their individual selections:

1. Did you optimize the project for the owner?
2. Are there any problems with your design?
3. Did you miss anything?

Round 1 Activity 2 - Instructions to Contractors

During this activity, the contractors work independently with the design narrative that emerged for their team in Round 1 activity 1. The participants establish a price for their scope of work. The Contractors use their unique sets of instructions (Figure 6) to identify the elemental costs associated with the design solution established and to determine the appropriate risk, additional costs and contingency related to the solution selected. Once completed, the general contractor assembles the project estimate for the contractor team (Figure 7).

The contractors are given the following instructions:

1. You have 15 minutes to assemble the project price as it was designed.
2. Your team is to price the design combination for your team on the board.
3. Each discipline must match the design solution to your price sheet.
4. Make sure you capture all the RISK that applies to your design!
5. You can only share your cost estimate with the General Contractor.
6. YOU ARE NOT ALLOWED TO COLLABORATE WITH EACH OTHER!

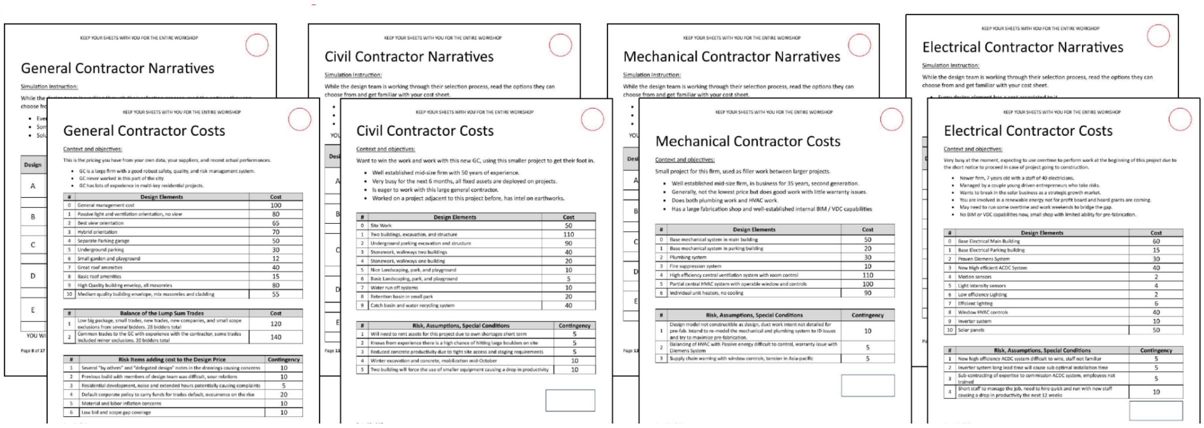


Figure 6: Round 1 Activity #2 Instructions to Constructors

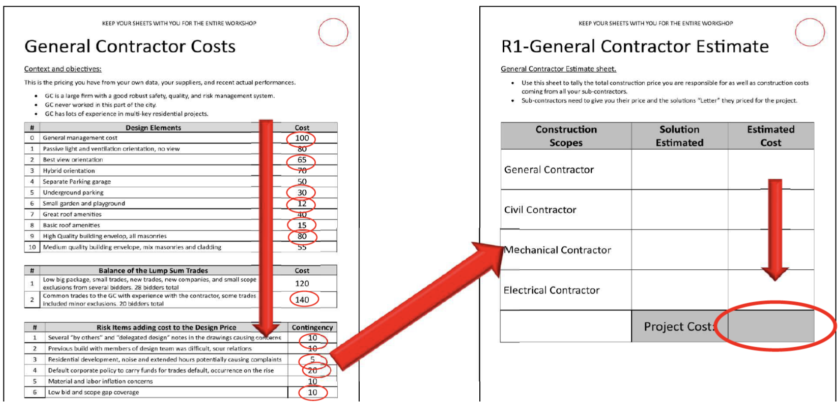


Figure 7: Round 1 Activity #2 General Contractor Estimated Cost

Once completed, the civil, mechanical and electrical contractors give their estimated solution and estimated cost to the general contractor who determines the project cost. (Figure 7) The workshop facilitator monitors the teams to ensure the assignment is complete before proceeding to a group discussion with all participants.

Round 1 – Group Discussion, Design and Contractor Pricing

To conclude round 1, the facilitator records the cost consultants and contractor estimates for comparison (Figure 8). During the debrief, the estimates are compared with the owner's budget and amongst each other. A facilitated discussion and group reflection is facilitated to assimilate learnings and make parallels with real life situations, why is this over budget? Where does the discrepancy come from? Does it meet the client's goals?, etc. Questions asked during the discussion can include:

- Why did we all select different combinations?
- Which is the lowest price?
- Why do we have such a variation in project costs?
- What is the degree of risk integration in the solutions?
- Which option provides the best value for the owner?
- What have you learned?

	Round 1 Activity #1				Round 1 Activity #2		Round 2	
	Solution Selected (Letters)				Cost	Contractors	TVD Outcomes	
	Architect	Civil	Mech	Elec	Consultant	Estimate	FTC	Added value
Team 1	A	A	D	A	1125	1269		
Team 2	B	D	D	A	1055	1072		
Team 3	B	D	D	A	1055	1425		
Team 4	A	A	C	A	1130	1159		
Team 5	C	C	D	C	1070	1070		
Team 6	D	D	D	D	1035	1214		
Team 7	A	B	C	C	1105	1222		
Team 8	A	C	D	B	1095	1509		
Team 9	A	E	C	D	1050	1174		
Team 10	A	C	D	A	1115	1144		

Figure 8: Round 1 Activity #2 - Estimates Comparison

There are 625 potential combinations of pre-established solutions that can be selected by teams in Round 1. The test runs showed a mixture of selection from project teams, demonstrating how each of the design narratives can appeal to different people with different backgrounds. The distribution of outcomes from the cost consultant estimates positions the outcome of Round 1 above the owner's budget 97% of the time (Figure 4). The contractor estimates can fluctuate based on participants scope omissions, calculation errors, risk tolerance and assumptions. As an example, despite estimating the same design solution, team 2 and team 3 (Figure 8) contractor's estimates were respectively 1072 and 1425, providing an opportunity to further discuss the challenges and variation experienced in industry with such siloed practices. Despite such fluctuation, all contractor estimates remained above the owner's budget in the test simulation. Such an outcome is desired for the simulation to establish a direct comparison between paradigms (Kuhn 1962) and to facilitate learning (Rybkowski et al. 2018) The utilization of a simplified but realistic process, with contextual information obtained from the first author's experience as an industry practitioner, and the addition of real-life challenges faced by construction teams, is intended to make the simulation connect with real construction projects to promote learning. (Rybkowski et al. 2021).

Round 2 Target Value Delivery

For participants to make a direct comparison between the two paradigms and experience the principles of Target Value Delivery, Round 2 brings the teams together from the beginning. The team made of Owner, Designers and Contractors is given a 30-minute introduction to the key principles of Target Value Delivery.

Round 2 - Team organization

For Round 2 teams are reorganized by table, where all disciplines from both the designers and contractors are represented in each of the groups. (Figure 9).

Figure 9: Round 2 - Integrated teams using TVD – Room logistics

Round 2 – Target Value Delivery Concepts

The concepts reviewed are the following:

- Early engagement of all key parties - Engaging key project parties, those who can help the team protect the project value proposition, ahead of critical design decisions to include their knowledge and expertise in assessing and improving decision making.
- Creating Alignment - Conditions of Satisfaction & Values - Establishing a dialog to ensure the owner's requirements are clearly understood by the key parties, questions and answers can be tabled, assumptions can be understood by all involved and project conditions of satisfactions (CoS) (i.e., conditions defined by the owner and the team to meet the project's goals, and known by project participants) and key drivers are understood by all.
- Collaboration, Integration & Synergies - True collaboration implies people's ideas and points of views are flexible and can be challenged by the parties. This involves bringing the parties' knowledge, expertise and available company assets, constraints, lessons learned and ideas to find how those can be combined to identify synergies that can enhance value delivery.
- Early risk evaluation - Each of the project parties have their own lenses in evaluating risk based on their own historical project experiences and contextual information regarding the project. Discussing those early, ahead of design work, enhances design conversations, establishes boundaries that can guide the parties to reach a better outcome sooner.
- Constructability as an input to design - The traditional process typically assigns means and methods to the constructors and removes such practices from design work. Opportunities for productivity improvement exist within contractor means and methods, such opportunities need to be evaluated and introduced in design work as a mechanism to enhance value.
- Design to a budget using a cost model approach - Starting design work with a financial model for each of the systems can help guide key decisions early in the design phase. Additionally, this practice can guide the team in determining where

efforts need to be placed to resolve financial conflicts between the project values and the cost of delivering such values.

Next, the facilitators clarify the owner's conditions of satisfaction, the base program, and list some added value items the owner wishes to add in case the team manages to innovate and find sufficient cost savings to add scopes under the allowable cost.

Round 2 - Clarification of Owner's Requirements

The owner's conditions of satisfaction provided are the following:

- Project cost under 1000 currency units
- Want to build a minimum 25 rental suites
- Meets owner's project objectives
- Be a good neighbor: no after-hours work
- Early procurement is allowed if design trends low
- Delivery of all suites in June
- Low operating cost

The base program provided must include the following:

- One building; 25 suites
- Solar ready building
- Motion sensors, central HVAC system
- Basic rooftop amenities

Added value Items:

- Extra suites = 30 currency units extra each
- Great rooftop amenities = 25 currency unit extra
- Playground = 8 currency units
- Solar panels = 50 currency units
- Garden = 4 currency units

Round 2 - Instructions to Project Teams

After the TVD principles are reviewed alongside the conditions of satisfaction and the base program, the teams are not constrained to select a predetermined solution as required in round 1. Participants are invited to select individual elements from each of the technical disciplines to satisfy the owner's objectives. The teams are invited to share their risk and find ways to mitigate risks and add more value to the project. The teams are given an early cost model to start their conversation (Figure 10). Additionally, the teams are challenged to include added value items and asked to keep the list of items that they will be able to include in the project during the round 2 facilitated debrief.

Participants are given the following instructions to proceed with their work in round 2:

1. You will be given 20 minutes to complete your design work
2. Start with the target cost of 1000 currency units
3. Collaborate to meet owner's value and CoS
4. Your table is your team's colocation space
5. Develop your solution with input from all team members
6. Ensure contractors' information is used as input to design

7. Refine your cost with working estimates
8. Define your Final Target Cost (FTC)
9. Identify all added value your team can deliver

KEEP YOUR SHEETS WITH YOU FOR THE ENTIRE WORKSHOP

TVD - Team Cost Modeling

Team Tally Sheet, Final Target Cost.

- Use this sheet to tally the total construction cost you are responsible for as a team.
- The initial cost model comes from historical data adapted to location and current market conditions.
- The team is to collaborate to negotiate tradeoffs and build final target cost and select design elements from the sheet provided before
- The team cannot exceed the allowable cost of 1000 "dollar."

Construction Scopes	Base Target Cost	Team Working Estimate		Final Target Cost	Added Value Items
General Contractor	440				
Civil	190				
Mechanical	200				
Electrical	130				
Contingency	40				
Total:	1000				

Figure 10: Round 2 - Team Cost Modelling

Round 2 - Review and Discussion

At the end of round 2, participants will share their results using the form shown in Figure 11 and answer the questions posed next to it. At the end of the discussion, participants will be asked:

- What did you learn from this simulation?
- What are some key takeaways from this exercise?

	Round 1 Activity #1				Round 1 Activity #2		Round 2	
	Solution Selected (Letters)				Cost Consultant Estimate	Contractors Estimate	TVD Outcomes	
	Architect	Civil	Mech	Elec			FTC	Added value
Team 1	A	A	D	A	1125	1269	985	Playground
Team 2	B	D	D	A	1055	1072	1003	Playground & Panels
Team 3	B	D	D	A	1055	1425	997	Playground
Team 4	A	A	C	A	1130	1159	984	Playground
Team 5	C	C	D	C	1070	1070	987	Playground
Team 6	D	D	D	D	1035	1214	994	N/A
Team 7	A	B	C	C	1105	1222	980	Extra suite and Playground
Team 8	A	C	D	B	1095	1509	944	N/A
Team 9	A	E	C	D	1050	1174	947	N/A
Team 10	A	C	D	A	1115	1144	980	N/A

Figure 11: Round 2 - Review of Team Performance: Table and Guidelines

Round 2 - Experienced Outcomes of Round #2

Figure 11 illustrates the outcome of the simulation from two of the test groups. Through round 2, most of the teams were able to steer the project under the final target cost (1,000) while maintaining the owner's conditions of satisfaction. Some of the teams added value items, and the decisions made by the teams and their resulting project cost varied depending on the context and the conversations inside each group. Given that each of the groups was given the same data, the simulation illustrated the groups' capacities to work toward a target while making contextual decisions inherent to each of the teams' dynamics.

Participants Feedback: Plus & Delta

A plus/delta was conducted at the end of every simulation. Table 2 outlines the plus/delta results relevant to the simulation material. Please note that the comments are mostly related to the mechanics of the simulation. However, as indicated in the literature reviewed, the comments in Table 1, the simulation contributed to learning, demonstrated the difference between the traditional and TVD paradigm (i.e., costs went down from round 1 to round 2), and addressed the gap in the literature by including contractors. It is worth noting that Plus/Delta comments are usually recorded in an aggregated format and do not reflect the number of participants in the groups who played the simulation.

Table 2: Plus/Delta from Target Value Delivery Simulation

Plus	Delta	Δ Addressed
Great engagement	Some solution chosen more often	Narrative edited
Pushes learning	Confusing at first, slow down explanation ahead of round 1	
Good time management	Include owner's role and build owner sheet in the team in round 2	Use odd number or facilitator
Travels well	Leave client requirement on the screen in round 2	Fix slides
Working with a buddy in round 1	Sheet given to GC/Architect Hard to get back. Keep for both rounds.	
People saw cost come down and could clearly articulate why	Sheets organization pre workshop	Print collated number manually
Includes the contractors	Long bid period for designers, simplify bid sheets for contractors	Sheet reworked using actual artifacts from facilitated workshop
Data recording worked well		
Easily scalable		

Using the feedback gathered in Table 2, the plus/deltas gathered from the initial simulation runs, a subsequent workshop was conducted, and a questionnaire was given to the participants. Participants included a mixture of university professors, graduate students, and industry practitioners. 32 were in attendance and 24 responses were received. The questions used and related responses to the questionnaire are depicted in Table 3.

Table 3: Questionnaire, Target Value Delivery Simulation

Questions	Rating: Strongly disagree	disagree	Neutral	Agree	Strongly agree
The simulation was interesting and stimulated my desire to learn more about target value delivery.	1	2	3	4	5
The simulation illustrates the value of integrating contractors in the project process to leverage Target Value Delivery.	1	2	3	4	5
The simulation illustrated the key principles of target value delivery.	1	2	3	4	5
The simulation is conducive to be used in university and colleges to support student learning about Target Value Delivery.	1	2	3	4	5
The simulation helped me make a direct connection with my work and challenges I face in industry.	1	2	3	4	5
I learned something new during the Target Value Delivery Simulation	1	2	3	4	5
I could use the simulation in my work to explain Target Value Delivery to my colleague.	1	2	3	4	5
The simulation shows how Target Value Delivery must be initiated before the design phase and must continue after design.	1	2	3	4	5
The simulation was easy to understand and well organized.	1	2	3	4	5
Overall, the Target Value Delivery simulation offers value not currently offered by other games and simulation available.	1	2	3	4	5

Questions	RESULTS: 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Average
The simulation was interesting and stimulated my desire to learn more about target value delivery.	5	5	4	4	5	5	5	5	5	5	4	5	5	4	3	5	5	5	5	5	5	5	4	5	4.71
The simulation illustrates the value of integrating contractors in the project process to leverage Target Value Delivery.	5	4	4	5	5	5	5	5	5	5	5	5	5	5	4	5	5	3	5	4	4	5	5	4	4.67
The simulation illustrated the key principles of target value delivery.	5	5	5	5	4	5	5	5	5	5	5	5	5	4	3	5	4	4	5	4	4	5	4	4	4.58
The simulation is conducive to be used in university and colleges to support student learning about Target Value Delivery.	5	3	4	5	5	5	5	5	5	5	4	5	5	5	3	5	3	4	5	5	5	5	4	4	4.54
The simulation helped me make a direct connection with my work and challenges I face in industry.	5	5	4	5	3	3	5	5	5	5	4	5	5	3	3	5	5	4	5	5	5	5	4	5	4.50
I learned something new during the Target Value Delivery Simulation	5	4	4	4	4	5	5	5	5	5	5	5	4	4	4	4	5	4	4	4	4	5	4	4	4.42
I could use the simulation in my work to explain Target Value Delivery to my colleague.	5	4	4	3	5	5	5	5	5	3	4	5	4	4	3	3	4	4	5	5	4	5	4	5	4.29
The simulation shows how Target Value Delivery must be initiated before the design phase and must continue after design.	5	3	4	5	3	5	4	5	5	5	2	4	4	5	4	5	5	4	5	3	3	5	3	5	4.21
The simulation was easy to understand and well organized.	4	4	5	5	5	5	5	5	5	5	4	5	5	3	3	4	2	5	4	4	3	5	2	3	4.17
Overall, the Target Value Delivery simulation offers value not currently offered by other games and simulation available.	3	3	4	3	4	5	5	5	5	5	3	5	3	3	3	5	4	3	4	3	5	5	4	2	3.92

The feedback offered to the facilitators by participants was generally positive, the simulation was delivered in both university conferences and industry conferences with similar results. The simulation as presented is easy to organize and facilitate. The simulation was delivered to groups of 16, 24, 48 and 64 participants. Similar results and feedback were experienced in all sessions.

Limitations and Future Research

The paper highlighted confusion in both academic and industry literature related to the use of interchangeable language and specifically acronyms to define what have been determined as two separate concepts, Target Value Design and Target Value Delivery. The authors recommend a better definition of terminologies in future publications and recommends the use of a differentiator when using acronyms: such as TVd for Target Value Design and TVD for Target Value Delivery.

Target Value Design (Macomber et al. 2007) and Target Value Delivery (Lean Construction Institute 2016) have both emerged out of industry practitioners. A literature review of the IGLC database illustrated 50 papers referencing Target Value Design and 10 referencing Target Value Delivery. Future research and publication on Target Value Delivery is recommended to document current practice and strengthen the understanding of the TVD and its related practices. The authors also concur with Ballard's (2020) statement indicating that Target Value Design should be "rejected because it suggests that steering to targets only occurs in design." (Ballard 2020) Such suggestion should be either debated or reinforced by the research community and industry participants.

The simulation was meant to be a first step in bridging the gap between design and delivery. The Target Value Delivery Simulation introduced the benefit of incorporating contractors to the process to go beyond both Target Value Design (TVd) and Integrated Design Practice (IDP). While the simulation remains related to the design phase of the project, further development is needed to include the construction phase and the notion of target production. Future simulations could be developed by adding other TVD elements such as operations, decommissioning, and the establishment of value attributes by user groups.

The definition of value early in the project remains a challenge to be addressed (Miron et al, 2015, Remila,2022). The simulation is contextualized in the private sector and starts with a set of pre-identified values, base program, and conditions of satisfaction. Future simulations could be developed to help the value definition phase of the project.

The simulation presented in this paper is intended to be more realistic with the intention to help participants make a cognitive connection with industry conditions. The simulation is built on the Silo Game by adding construction participants and elements of contextual irreducible uncertainties and other external conditions. Such contextualization was made for northern climate construction and could lose some effectiveness when delivered in a different climate context. Researchers and instructors are encouraged to evaluate, adapt and improve the information contained in the simulation to maximize value for the audience and context where it is delivered.

Conclusions

The Target Value Delivery simulation was created to illustrate the key principles of Target Value Delivery in a simulated setting that mimics practice to a realistic extent including the collaborative work of designers and trade partners during the design phase. The simulation is based on the Silo Game (Alves 2022). The Silo Game established the framework for this simulation and facilitation characteristics that enabled the creation of the Target Value Delivery simulation. The simulation added realistic contextual elements adding construction participants and elements of contextual irreducible uncertainties and other external conditions experienced by contractors. The simulation illustrates the benefits of Target Value Delivery, and the contribution made by the contractors in the process. This simulation demonstrates how TVD can benefit stakeholders by enabling teams to increase the density of value delivered, within the limitations and CoS, by eliminating waste hidden in the traditional delivery process. This new simulation is easy to deploy, simple to scale, and relatable by participants throughout the built environment.

References

Alves, T. C. L., Lichtig, W., and Rybkowski, Z.C., (2017). “Implementing Target Value Design: Tools and Techniques to Manage the Process”, *Health Environments Research & Design Journal* 2017, Vol. 10(3) 18-29

Alves, T. C. L. (2022). "The Silo Game: A Simulation on Interdisciplinary Collaboration." *Proceedings of the 30th Annual Conference of the International Group for Lean Construction (IGLC-30)*, 1052-1063.

Ballard, G., Reiser, P. (2004). "The St. Olaf College Fieldhouse Project: A Case Study in Designing to Target Cost." *Proceedings of the 12th Annual Conference of the International Group for Lean Construction (IGLC12)*. 9pp.

Ballard, G. (2006). Rethinking Project Definition in Terms of Target Costing,14th Annual Conference of the International Group for Lean Construction, 77-89.

Ballard, G. (2009). *"An update on Target Value Design”* Design Forum Presentation, June 18-19 2009, St.Louis, MO

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

Ballard, G. (2012). "Target Value Design". *International Design Conference – Design 2012, Dubrovnik – Croatia, May 21- 24, 2012* pp 11-22

Ballard, G. (2020). "Target Value Delivery." In: Lean Construction: Core Concepts and New Frontiers, Routledge, 148

Ballard, G. (2024). “Target Value Delivery of Building Projects”. LCI Ireland Webinar Presentation, Project Production Systems Laboratory, University of California, Berkeley. May 23, 2024

Bhatnagar, S., Jacob, G., Devkar, G., Rybkowski, Z. K., Arefazar, Y., and Obulam, R. (2022). “A systematic review of lean simulation games in the construction industry.” *Architectural Engineering and Design Management*, 19:6, 701-719.

Devkar, G., Trivedi, J., and Pandit, D. (2019). “Teaching Target Value Design: Learnings and Challenges.” *Proceedings of the 27th Annual Conference of the International Group for Lean Construction (IGLC27)*, 479-490.

Drevland, F. and Lohne, J. (2015). "Nine Tenets on the Nature of Value." *Proceedings of the 23rd Annual Conference of the International Group for Lean Construction (IGLC23)*, 475-485.

Drevland, F. and Lohne, J. (2023). "Untangling the concepts of value and values.” *Proceedings of the 31st Annual Conference of the International Group for Lean Construction (IGLC31)*, 572–583.

Forges, D and Koskela, L (2008) The influence of procurement on performance of integrated design and construction, Building, Abroad, Montreal P.245-257

Jacob,G.,Sharma,N.,Rybkowski,Z.K.,& Devkar,G.(2021).”Target value design: Development and testing of a virtual simulation.” *Proceedings of the 29th Annual Conference of the International Group for Lean Construction (IGLC29)*, Lima, Peru. http://iglc.net/Papers/Details/1884

Khun, T. (1962). *The structure of scientific revolutions*. The University of Chicago Press, Chicago IL. 4th edition P. 77-91

Kim, S., Rybkowski, Z. K. & Jeong, H. D. (2023). “Developing and testing computer- and virtual reality-based target value design simulations.” *Proceedings of the 31st Annual Conference of the International Group for Lean Construction (IGLC31)*, 629–638.

Knudstrup, M. (2004). Integrated Design Process in PBL. In: The Aalborg PBL Model, red. Annette Kolmoes, Flemming K. Fink, and Lone Krogh. Aalborg University Press 2004. Denmark.

Koskela, L. (1992) *Application of the New Production Philosophy to Construction*. Stanford University, CIFE, Technical Report # 72, 87 pp.

Koskela, L. (2000) *An Exploration Towards a Production Theory and its Application to Construction*. Ph.D. Dissertation, VTT Publications 408. VTT: Espoo, Finland, 296 pp.

Larsson, N. (2002), The Integrated Design Process: Report on a National Workshop held in Toronto in October 2001, Natural Resources Canada: Ottawa. p. 7.

Lean Construction Institute (2016). *“Target Value Delivery – Practitioner Guidebook to Implementation Current State 2016”,* Arlington, VA

Macomber, H., Howell, G., and Barberio, J. (2007). *Target Value Design: Nine foundational practices for delivery surprising client value*. Lean Project Consulting, Louisville, CO1-2.

Malvik, T.O., Kalsaas, B.T., Shabani, R., and Sandvik, K.O. (2021). “The Impact of BVP in a TVD Based Project Delivery” *Proceedings of the 29th Annual Conference of the International Group for Lean Construction (IGLC29)*, Alarcon, L.F. and González, V.A. (eds.), Lima, Peru, pp. 23–32, doi.org/10.24928/2021/0162, online at iglc.net.

Mintzberg, H. (2019). *Bedtime Stories for Managers: Farewell to Lofty Leadership. . . Welcome Engaging Management*. Berrett-Koehler Publishers, Business & Economics, 200 pp, ISBN 1523098791, 9781523098798

Miron, L.I.G., Kaushik, A. and Koskela, L. (2015). “Target Value Design: The Challenge of Value Generation.” Proceedings of the *Annual Conference of the International Group* *for Lean Construction (IGLC23)*. Perth, Australia, July 29-31, pp. 815-825, available at www.iglc.net

Munankami, M. B. (2012). *Development and testing of a simulation (game) to illustrated basic principles of Integrated Project Delivery and Target Value Design: A First Run Study*, Graduate Thesis, Texas A&M University, College Station, TX.

Musa, M., Pasquire, C., and Hurst, A. (2019). "Using TVD Simulation to Improve Collaboration." *Proceedings of the 27th Annual Conference of the International. Group for Lean Construction (IGLC27)*, Pasquire C. and Hamzeh F.R. (ed.), Dublin, Ireland, pp. 503-514. DOI: https://doi.org/10.24928/2019/0268 Available at: <www.iglc.net>.

Narum, K. B. , Engebø, A. , Lædre, O. & Torp, and O. (2022). "Collaborative Project Delivery With Early Contractor Involvement and Target Cost." *Proceedings of the 30th Annual Conference of the International Group for Lean Construction (IGLC30)* , 984 995. doi.org/10.24928/2022/0208

Ng, M. S., and Hall, D. M. (2021). "Teaching target value design for digital fabrication in an online game: Overview and case study." *Proceedings of the 29th Annual Conference of the International Group for Lean Construction (IGLC29)*, Lima, Peru. http://iglc.net/Papers/Details/1850

Ohno, T. (1988). *Toyota Production System: beyond Large-Scale Production*. Productivity Press: Cambridge, Mass. 142pp.

Pennanen, A. , Ballard, G. & Haahtela, Y. 2010. "Designing to Targets in a Target Costing Process", *Proceedings of the 18th Annual Conference of the International Group for Lean Construction (IGLC18)*, 161-170.

Remila, K. (2022). *La demanche participative du project Dow: Une etude de cas*. These de Maitrise, Ecole de Technologie Superieure, Montreal, Canada

Rybkowski, Z. K., Alves, T.C.L., and Liu, M. (2021). "The emergence and growth of the on-line serious games and participatory simulation group 'APLSO'." *Proceedings of the 29th Annual Conference of the International Group for Lean Construction (IGLC29)*, Lima, Peru, July 12-18, 10 pp.

Rybkowski, Z. K., and Forbes, L. H. (2016). Lean construction. In R. Rumane (Ed.), Handbook of construction management: Scope, schedule, cost, control. CRC Press. doi:10.1201/9781315373522

Rybkowski, Z. K., Forbes, L. H., and Tsao, C. Y. (2018). "The evolution of lean construction education (Part 1 of 2): At US-based universities," *Proceedings of the 26 th Annual Conference of the International. Group for Lean Construction (IGLC26)*, González, V.A. (ed.), Chennai, India, pp. 1013–1023.

Rybkowski, Z. K., Munankami, M., Shepley, M. M., and Fernández-Solis, J. L. (2016). "Development and testing of a lean simulation to illustrate key principles of Target Value Design: A first run study." *Proceedings of the 24th Ann. Conf. of the Int'l. Group for Lean Construction*, Boston, MA, USA, sect.4 pp. 133-142. Available at: <www.iglc.net>.

Smith, A. (1776). *An Inquiry into the Nature and Causes of the Wealth of Nations*.

Taylor, F (1911,1939,1947). *Scientific Management*. Harper & Brothers, London, UK. 3rd edition.

Tommelein, I.D. and Ballard, G. (1997). *Coordinating Specialists*.Technical ReportNo.97-8, Construction Engineering and Management Program, Civil andEnvironmental Engineering Department, University of California, Berkeley, CA. 11p.

Tommelein, I. D., Riley, D. R., Howell, G. A. (1999). "Parade game: Impact of work flow variability on trade performance." Journal of Construction Engineering and Management 125(5): 304-310.

Tommelein, I.D. and Ballard, G.(2016). *Target Value Design: Introduction, Framework, and Current Benchmark* (Report). Project Production Systems Laboratory, University of California: Berkeley, CA, USA.

Appendix - Instructions and Forms used for the Principles of Target Value Deliver Simulation

(BLANK TVD Workshop Handouts: updated July 30 2024)

R1-Owner Requirements

GIVE THIS SHEET TO THE ARCHITECTS OR USE AN "OWNER PLAYER"

Project narrative

You acquired a lot in a mature residential neighborhood in your northern city and you want to build a multi-key building to satisfy the shortage of rental units in the marketplace.

The is slopped on a hill near downtown and the university district. You can see the city skyline from the lot above the tree line.

Project Scope

- You have a 1000 Currency budget.
- You want to build a minimum of 25 rental units.
- You are passionate about sustainability, at the right price.
- You want to be recognized as a progressive green developer.
- You want it to be open for tenants in June, 2 years from now.
- You start design work in January, using funds from your new fiscal year.

Owners' concerns and uncertainties

- Other buildings in the neighborhood have already installed solar panels.
- You are not sure what you can afford for your maximum 1000 currency budget.
- You have requested a budget from a cost consultant to get an ROI on design pricing.
- You trust your design team to make the best decisions for your business case.
- You believe in Traditional Delivery to leverage market despair and competition.
- The tender documents should be ready by October to procure your contractors.

Architect Design Solutions

Your Design Objectives:

You are hired to provide a design that addresses the following desires as expressed by the owner.

- Develop a building that blends in the space and surroundings.
- Develop a project that attract young professionals desiring to have children.
- Design a project that supports the wellbeing of the occupants.
- Design a project that supports the sustainability aspirations of the owner.
- Design a project that supports the esthetics needs of the clients and is appreciated by the neighbors.
- Design spaces and amenities that will make the building competitive in the marketplace.

Select the solution that best satisfies the owner's requirements		
Solution	**Design Narratives**	**Cost Consultant Estimate**
A	Design a building that is oriented to maximize the use of passive light and ventilation with a limited view of the city skyline. Design a separate parking garage building to maximize the use of solar panels. Include a design for a small garden and playground. Design various high quality rooftop amenities for tenants and design a high-quality building envelope with bricks on all sides.	510
B	Design a building oriented to give the occupants the best city skyline views, design an underground parking space. Include the design for a small garden and playground. Design high quality roof top amenities and a mid-quality building envelope with a mix of bricks and aluminum cladding.	480
C	Design a building oriented to give the occupants the best city skyline views. Design an underground parking space. Design basic quality rooftop amenities for tenants to use since you give them great views and design a high-quality building envelope with bricks on all sides.	470
D	Design a building that is oriented to get a partial view of the city skyline to the occupants and get limited passive lights and ventilation. Design an underground parking space. Include the design for a small garden and playground. Design various high quality rooftop amenities for tenants to use and design a high-quality building envelope with bricks on all sides.	500
E	Design a building that is oriented to maximize the use of passive light and ventilation with a limited view of the city skyline. Design a separate parking garage building to maximize the use of solar panels. Design basic roof top amenities and a mid-quality building envelope with a mix of bricks and aluminum cladding.	460

R1-Architect Project Estimate

Project Estimated Cost During Design

- Use this sheet to tally the total estimated construction cost as supported by the cost consultants.
- Obtain the Solution "Letter" retained by your sub consultants.
- Write their Cost Consultant Estimate and tally the total for the project.

Design Consultant	Solution Selected (A-B-C-D-E)	Cost Consultant Estimate
Architect		
Civil		
Mechanical		
Electrical		
	Architect Estimated Cost:	

Civil Design Solutions

Your Design Objectives:

You have been hired to provide a civil and structural design that addresses the following desires as expressed by the owner.

- Produce a design that minimizes construction risk related to civil and earthworks.
- Develop a solution that supports the sustainability aspirations of the owner.
- Design a solution that attract a young professional with desire to have children.
- Provide a design solution that supports the wellbeing of the occupants.
- Provide a design solution to satisfy the development requirements.
- Provide a design for the necessary access and egress for the property.

Select the solution that best satisfies the owner's requirements		
Solution	**Design Narratives**	**Cost Consultant Estimate**
A	Site work, including grading to be completed, you are designing a separate parking garage building and will require a concrete walkway to tie the two buildings and the nearby streets. You are including nice landscaping to suit the park and playground and designing a small retention basin in the park to collect the storm water run offs.	225
B	Site work, including grading to be completed, you are designing a separate parking garage building and will require a concrete walkway to tie the two buildings and the nearby streets. You are designing a simple water runoffs system.	195
C	Site work, including grading to be completed, you are designing a parking garage under the main building and will need a concrete walkway to tie the one building and the nearby streets. You are including nice landscaping to suit the park and playground and designing an environmentally friendly catch basin with water recycling system near the main building.	225
D	Site work, including grading to be completed, you are designing a parking garage under the main building and will need a concrete walkway to tie the one building and the nearby streets. You are including basic landscaping to suit the park and playground and designing a small retention basin in the park to collect the storm water run offs.	210
E	Site work, including grading to be completed, you are designing a parking garage under the main building and will need a concrete walkway to tie the one building and the nearby streets. You are designing a simple water runoffs system.	185

Mechanical Design Solutions

Your Design Objectives:

You have been hired to provide a design that addresses the following desires as expressed by the owner.

- Develop a design that is environmentally friendly.
- Provide a building that supports the wellbeing and comfort of the occupants.
- Provide a solution that optimizes operating costs.
- Provide a solution that optimizes maintenance cost.

Select the solution that best satisfies the owner's requirements		
Solution	**Design Narratives**	**Cost Consultant Estimate**
A	Design a mech system for a main building and separate parking building, design a plumbing system and a fire suppression system. Include a high efficiency HVAC system with individual room controls.	220
B	Design a mech system for a main building with underground parking, design a plumbing system and a fire suppression system. Include a partial HVAC system with controls per suites and sensors for the operable windows to maximize the use of sun light and wind breeze.	200
C	Design a mech system for a main building with underground parking, design a plumbing system and a fire suppression system. Include a high efficiency HVAC system with individual room controls.	215
D	Design a mech system for a main building and separate parking building, design a plumbing system and a fire suppression system. Include a partial HVAC system with controls per suites and a controls system for the operable windows.	210
E	Design a mech system for a main building with underground parking, design a plumbing system and a fire suppression system. Design a heating system with individual unit heaters with no cooling.	190

Electrical Design Solutions

Your Design Objectives:

You have been hired to provide a design that addresses the following desires as expressed by the owner.

- Develop a design that is environmentally friendly.
- Provide a building that supports the wellbeing and comfort of the occupants.
- Provide a solution that supports energy efficiency.
- Provide a solution that is cheap to maintain and reduces other operating costs.

Select the solution that best satisfies the owner's requirements		
Solution	**Design Narratives**	**Cost Consultant Estimate**
A	Design an electrical system for the main building and separate parking structure using reliable mid efficiency Diemens equipment. Install motion-based occupancy sensors, install sensors to control light intensity. Select efficient lighting and include an inverter system and solar panels.	160
B	Design an electrical system for the main building structure using high efficiency ACDC equipment. Install motion-based occupancy sensors. Select low efficiency lighting and design a control system and sensors to manage operable windows.	150
C	Design an electrical system for the main building structure using high efficiency ACDC equipment. Install motion-based occupancy sensors. Select efficient lighting and include an inverter system and solar panels.	170
D	Design an electrical system for the main building using reliable mid efficiency Diemens equipment. Install motion-based occupancy sensors, install sensors to control light intensity. Select efficient lighting and design a control system and sensors to manage operable windows.	145
E	Design an electrical system for the main building and separate parking structure using high efficiency ACDC equipment. Install motion-based occupancy sensors, install sensors to control light intensity. Select efficient lighting and include an inverter system and solar panels.	175

General Contractor Costs

Context and objectives:

This is the costs you have from your own private data, your own suppliers, and historical performances.

- The General Contractor is a large firm with a good robust safety, quality, and risk management system.
- The General Contractor has never worked in this part of the city.
- The General Contractor has experience with multi-key residential projects.

#	Design Elements	Cost
0	General management cost	100
1	Passive light and ventilation orientation, no view	80
2	Best view orientation	65
3	Hybrid orientation	70
4	Separate Parking garage	50
5	Underground parking	30
6	Small garden and playground	12
7	Great roof amenities	40
8	Basic roof amenities	15
9	High Quality building envelop, all masonries	80
10	Medium quality building envelope, mix masonries and cladding	55

#	Balance of the Lump Sum Trades	Cost
1	Low big package, small trades, new trades, new companies, and small scope exclusions from several bidders. 28 bidders total	120
2	Common trades to the GC with experience with the contractor, some trades included minor exclusions. 20 bidders total	140

#	Risk Items adding cost to the Project	Contingency
1	Several “by others” and “delegated design” notes in the drawings causing concerns	10
2	Previous build with members of design team was difficult, sour relations	10
3	Residential development, noise and extended hours potentially causing complaints	5
4	Default corporate policy to carry funds for trades default, occurrence on the rise	20
5	Material and labor inflation concerns	10
6	Low bid and scope gap coverage	10

General Contractor Narratives

Simulation Instructions:

While the design team is working through their selection process, read the design narratives they have available for selection and familiarize yourself with your cost sheet.

- Every design element in the narrative has a cost associated to it.
- Some narratives have more design elements than others.
- Solutions may require different contingencies.

YOU WILL KNOW WHICH SOLUTION TO ESTIMATE AFTER THE FACILITATOR DESIGN REVIEW

Design	Design Narratives							
A	Estimate a building that is oriented to maximize the use of passive light and ventilation with a limited view of the city skyline. Estimate a separate parking garage building to maximize the use of solar panels. Include an estimate for a small garden and playground. Estimate various high quality rooftop amenities for tenants and estimate a high-quality building envelope with bricks on all sides							
B	Estimate a building oriented to give the occupants the best city skyline views, Estimate an underground parking space. Include the Estimate for a small garden and playground. Estimate high quality roof top amenities and a mid-quality building envelope with a mix of bricks and aluminum cladding.							
C	Estimate a building oriented to give the occupants the best city skyline views. Estimate an underground parking space. Estimate basic quality rooftop amenities for tenants to use since you give them great views and estimate a high-quality building envelope with bricks on all sides.							
D	Estimate a building that is oriented to get a partial view of the city skyline to the occupants and get limited passive lights and ventilation. Estimate an underground parking space. Include the estimate for a small garden and playground. Estimate various high quality rooftop amenities for tenants to use and estimate a high-quality building envelope with bricks on all sides							
E	Estimate a building that is oriented to maximize the use of passive light and ventilation with a limited view of the city skyline. Estimate a separate parking garage building to maximize the use of solar panels. Estimate basic roof top amenities and a mid-quality building envelope with a mix of bricks and aluminum cladding.							

R1-General Contractor Estimate

General Contractor Estimate sheet.

- Use this sheet to tally the total construction price you are responsible for as well as construction costs coming from all your sub-contractors.
- Sub-contractors need to give you their price and the solutions “Letter” they priced for the project.

Construction Scope	Solution Estimated (A, B, C, D or E)	Estimated Cost
General Contractor		
Civil Contractor		
Mechanical Contractor		
Electrical Contractor		
	Construction Estimate:	

Civil Contractor Costs

Context and objectives:

You want to win and work with this GC, using this smaller project to start working with them.

- You are a well-established mid-size firm with 50 years of experience.
- You are very busy for the next 6 months; all your fixed assets are deployed on projects.
- You are eager to work with this new large general contractor.
- You have worked on a project adjacent to this site before.
- You have a good understanding of the local ground conditions.

#	Design Elements	Cost
0	Site Work	50
1	Two buildings, excavation, and structure	110
2	Underground parking excavation and structure	90
3	Stonework, walkways two buildings	40
4	Stonework, walkways one building	20
5	Nice Landscaping, park, and playground	10
6	Basic Landscaping, park, and playground	5
7	Water run off systems	10
8	Retention basin in small park	20
9	Catch basin and water recycling system	40

#	Risk, Assumptions, Special Conditions	Contingency
1	Will need to rent assets for this project due to own shortages short term	5
2	Knows from experience there is a high chance of hitting large boulders on site	5
3	Reduced concrete productivity due to tight site access and staging requirements	5
4	Winter excavation and concrete, mobilization mid-October	10
5	Two building will force the use of smaller equipment causing a drop in productivity	10

Civil Contractor Narratives

<u>Simulation Instructions:</u>

While the design team is working through their selection process, read the design narratives they have available for selection and familiarize yourself with your cost sheet.

- Every design element in the narrative has a cost associated to it.
- Some narratives have more design elements than others.
- Solutions may require different contingencies.

YOU WILL KNOW WHICH SOLUTION TO ESTIMATE AFTER THE FACILITATOR DESIGN REVIEW

<table>
<tr><th>Design</th><th colspan="8">Design Narratives</th></tr>
<tr><td>A</td><td colspan="8">Estimate site work, including grading to be completed, you are estimating a separate parking garage building and will require a concrete walkway to tie the two buildings and the nearby streets. You are including nice landscaping to suit the park and playground and estimating a small retention basin in the park to collect the storm water run offs.</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>B</td><td colspan="8">Estimate site work, including grading to be completed, you are estimating a separate parking garage building and will require a concrete walkway to tie the two buildings and the nearby streets. You are estimating a simple water runoffs system.</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>C</td><td colspan="8">Estimate site work, including grading to be completed, you are estimating a parking garage under the main building and will need a concrete walkway to tie the one building and the nearby streets. You are including nice landscaping to suit the park and playground and estimating an environmentally friendly catch basin with water recycling system near the main building.</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>D</td><td colspan="8">Estimate site work, including grading to be completed, you are estimating a parking garage under the main building and will need a concrete walkway to tie the one building and the nearby streets. You are including basic landscaping to suit the park and playground and estimating a small retention basin in the park to collect the storm water run offs.</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>E</td><td colspan="8">Estimate site work, including grading to be completed, you are estimating a parking garage under the main building and will need a concrete walkway to tie the one building and the nearby streets. You are estimating a simple water runoffs system.</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Mechanical Contractor Costs

Context and objectives:

This is a small project for this firm, used as filler work between other larger projects.

- You are a well-established mid-size firm, in business for 35 years, second generation.
- You are not the lowest price but do good work with little warranty issues.
- Your firm does both plumbing, ventilation scopes of work.
- You have a large fabrication shop and well-established BIM / VDC capabilities.

#	Design Elements	Cost
0	Base mechanical system in main building	50
1	Base mechanical system in parking building	20
2	Plumbing system	30
3	Fire suppression system	10
4	High efficiency central ventilation system with room control	110
5	Partial central HVAC system with operable window and controls	100
6	Individual unit heaters, no cooling	90

#	Risk, Assumptions, Special Conditions	Contingency
1	Design model not constructible as design, duct work intent not detailed for pre-fabrication. You will need to re-model the mechanical and plumbing system to identify issues and try to maximize pre-fabrication.	10
2	Balancing of HVAC with Passive energy difficult to control, warranty issue with Diemens System	5
3	Supply chain warning with window controls, tension in Asia-pacific	5

Mechanical Contractor Narratives

<u>Simulation Instruction:</u>

While the design team is working through their selection process, read the design narratives they have available for selection and familiarize yourself with your cost sheet.

- Every design element in the narrative has a cost associated to it.
- Some narratives have more design elements than others.
- Solutions may require different contingencies.

YOU WILL KNOW WHICH SOLUTION TO ESTIMATE AFTER THE FACILITATOR DESIGN REVIEW

Design	Design Narratives							
A	Estimate a mech system for a main building and separate parking building, Estimate a plumbing system and a fire suppression system. Include a high efficiency HVAC system with individual room controls.							
B	Estimate a mech system for a main building and separate parking building, Estimate a plumbing system and a fire suppression system. Include a partial HVAC system with controls per suites and a controls system for the operable windows.							
C	Estimate a mech system for a main building with underground parking, Estimate a plumbing system and a fire suppression system. Include a high efficiency HVAC system with individual room controls.							
D	Estimate a mech system for a main building with underground parking, Estimate a plumbing system and a fire suppression system. Include a partial HVAC system with controls per suites and a controls system for the operable windows to maximize the use of light and breeze.							
E	Estimate a mech system for a main building with underground parking, Estimate a plumbing system and a fire suppression system. Estimate a heating system with individual unit heaters with no cooling.							

Electrical Contractor Costs

<u>Context and objectives:</u>

You are very busy in the field now, you will need to work overtime to perform the project at the beginning, in part due to the short notice to proceed to construction upon award.

- You are a newer firm, seven years old with a staff of 40 electricians.
- You and your business partner are a couple young and driven entrepreneurs who take risks.
- You want to establish your company the solar business as a strategic growth market.
- You are involved in a renewable energy not for profit board and heard grants are coming.
- You will need to work overtime at night and weekends to solve your labor shortage issue.
- You have no BIM or VDC capabilities and have a small shop with limited ability for pre-fabrication.

#	Design Elements	Cost
0	Base Electrical main building	60
1	Base Electrical parking building	15
2	Proven Diemens System	30
3	New high efficiency ACDC System	40
4	Motion sensors	2
5	Light intensity sensors	4
6	Low efficiency Lighting	2
7	Efficient lighting	6
8	Window HVAC controls	40
9	Inverter system	10
10	Solar panels	50

#	Risk, Assumptions, Special Conditions	Contingency
1	New high efficiency ACDC system difficult to install, staff not familiar	5
2	Inverter system long lead time will cause sub optimal installation time	5
3	Sub-contracting of expertise to commission ACDC system, employees not trained	5
4	Short staff to manage the job, need to hire quickly and operate with new staff causing a drop in productivity for the first 12 weeks	10

Electrical Contractor Narratives

<u>Simulation Instructions:</u>

While the design team is working through their selection process, read the design narratives they have available for selection and familiarize yourself with your cost sheet.

- Every design element in the narrative has a cost associated to it.
- Some narratives have more design elements than others.
- Solutions may require different contingencies.

YOU WILL KNOW WHICH SOLUTION TO ESTIMATE AFTER THE FACILITATOR DESIGN REVIEW

Design	Design Narratives							
A	Estimate an electrical system for the main building and separate parking structure using reliable mid efficiency Diemens equipment. Install motion-based occupancy sensors, install sensors to control light intensity. Select efficient lighting and include an inverter system and solar panels.							
B	Estimate an electrical system for the main building structure using high efficiency ACDC equipment. Install motion-based occupancy sensors. Select low efficiency lighting and estimate a control system and sensors to manage operable windows.							
C	Estimate an electrical system for the main building structure using high efficiency ACDC equipment. Install motion-based occupancy sensors. Select efficient lighting and include an inverter system and solar panels.							
D	Estimate an electrical system for the main building using reliable mid efficiency Diemens equipment. Install motion-based occupancy sensors, install sensors to control light intensity. Select efficient lighting and estimate a control system and sensors to manage operable windows.							
E	Estimate an electrical system for the main building and separate parking structure using high efficiency ACDC equipment. Install motion-based occupancy sensors, install sensors to control light intensity. Select efficient lighting and include an inverter system and solar panels.							

TVD- Owner Requirements & CoS

GIVE THIS SHEET TO THE TEAM OR USE AN "OWNER PLAYER"

Project narrative

You acquired a lot in a mature residential neighborhood in your northern city and you intend to build a multi-key building to satisfy the shortage of rental units in the marketplace.

The land is on a gentle slope on a hill, near downtown and the university district. You can see the city skyline from the lot above the tree line.

Your Team Conditions of Satisfaction

- The cost model has been set to 1000 currency units from the allowable cost.
- The team needs to build a minimum of 25 rental suites.
- The team needs to be a good neighbor, no after hour work has been promised.
- The team can do early procurement if the design base program is under the cost model.
- The delivery of all suites must be in June two years from now.
- The team needs to minimize the building operating cost.
- The team needs to collaborate, REALLY collaborate, to innovate!

BASE PROGRAM	ADDED VALUE INCENTIVE ITEMS
One building, 25 suites	Extra suites, 30 currency each
Electrical System solar ready, inverter in	Great rooftop amenities 20 currency
Central HVAC with motion sensors	Playground 8 currency
Basic rooftop amenities	Solar panels 50 currency
	Garden 4 currency

COLLABORATE WITH THE OWNER

AS YOU HAVE A NEED FOR DECISIONS TO BE MADE

TVD - Team Cost Modeling

Team Working Sheet, Final Target Cost.

- Use this sheet to tally the total construction cost you are responsible for as a team.
- The initial cost model comes from historical data adjusted for location and current market conditions.
- The team is to collaborate to negotiate tradeoffs in the selection of design elements.
- The design elements are to be selected individually from the sheet provided in your cost sheets.
- The team cannot exceed the established cost model of 1000 "currency."
- The team needs to establish the project Final Target Cost by discipline.
- The team needs to establish the Added Value Items it can include in the base program, if any.

Construction Scope	Cost Model	Team Continuous Estimating			Final Target Cost	Added Value Items
General Contractor	440					
Civil	190					
Mechanical	200					
Electrical	130					
Contingency	40					
Total:	1000					

TVD - Team Design Elements

<u>Team Working Sheet, Design Elements Selection</u>

- Use this sheet to write down the design elements you have retained to build your program.
- Identify the Added Value Items you will integrate in the Base Program before Final Target Cost.

Design Elements Selected by the Team	Discipline	Cost