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DISSEMINATION OF TARGET VALUE DESIGN PRINCIPLES THROUGH A BRIDGE CONSTRUCTION ONLINE SIMULATION: OVERVIEW AND CASE STUDY

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ABSTRACT

This paper aims to qualitatively investigate the impact of Target Value Design (TVD) principles within academic and professional spheres through the creation and evaluation of an innovative and interactive serious game. A novel online TVD simulation was designed and tested, challenging participants to construct a bridge while balancing constraints related to cost, aesthetics, and quality. The bridge format of this TVD game resolved the "gravity challenge" experienced by past TVD simulations that required constructing a tower. The simulation aims to mirror real-world decision-making under TVD guidelines. The findings reveal that participants applying TVD principles were able to identify a market-based cost for the bridge and subsequently reduce project costs by 11% to 34% to meet the owner's target cost. These results underscore the effectiveness of the game in testing and conveying key TVD principles. This study seeks to expand the reach of TVD principles, which are now becoming integral to the practice of lean construction. The accessible online format offers a valuable learning tool for emerging construction science professionals, enabling them to grasp TVD concepts in an engaging and practical manner.

KEYWORDS:

Target Value Design; Online lean simulation, Gaming Pedagogy, Construction

INTRODUCTION

Lean construction principles, originally conceptualized within the Toyota Production System, focus on minimizing waste, improving workflow efficiency, and maximizing value in processes (Koskela 1992). Over the years, these principles have evolved into a transformative approach in the Owner, Architecture, Engineering, and Construction (OAEC) industry, delivering tangible results when applied effectively (Ballard and Howell 2002). Among the key lean techniques is Target Value Design (TVD)—a robust method that aims to build at a target cost with pre-agreed profit margin by all stakeholders (Zimina et al. 2012). Unlike traditional value engineering, TVD goes beyond cost control by fostering collaborative alignment between

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design and construction teams to meet financial objectives while achieving high-quality outcomes (Rybkowski et al. 2016). This alignment not only ensures financial feasibility but also integrates core lean concepts such as continuous improvement, respect for stakeholders, and efficient flow of tasks—elements crucial for optimizing construction processes. TVD exemplifies these principles by embedding the client's budget into design decisions from the outset of a project, allowing for a seamless blend of cost management and quality delivery (Miron et al. 2015). To facilitate a broader understanding of TVD, particularly among individuals new to lean principles, the authors of this paper developed and tested an interactive, user-friendly, online simulation game.

A number of researchers have designed and tested TVD simulations in both physical and online formats. For example, Munankami (2012) and Rybkowski et al. (2016) developed a two-round TVD simulation that requires participating teams to construct 2-ft. (61 cm.) tall, free-standing, table-top towers comprising drinking straws, dry spaghetti, bamboo skewers, coffee stirrers, and masking tape, that can support a single marshmallow that are no more than 2-in. (51 mm.) out-of-plumb. During Round One, participants are unaware of the cost of each item—and the total cost per tower—until they are required to report the number of each item used, which is entered into a master spreadsheet, and projected onto a wall for all to see. Teams are then challenged to redesign their towers in Round Two, at a 20% reduced cost per tower. The intent of the simulation is to impress upon OAEC[6] stakeholders the importance of fulfilling an Owner's defined *Conditions of Satisfaction* (CoS) (as proposed by Lean Construction Institute) at a price point that makes business sense for the Owner (in this case, 15% below market cost).

Additional TVD simulations include a two-dimensional digital tower by Jacob et al. (2021), a digital salad by Ng and Hall (2021), both of which can be played remotely via Zoom™, and two, three-dimensional Unity™-based simulations by Kim et al. (2023) that use the same elements as the physical marshmallow tower simulation, but that virtually mimic the pull of gravity. Digital and virtual simulations became especially popular during COVID-19 when social distancing requirements meant training needed to be handled remotely. That said, even though the TVD tower simulations by Kim et al. (2023) mimic gravity, the simulations' use of the gaming software Unity also increased its complexity among participants who may be less comfortable using keyboards and Virtual Reality (VR) headsets to lift, rotate, and place virtual objects onto a virtual tabletop.

This research resolves one of the challenges of the above-mentioned TVD games. The game challenges participants to construct a bridge under realistic cost and quality constraints, offering a practical introduction to TVD concepts. It offers the relatability of constructing a structure appropriate for OAEC professionals, but as it requires players to construct a bridge that must span a chasm rather than build a tower, successfully covering the necessary distance becomes intuitively obvious. Gravity simulation is no longer required, so a simplified two-dimensional format that can be easily played via Zoom is sufficient.

This paper is structured into five sections. Following this introduction, the second section explores the background of existing TVD-based simulations. The third section provides an overview of the game developed by the authors, while the fourth section details the game's instructions. The paper concludes with a discussion of post-game observations, results, and conclusions drawn from the simulation.

BACKGROUND OF LEAN-TVD BASED SIMULATIONS

Target Value Design (TVD) has emerged as a pivotal framework in lean construction, facilitating cost-effective and resource-conscious decision-making throughout project phases.

[6] OAEC is used to refer to Owner, Architect, Engineer, and Contractor, where the Owner is listed first to remind stakeholders that their needs take priority.

As highlighted by Howell and Ballard (1998), the approach encourages early-stage collaboration among stakeholders, fostering alignment on financial, quality and long-term value generation objectives. Unlike traditional value engineering practices, TVD principles not only address cost control but also strongly emphasize *Conditions of Satisfaction*, culture of respect, innovation and quality control, as underscored by Abdelhamid and Salem (2005). The authors advocate for TVD as a driver of innovative thinking in the Architecture, Engineering, and Construction (AEC) industry, particularly when integrated with simulation-based learning to mimic real-world challenges. This approach actively engages participants, empowering them as decision-makers tasked with balancing costs alongside essential project requirements.

Simulation games have emerged as highly effective educational tools for teaching lean principles, offering controlled environments—whether online, face-to-face, or in virtual reality—where participants can experience real-world decision-making, explore both traditional and lean methodologies, and directly compare their outcomes. Hamzeh et al. (2017) demonstrated the potential of these tools in academic settings, where hands-on activities enhance students' understanding of production variability and lean principles. At least 122 researchers have developed and tested the efficacy of simulation games for lean construction stakeholders and project management students as demonstrated by an in-depth systematic literature review chronicling 52 papers from over 15 countries on simulation games for lean construction (Bhatnagar et al. 2023).

While simulation games offer significant educational value, challenges remain in achieving the right balance between simplicity and depth. Bashir et al. (2015) identified financial, educational, governmental, and technical barriers, with educational challenges being particularly significant in the adoption of lean principles. Badurdeen et al. (2010) reviewed existing lean-based games and identified critical gaps, including insufficient emphasis on soft skills, a flawed focus on linear lean, and a lack of realism. These findings underscore the importance of designing games that are not only engaging but also accurately reflect real-world complexities. Overly simplified games risk failing to convey the full scope of TVD principles (Bashir et al., 2015). On the other hand, Sarhan and Fox (2013) emphasized that the lack of practical experience, awareness and knowledge among professionals hinders lean adoption. Supporting these endeavours, digital technologies, such as virtual reality, offer opportunities to enhance the realism and accessibility of these games, as noted by Kim et al. (2023). Online and VR platforms can provide immersive experiences that replicate the complexities of large-scale projects.

Simulations tailored to construction projects, such as those focused on structural builds, add an extra layer of complexity. By incorporating elements such as material cost constraints, structural quality, and safety standards, simulations can align closely with real-world scenarios. Jacob et al. (2021), Ng and Hall (2021), and Kim et al. (2023) demonstrated the effectiveness of TVD principles through an online TVD simulation game, where participants gained a deeper understanding of budget constraints and decision-making. This supports the primary objective of TVD: controlling costs early in the design process to prevent costly revisions later.

The TVD-based bridge construction simulation presented in this paper contributes to the growing body of knowledge on online TVD simulations, serving as a valuable tool for advancing the dissemination of Lean principles in the AEC industry. Desmarais and Alves (2024) developed a simulation game to emphasize the importance of creating an integrated delivery process where TVD now stands for Target Value *Delivery* (versus Target Value Design). This modified version of TVD addresses a fuller process that is beyond the scope of this paper.

GAME OVERVIEW

This research explored the application of Target Value Design (TVD) principles in a collaborative and interactive game format designed to disseminate lean construction practices. The game involved teams comprising of three participants, each assuming one of the three critical roles, namely: Owner, Designer, and Contractor. The primary objective for each team was to construct a bridge 47 m long over a water body (see Figure 1) that satisfied the Owner's criteria of cost, stability, and aesthetics.

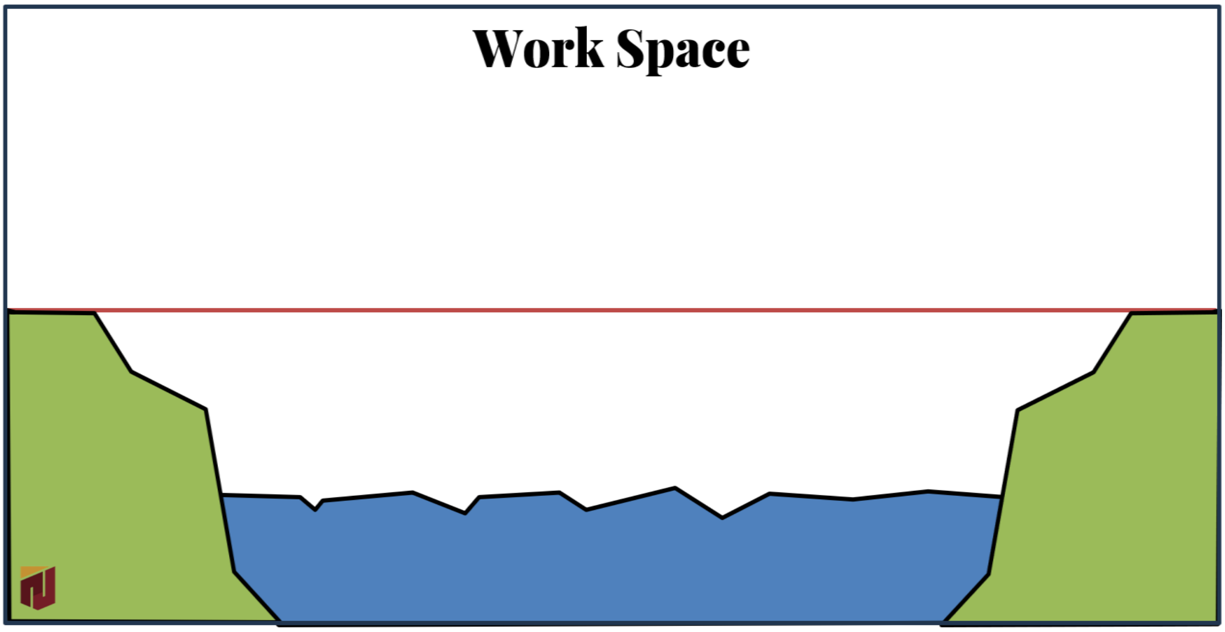


Figure 1: The workspace provided to game participants, where they are tasked with constructing a bridge over the red line, representing the bridge deck.

The game emphasized the practical implementation of TVD principles by requiring participants to balance design constraints, resource management, and cost optimization. The participants in the game were a mix of teaching and industry professionals, such as academics from leading universities, lean practitioners, lean coach, and researcher scholars. Round 1 was played in the non-TVD way (mimicking Design-bid-build model) and Round 2 in the TVD way. In Round 1, the participants played the game unaware of the cost of the components. At the end of Round 1, as an intervention, teams were exposed to the cost of the components that allowed them to tabulate the cost of construction of the bridge. Using TVD principles, market cost and allowable cost were then established. Subsequently, Teams set their target cost and in Round 2, designed to the set Target cost, optimizing the design strategically to meet the clients' requirement of cost, stability and aesthetics. Details of each round is further explained below.

GAME INSTRUCTIONS AND ROUNDS

In **Round 1**, Teams comprising of the owner, designer and the contractor were provided with a workspace as in Figure 1 and a resource sheet containing various structural components of the bridge, including trusses of different types, piers (for use over river area), side piers (for use on green ground area), connectors, and a bridge deck as in Figure 2. These truss elements and others had to be strategically assembled to create a stable bridge structure while avoiding visible voids between various structural components. To ensure stability, all truss (single, two, three, four and/or reduced type) connections were required to rest on a pier support. Lower support truss was necessary only when a four-truss type was used in the valley region. This could however be avoided if the four-truss type rested partially on the abutments. Additionally, the teams were provided with a single reduced-sized two-truss element, which could be used once, to meet the desired length. Modifications to the sizes of structural members were not allowed with the exception of support piers, to maintain the integrity of the design constraints.

In this round, participants were required to mimic conventional design-bid-build contract type and therefore the communication among team members was allowed only through Zoom chat box. A standardized communication framework was implemented to ensure clarity and accountability such as through Request for Information ‘RFI’. For instance, an "RFI_Designer to Client (Team: X)" and "RFI_Contractor to Designer (Team: X)" was used for requests and responses. This controlled communication environment mirrored real-world scenarios in the traditional Design-Bid-Build projects where formal documentation of exchanges is critical. In the first non-TVD round, the design phase necessitated that the Designer draft a bridge model based on the Client’s predefined criteria as specified in the drawings and project Specification Book. Designers also required a formal approval from the Client before handing it over to the Contractor and the commencement of the construction phase, ensuring alignment with the Client’s expectations regarding stability and aesthetics. Structural stability was a key requirement during Round 1.

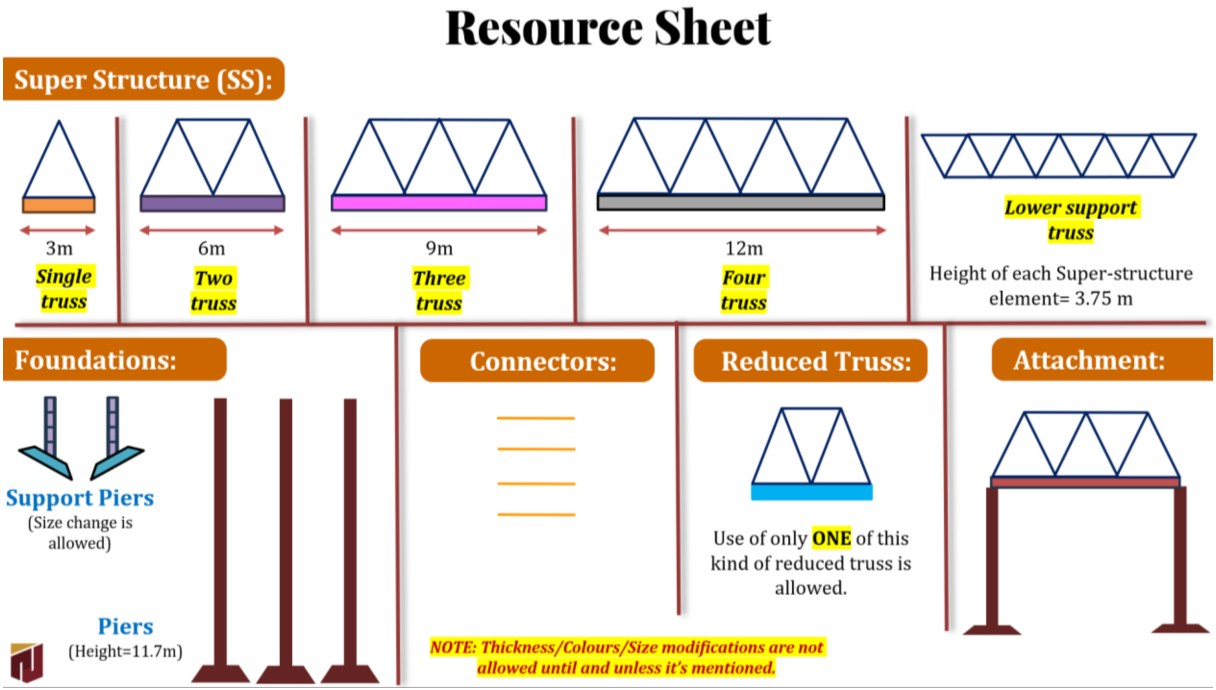


Figure 2: Various Components of the Bridge.

Adding to the complexity, it was envisaged that the client dealt with overproduction concerns by requiring the participating teams to select and implement one of three options such as either the use of a minimum of four single truss types or five piers, or six connectors. Teams were sent to breakout rooms and given 20 minutes to play the first round and build a bridge.

After constructing the bridge, teams assembled in the common zoom space. They were then shared with component cost. Teams calculated the total cost of the structure using component costs (Refer to Figure 3 for bridge component costs) and added a 10% profit margin to the cost of construction, all of which were computed on the shared excel template as shown in Figure 4. Upon completion of Round 1, each team declared their total cost and the host computed the average market cost and allowable cost with a reduction of 15% from the market cost. This allowed Teams to establish and set a target cost for Round 2.

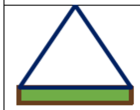
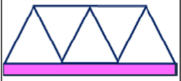
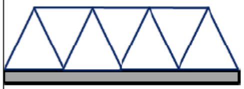
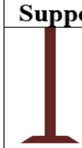
Item	Unit Cost ($ Million)	No. of quantity used	Total	Item	Unit Cost ($ Million)	No. of quantity used	Total
 Single Truss	15			 Two Truss	20		
 Three Truss	30			 Four Truss	35		
 Support Pier	25			 Lower Support Truss	15		
 Bottom Pier	30				5		

Figure 3: Cost of Various bridge components

Team No:

Round-1

Item	Unit Cost ($ Million)	Length	No. of Quantity Used	Total
Single	15	3		0
Two	20	6		0
Three	30	9		0
Four	35	12		0
Lower Support Truss	15			0
Support Piers	25			0
Piers	30			0
Connectors	5			0
Reduced- 2 Truss	22	5		0
Total Length		0		
Total Cost Before Profit				0
Profit @ 10%				0
Total Cost After Profit				0

Round-2

Item	Unit Cost ($ Million)	Length	No. of Quantity Used	Total
Single	15	3		0
Two	20	6		0
Three	30	9		0
Four	35	12		0
Lower Support Truss	15			0
Support Piers	25			0
Piers	30			0
Connectors	5			0
Reduced- 2 Truss	22	5		0
Total length		0		
Total Cost Before Profit				0
Profit @ 10%				0
Total Cost After Profit				0

Analysis Table

Parameter	Cost	Comments
Market Cost (Round: 1)		
Allowable Cost (15% Reduction)		
Allowable Cost (20% Reduction)		
Target Cost		
Difference of 2 rounds ($ Million)		
Achieved difference in %		

Figure 4: Automated cost calculation Excel sheet for Round 1 and Round 2

Round 2 introduced greater flexibility in communication, allowing open microphone discussions to promote dynamic interaction and collaborative problem-solving. Teams were again sent to breakout rooms. Participants engaged in structured discussions for a minimum of five minutes, focusing on refining their strategies based on the outcomes of the first round. Each team declared a target cost for their bridge, which was 15–20% lower than the average total cost calculated in Round 1 by all teams. This emphasis on cost reduction reflected the core principles of Target Value Design. In constructing the bridge during Round 2, participants aimed to meet or surpass their declared target cost while maintaining compliance with the stability and aesthetic requirements outlined in the first round and also by integrating lessons learnt in Round 1.

Teams were again given 20 minutes to re-build the bridge to their set target cost. Yet another workspace for Round 2 was shared with the participants. Communication was open and teams designed in a collaborative manner. Upon completion of the task, teams computed the cost of the re-built bridge. The cost calculation process remained consistent, with the excel sheet (Refer Figure 4) ensuring accuracy and uniformity in evaluating financial performance. On assembling back in the common zoom space, each team declared their cost to the host, who then computed each of the teams cost reduction and effectiveness achieved in Round 2 in comparison to the cost achieved in Round 1 and declared the overall team results on the excel sheet. Through these iterative rounds, participants demonstrated their ability to integrate cost optimization, resource management, and collaborative design within a TVD project. Teams were then allowed time to reflect on the game and share their feedback as plus delta.

POST SIMULATION DISCUSSION AND RESULTS

This game was tested with participants from the United States, India, Brazil, New Zealand, France, England, and Germany, using the On-Line Serious Games and Participatory Simulation Group platform, APLSO, which was originally introduced by Rybkowski et al. (2016) during the COVID-19 pandemic. Four teams participated, each consisting of three members: an owner, a designer, and a contractor. In the first round of the simulation, which simulated traditional construction practices, the average Market Cost (MC) for completing the bridge across all four teams was $474.7 million (Refer to Table 1).

Table 1: Results from Gameplay in APLSO (in $M).

S.No	Parameter	Team: 1	Team: 2	Team: 3	Team: 4
1	Market Cost (MC, **Round: 1**)	486.2	464.2	467.5	480.7
2	Average MC		**474.7**		
3	20% Reduction	388.96	371.4	374.0	384.6
4	Average Reduction		379.7		
5	Allowable Cost (15% cost reduction)	413.3	394.6	397.4	408.6
6	Average AC		**403.5**		
7	Target Cost (TC)	413.3	394.6	397.4	408.6
8	Average TC		403.5		
9	Cost Achieved (Round: 2)	321.2	321.2	414.7	321.2
10	Average Cost Achieved		**344.6**		
11	% Difference in Cost Reduction	**33.9**	**30.8**	**11.3**	**33.2**
12	Average Cost Reduction		**27.3%**		

In the second round, participants applied the TVD framework, which required a minimum 15% reduction from the MC to establish the Allowable Cost (AC). This effort brought the average AC across all teams down to $403.45 million, with the reduction contingent upon meeting the structural and aesthetic requirements outlined in the game overview. Team-specific outcomes showed that Team 1 achieved the greatest cost reduction, lowering their project cost from $486.2 million to $321.2 million, a reduction of 33.9%. Team 4 closely followed with a 33.2% reduction, lowering their cost from $480.7 million to $321.2 million, and Team 2 achieved a 30.8% reduction, reducing costs from $464.2 million to $321.2 million. These teams attributed their success to open communication during the bridge component selection phase, enabling effective collaboration while adhering to all specified requirements. Conversely, Team 3 managed only a 11.3% reduction, decreasing their cost from $467.5 million to $414.7 million. This fell short of the 15% target and was attributed to misalignment among stakeholders and less effective collaboration.

Table 2: Comparison Between Market Costs in Round 1 and Achieved Costs in Round 2.

Team	Market Cost (Round 1, $M)	Allowable Cost (15% Reduction, $M)	Achieved Cost (Round 2, $M)	Cost Reduction (%)
Team 1	486.2	413.3	321.2	33.9
Team 2	464.2	394.6	321.2	30.8
Team 3	467.5	397.4	414.7	11.3
Team 4	480.7	408.6	321.2	33.2

The results highlighted in Table 2 signifies that teams emphasizing open communication and collaboration between the owner, designer, and contractor consistently exceeded expectations, achieving cost reductions well beyond the 15% target. Teams 1, 2, and 4 demonstrated the significant potential of the TVD framework when robust stakeholder alignment was achieved. In contrast, Team 3's underperformance emphasized the critical role of collaboration and shared understanding in realizing the full benefits of lean construction practices. These findings reinforce the importance of cohesive decision-making and effective stakeholder engagement in achieving substantial cost efficiencies in construction projects.

Figure 5 presents the bridges constructed by all four teams during Round 1 and Round 2 of the game. The bridges in the Round 2 column demonstrate significant aesthetic improvements and appear structurally stable, reflecting the focus on maintaining design quality despite cost reductions. This is possibly due to the learning curve in Round 1 and the introduced intervention of the cost component making the construction of the bridge not only aesthetically appealing and stable but also economically feasible. Notably, Team 1, which achieved an impressive 33.9% cost reduction in Round 2, showcases a visually apparent optimization in their bridge design. This alignment of reduced costs with structural and aesthetic integrity underscores the effectiveness of collaborative efforts and the TVD framework in delivering high-value outcomes.

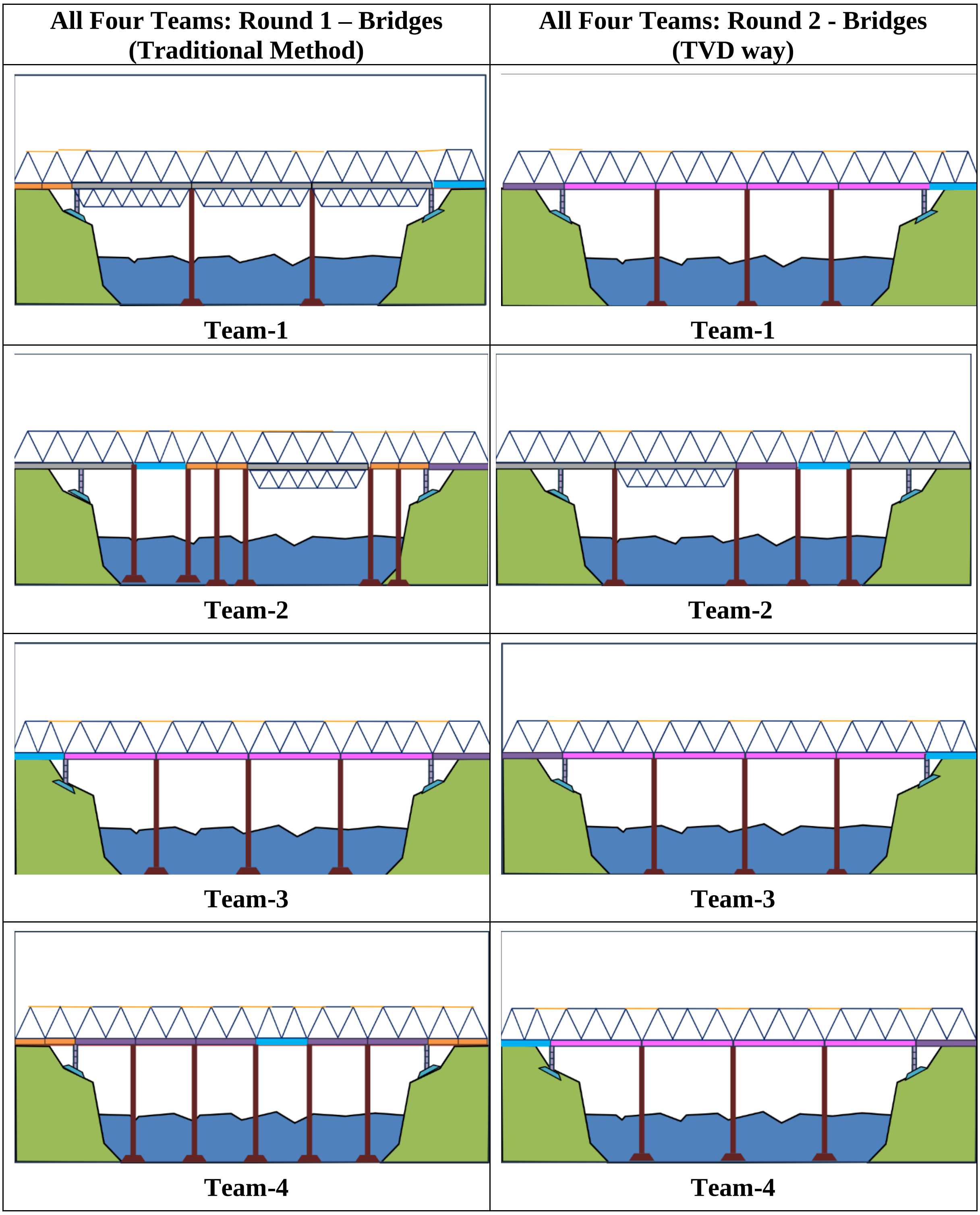


Figure 5: Bridge Designs by the Four Teams in Round 1 (Traditional Method) and Round 2 (TVD Method)

CONCLUSIONS

This study highlights the effectiveness of serious games in teaching and applying Target Value Design (TVD) principles within lean construction. Participants from various countries engaged in a two-round simulation focused on constructing a bridge over a valley mimicking a realistic infrastructure project while addressing cost, structural, and aesthetic constraints. In the first round, simulating traditional construction practices, the average market cost (MC) across teams was $474.7 million. In the second round, the TVD framework was introduced, requiring a minimum 15% cost reduction to establish the allowable cost (AC). Most teams successfully exceeded this target, with the average AC dropping to $403.45 million. Teams 1, 2, and 4 achieved remarkable cost reductions of 33.9%, 30.8%, and 33.2% respectively. These teams credited their success to open communication and effective collaboration between the owner, designer, and contractor in Round 2 of the game, enabling them to meet structural and aesthetic requirements while significantly reducing costs. On the other hand, Team 3 only managed a 11.3% reduction, primarily due to misalignment among the game participants and less effective teamwork, which signifies the importance of collaboration in lean construction. The results underscore the value of shared understanding and collaborative decision-making in achieving meaningful cost efficiencies. Teams that embraced these principles not only met but exceeded expectations, demonstrating the potential of TVD to deliver high-quality outcomes. The game's online format provided an engaging and practical platform for participants to apply TVD principles, making it a valuable tool for both professionals and students aiming to adopt lean practices in real-world scenarios. This study was different from the earlier simulation games that were either predisposed to addressing gravity challenges (Rybkowski et al. 2016; Jacob et al. 2021) or as observed to be challenging due to its design through a gaming software and its applicability across the wide user spectrum (Kim et al. 2023). In retrospect, this study advances prior knowledge in the field. For instance, this TVD simulation game mimicked an infrastructure project through a bridge design on a valley that defies gravity concerns posed by earlier simulations. The simplified 2D format further made the game less complex for the participants and allows for a wider spectrum and reach as a tool for teaching and learning powerful concepts of TVD principles through gamification. Results from the simulation provide support for claims in peer-reviewed lean construction literature that implementation of TVD can substantially reduce project costs.

REFERENCES

Abdelhamid, T., and Salem, S. (2005). "Lean construction: A new paradigm for managing construction projects." Proceedings of the International workshop on Innovations in Materials and Design of Civil Infrastructure, 28-29. https://www.researchgate.net/publication/242085758

Badurdeen, F., Marksberry, P., Hall, A., & Gregory, B. (2010). Teaching lean manufacturing with simulations and games: A survey and future directions. Simulation & Gaming, 41(4), 465–486. https://doi.org/10.1177/1046878109334331

Ballard, G., and Howell, G. (2002). "Lean project management." Building Research & Information, 31(2), pp. 119–133. https://doi.org/10.1080/09613210301997

Bashir, A. M., Suresh, S., Oloke, D. A., Proverbs, D. G., & Gameson, R. (2015). Overcoming the challenges facing lean construction practice in the UK contracting organizations. International Journal of Architecture, Engineering and Construction, 4(1), 10–18. https://doi.org/10.7492/IJAEC.2015.002

Bhatnagar, S., Jacob, G., Devkar, G., Rybkowski, Z. K., Arefazar, Y., and Obulam, R. (2023). "A systematic review of lean simulation games in the construction industry," Architectural Engineering and Design Management, 19(6), 701-719, https://doi.org/10.1080/17452007.2022.2155604

Desmarais, D, and Alves, T C.L. (2024). Target Value Delivery: A Simulation Lean Construction Journal 2024 pp 41-81 https://doi.org/10.60164/ehgzibhh2

Hamzeh, F., Theokaris, C., Rouhana, C., & Abbas, Y. (2017). Application of hands-on simulation games to improve classroom experience. European Journal of Engineering Education, 42(5), 471–481. https://doi.org/10.1080/03043797.2016.1190688

Howell, G., and Ballard, G. (1998). "Implementing lean construction: Understanding and action." In: Proc. 6th Annual Conf. of the Int'l Group for Lean Construction (IGLC-6), Guarujá, Brazil, https://iglc.net/Papers/Details/46

Jacob, G., Sharma, N., Rybkowski, Z. K., & Devkar, G. (2021). Target value design: Development and testing of a virtual simulation. 29th Annual Conference of the International Group for Lean Construction (IGLC), Lima, Peru. https://doi.org/10.24928/2021/0185

Kim, S., Rybkowski, Z. & 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) (pp. 629–638). https://doi.org/10.24928/2023/0194

Koskela, L. (1992). "Application of the new production philosophy to construction." Technical Report No. 72, Center for Integrated Facility Engineering, Stanford University, Stanford, CA. https://purl.stanford.edu/kh328xt3298

Miron, L. I. G., Kaushik, A. and Koskela, L. (2015) Target Value Design: The Challenge of Value Generation. In: Proceedings of the 23rd Annual Conference of the International Group for Lean Construction. IGLC (23). IGLC.net, Perth, Australia, pp. 815-825. www.iglc.net

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

Ng, M. S. & Hall, D. M. (2021). Teaching Target Value Design for Digital Fabrication in an Online Game: Overview and Case Study. Proc. 29th Annual Conference of the International Group for Lean Construction (IGLC) (pp. 249–258). https://doi.org/10.24928/2021/0117

Rybkowski, Z. K., Alves, T. d. C. L., and Liu, M. (2021). "The emergence and growth of the on-line serious games and participatory simulation group APLSO." In: Proc. 29th Annual Conf. of the Int'l Group for Lean Construction (IGLC-29), Alarcon, L.F. and González, V.A. (eds.), Lima, Peru, pp. 269–278. https://doi.org/10.24928/2021/0135

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 annual conference of the International Group for Lean Construction*; Boston, MA. IGLC.net - Details

Sarhan, S and Fox, A (2013) 'Barriers to Implementing Lean Construction in the UK Construction Industry', The Built & Human Environment Review, 6, 1-17. https://www.researchgate.net/publication/263658667

Zimina, D., Ballard, G., and Pasquire, C. (2012). "Target value design: Using collaboration and a lean approach to reduce construction cost." Construction Management and Economics, 30(5), pp. 383–398. https://doi.org/10.1080/01446193.2012.676658