Sobh, D., Desmarais, D., Budiab, R., Russell, J., & Hamzeh, F. (2026). Sync or Sink: a simulation to expose variation, mitigate impacts, and improve flow. In F. Hamzeh, M. Poshdar, N. P. Garcia-Lopez, & V. Gan (Eds.), *Proceedings of the 34th Annual Conference of the International Group for Lean Construction* (IGLC34) (pp. 680–691). https://doi.org/10.24928/2026/0138

SYNC OR SINK™: A SIMULATION TO EXPOSE VARIATION, MITIGATE IMPACTS, AND IMPROVE FLOW

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ABSTRACT

Games and simulations, with their immersive learning and tactical dimensions, have long been used across many industries to help people shake their biases and make connections between traditional practices and novel ideas. The lean construction community has been active in creating new games and simulations to explain its paradigm to students and practitioners. This paper presents a new game called "Sync or Sink™," created to support participants' experience when learning the impacts of variation on workflow and project production systems. The game highlights potential sources of variation on projects through narratives and anecdotes and supports meaningful engagement with their peers while respecting their humanity. A preliminary pilot study (n = 7) of the game was conducted with participants followed by a post-game survey. The survey supported the claim that the game was engaging and resonated with real-life experiences. The participants reported that the game helped illustrate the source and impact of variability in workflows and the benefits of collaboration to attenuate its impact. The paper presents the initial version of Sync or Sink™ and establishes the foundation for a new lean simulation game that supports experiential learning.

KEYWORDS

Simulation, serious game, flow, variation, collaboration.

INTRODUCTION

Lean construction can be difficult to grasp for people unfamiliar with its principles. A comprehensive understanding of novel ideas can take time and can lead to challenges in implementation (Brady et al., 2011). Serious games and simulations can play a significant role in reinforcing and deepening one's learning (Rybkowski et al., 2018). When confronted with unexpected ideas, participants need mechanisms to support them by making tangible connections between the old and new paradigms (Kuhn & Hacking, 2012). Teaching lean offers unique challenges when delivered in university settings since the students do not have field experiences yet (Rybkowski et al., 2018). Several games have been developed since the

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establishment of the lean construction community (Bhatnagar et al., 2023), illustrating the continued interest in developing simple educational tools to promote its learning.

The popularity of the Parade of Trades™ (PoT) in both university and industry reveals the utility of such a game to illustrate the impact of variation on systems' performance. The PoT simulation creates variations but does not illustrate sources of such variation, leaving the participants to make a direct connection to the real world themselves, exposing a gap in learning. The PoT does not offer participants the ability to take actions during the game to mitigate the impact of variation. Participants have expressed their lack of agency in influencing the outcomes of the simulation, suggesting a potential gap in relatedness. Game facilitators have identified challenges with data recording accuracy and facilitation challenges when group sizes change with limited notice, leading us to explore a new mechanism for an alternative game. This research investigated the following question: Can a new game be created to expose the impact of variation on system performance, while also providing insight into the source of variations, giving players a level of agency, while offering adaptability and ease of facilitation?

This paper presents the development of *Sync or Sink*™, a new simulation game, designed to experientially visualize the sources and consequences of variation on system performance. The paper builds on prior lean simulations and intentionally shifts attention from general task assignment to the underlying causes of variation and its propagation across interdependent workflows. *Sync or Sink*™ exposes specific sources of variation using cards containing a series of work-related anecdotes. The game introduces the use of narrative theory into lean construction games by offering a path for participants to enrich their understanding through the sharing of their own experiences. This game reflects the premise that variability can be both amplified or mitigated by planning decisions, and that stakeholders have choices to make. The simulation helps players connect with sources of variation that can be mitigated through collaborative planning cycles such as the Weekly Work Plans. The game brings a focus to responsibility and emphasizes the role of planning in production control. The game can be played in educational and industry settings and offers avenues for contextual refinements.

This paper reviews relevant lean construction games and outlines the foundation that guided the design of *Sync or Sink*™. It presents the main game principles and reports findings from an initial qualitative evaluation. The paper contributes to advancing simulation-based learning by introducing a human-centered approach to variation exposure and management, while maintaining a simple and practical way for facilitators to deliver these learning experiences.

LITERATURE REVIEW

CONSTRUCTION EDUCATION

Simulation games are useful tools to bridge the gap between theory and practice in lean construction education. Educational experts recommend engaging students across all cognitive levels of Bloom's taxonomy: remembering, understanding, applying, analyzing, evaluating, and creating (Bloom et al., 1956). To engage learners at all levels of the taxonomy, simulation games can be used as an interactive and educational tool. The literature shows many definitions for "serious" games, with the most common definition being games with a primary educational purpose that include an entertainment dimension (Michael & Chen, 2006; Laamarti et al., 2014).

According to Tsao and Howell (2022), simulations are essential to transfer lean construction concepts to learners in an interactive manner that mimics real construction challenges instead of simply listening to lectures. Tsao et al.'s study demonstrated that incorporating simulations helps both students and experienced professionals to better understand lean principles and relate them to the construction industry (Tsao et al., 2012). According to Hamzeh et al. (2017), incorporating hands-on simulation games leads to an engaging learning environment while allowing students to develop a deeper understanding of lean principles. Lean educators across

universities from many countries are increasingly moving towards integrating simulation games in their educational strategies to enhance students' understanding and application of lean construction methods (Tsao et al., 2013). Lean simulation games have extended from academia to the construction industry, where they are used as tools to teach employees lean philosophy and methods by supporting an understanding of real-life challenges and driving behavioural change (Bhatnagar et al., 2023). While students may grasp lean concepts more readily through structured educational methods, construction workers encounter greater challenges in adopting lean due to workplace culture and practical constraints (Ahmed & Sobuz, 2019), making teaching lean arguably more challenging in construction workforce context. These insights apply broadly to construction education, and simulation games have been increasingly explored in the context of lean construction to support the teaching of its principles.

SIMULATION GAMES FOR TEACHING LEAN

Building on the role of simulations in construction education, lean-specific simulation games have been developed to teach core lean principles and practices. The earliest simulations in construction were developed in the 1990s by Greg Howell and Tim Karpoff for leadership development and conducting partnering sessions (Tsao & Howell, 2022). A systematic review of lean simulation games in the construction industry published between 1990 and 2021 identified 96 games, with the most popular simulation games being Parade of Trades™, LEAPCON Simulation, Lego Airplane Game, Plan2Flow® (formerly called Villego®), and Silent Squares (Bhatnagar et al., 2023).

Lean simulation games can be digital or physical and are designed to introduce the player to various lean concepts. The Parade of Trades™ illustrates the impact of variability and dependence across multiple trades in a construction environment (Choo & Tommelein, 1999). LEAPCON, a construction simulation focused on high-rise apartment buildings, demonstrates the importance of single-piece flow under pull-scheduling (Sacks et al., 2007). The Lego Airplane Game teaches participants the importance of adding pull into a production system, managing work in smaller batches, and balancing workflow to improve quality and productivity (Tsao & Howell, 2022). Plan2Flow®, a detailed simulation designed to support the Plan-Do-Check-Act cycle of the Last Planner® System (LPS), displays the importance of collaboration and continuous improvement. Silent Squares emphasizes the importance of collaboration across teams as early on to achieve collective success (Tsao et al., 2014). The need for candid conversations in learning is often overlooked; people are at the heart of lean, and it is important to include such ideas (Khalife & Hamzeh, 2023). New simulations continue to be developed, such as those presented in the 2024 special edition of the Lean Construction Journal (Desmarais & Alves, 2024; Ouma et al., 2024; I. Tommelein, 2024).

EVOLUTION OF THE PARADE OF TRADES™ GAME

The Parade of Trades™ game has been defined, refined, and heavily discussed over the years. Greg Howell developed an early form of the game Parade of Trades™ in 1997 (Tsao & Howell, 2022), which was later presented at the IGLC6 (Choo & Tommelein, 1999); and then Tommelein et al. thoroughly studied and documented the game (I. D. Tommelein et al., 1998, 1999; Choo & Tommelein, 1999). In the early 2000s, the direction of the dice was altered, and by the early 2010s, four distinct color dice were custom-fabricated and introduced to the game, all averaging 3.5 (Tsao & Howell, 2022). Moreover, multiple computer simulations of the game have been created to collect statistics and study the impact on project cost and schedule (Choo & Tommelein, 1999). Alarcón and Ashley (1999) used a production rate of 5 with 100 production units and incorporated inventory buffers to analyze the impact on project duration and cost. Abbasian-Hosseini et al. (2018) explored replacing the die with a probability distribution function that would define the production of each trade every week, with an average

of 10. Han and Park (2011) developed an interactive internet-based simulation version of the game and incorporated managerial actions, allowing players to take actions to offset the impact of duration variability and productivity.

The Parade of Trades™ is a widely popular simulation game used in lean education (Rybkowski et al., 2018) to demonstrate the impact of variability among sequential trades in construction. The game exposes the impacts of variation effectively but remains silent about the multiple origins of such variations. Variation can originate from both emerging tasks, unforeseen challenges, or planners actions, which must be addressed in a lookahead planning or weekly planning process (Daou et al., 2015). Moreover, the PoT excludes the managers control function to mitigate impacts, even though this active role impacts the workflow. Recent work has begun to expand these pedagogical mechanisms. For example, Shehab et al. (2024) developed a new game using discrete event simulation that allows participants the ability to interact with variation and offers an effective way to tabulate outcomes. The game is played individually on a computer, offering the participants agency while integrating with the source of variation.

LEAN, VARIATION, AND MANAGEMENT

"Lean" was first used as an adjective to categorize a type of production system in a 2x2 matrix, describing it as a "non-buffered" production (Krafcik, 1988). Yet, unbuffered production systems with effective flow existed before their qualification as "lean" by Womack (2007). Buffers are used to protect systems against variation and are useful in construction with a goal to establish an operational control system that can produce predictable and reliable workflows (Ballard, 2000; Hamzeh, 2009). Taking actions to reduce variation by managing buffers is a key management activity in such systems. Japanese companies built production systems leaning on knowledge acquired from others who preceded them. They called their system "Just-in-Time." According to Ōno and Mito (1988), the more precise translation should be, "Exactly-in-Time." Buffers, in the form of waiting inventories, time, or work-in-progress, are considered waste and are targeted for elimination. Actions taken are contextual and results from events combinations observed live in production.

Koskela (2000) identified the emphasis of construction on transformation and suggested the necessity to increase management emphasis on two other attributes of production to improve performance. Flow can be used as a beacon for monitoring work movement between specialists, a key lead indicator of performance. Variations can be measured by the handoff between specialists using a control system like the Last Planner System. Measurement is one aspect but without taking actions, measurement alone can also become waste. Deming suggested that 94% of company problems are due to their management system (Deming, 1982, p. 315). A simulation called Red Bead was created to illustrate his points to managers as they are subject to misunderstanding, biases, paradigms, lack of interest, and require on-going development, suggesting new approaches to expose managers to their own bias, misunderstanding, and preconceptions about their own system is a key aspect of improvement work.

Ishikawa (1987, p. 138) indicated that it became quickly apparent for Japanese management that workers needed to be involved in the process to produce excellent quality. He observed that Western companies fail to implement "just-in-time" because of their poor understanding of what it took for this type of management system to emerge (Ishikawa, 1987, p. 9). Quality circles solve real business problems, respect people's humanity (Kondo, 1991), and reach higher possibilities by leveraging workers' entire capabilities (Ishikawa, 1987, p. 140). This suggests that peoples' entire humanity needs to be engaged in surfacing and removing causes of variation that require the utilization of buffers to reach the objectives of a Just-in-Time operating system. Current simulations exposing variations in construction do not engage

participants in all aspect of their humanity as suggested by Kondo (1991). This concept is at the core of the development of the new simulation presented in this paper.

METHODOLOGY

This study adopts a Design Science Research (DSR) methodology to guide the development and evaluation of a lean simulation game. The DSR approach is appropriate for this research because it focuses on creating an artifact designed to address a practical problem (Hevner et al., 2004). The development of the simulation framework follows three key steps: (1) problem identification and assessing the need for a framework, (2) artifact development, and (3) artifact evaluation. DSR has been widely adopted in the development of frameworks supporting lean implementation, including the work of Barkokebas et al. (2021) and (Eivazi Ziaei et al., 2023).

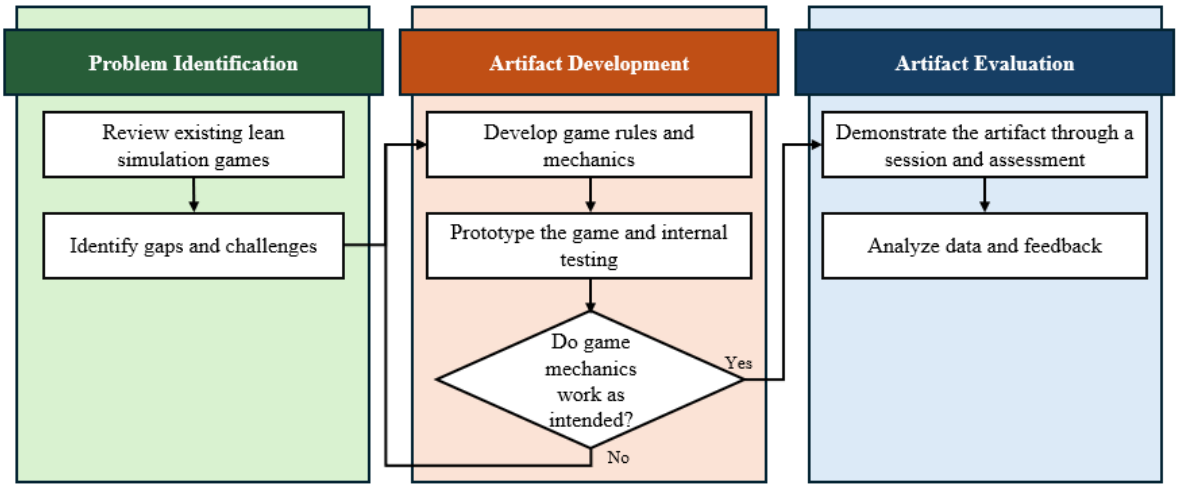

Figure 1: Research methodology to develop and evaluate Sync or Sink™

This research implements the DSR methodology to develop and test a lean simulation game, followed by an evaluation of the artifact through a survey to assess its effectiveness in conveying lean construction concepts. The study begins with an analysis of existing simulation games through the authors' firsthand experiences, direct observations, and interviews with lean experts who have administered these games. Insights from this analysis were used to identify limitations in current approaches and to define design objectives for a new simulation. These design objectives included the game's ability to illustrate the impact of workflow variability, promote collaboration and coordination among participants, and support experiential learning of lean construction principles. After that, the game was developed through an iterative process, leading to the creation of a prototype. The prototype was pilot tested with a participant group and evaluated using a post-game survey.

PROBLEM IDENTIFICATION AND GAP ANALYSIS

An analysis of current simulation games was conducted to identify gaps and challenges, including playthroughs of Parade of Trades™, Airplane Game, and the Silo Game. The Parade of Trades™ emerged as a source of inspiration and was analyzed further to better understand its mechanics and potential adaptations. Attention was placed on mechanics that could be reflect realistic environments and participant experience, including replacing the use of a die roll with gameplay elements more grounded in real-world construction scenarios. The objective was to create a game that complements existing simulations by addressing identified pedagogical opportunities, supporting the teaching of lean concepts, and improving player engagement. Existing research on flow efficiency, variability, and the lean production system was analyzed

to identify underlying principles that could be translated into gameplay mechanics. Research on serious games and active learning techniques was also reviewed to establish best practices for integrating educational content into an interactive experience.

The research team conducted interviews with lean construction experts who are using the Parade of Trades™ as a teaching tool. These interviews helped identify opportunities for enhancement in existing simulation-based teaching approaches. Table 1 summarizes the identified improvement areas.

Table 1: Identified improvement areas for the parade of trades

	Improvement Opportunities	Design Category
1.	The game is long, 90 minutes for two consecutive rounds.	Structure
2.	The sheet can be difficult to fill out, and errors can occur.	Tabulation
3.	Crew assignment through dice rolls may reduce clarity.	Mechanics
4.	Participant engagement could be further strengthened.	Structure
5.	The math at the end is time-consuming; people are waiting.	Tabulation
6.	The outcome and reflections are dependent on the sheet's accuracy.	Tabulation
7.	During the second round, players “get the point” after 1 week; the round completion is primarily for data comparison.	Structure
8.	The game premise could be further adapted to improve its relevance for owners and designers.	Naming
9.	The number of players is inflexible when comparing outcomes.	Mechanics

The authors conducted multiple brainstorming sessions to develop potential game concepts, identify the target audience, and define the core values the game should convey. Through a collaborative process, the authors agreed to introduce a new mechanics that would grant players agency grounded in their real-world experiences, aimed at improving the relatability of the simulation. The game mechanics were structured to be representative of how players could act independently and determine their own courses of action, with outcomes emerging as direct consequences of those actions.

The authors developed an initial version of the game as a prototype and tested the first set of mechanics through repeated playthroughs. Feedback from these sessions prompted several design iterations and improvements to gameplay elements.

GAME DESIGN AND LEARNING LOGIC

The main objective of the game is to help participants experience how variation propagates through interdependent process steps and influences overall system performance, rather than to optimize individual task execution. Work flows sequentially across roles and reflects the interdependencies typical of construction production systems. The game is designed to include two rounds that intentionally contrast in structure, with the first round playing independently and the second round reflecting collaborative planning.

The table setup and clockwise rotation from the last process step to the first step are inspired by the mechanics of the Parade of Trades. Certain game mechanics and tallying mechanisms are simplified to improve participation while minimizing administrative burden. The game is designed to be flexible and can be played by groups of between 7 and 10 players. It can also be adapted to different educational and industry contexts through the creation of a card deck with contextual anecdotes.

The game is designed for players to experience the potential sources and implications of variations on project performance, the potential benefits, and residual limitations of collaborative planning efforts. The cards contain short project anecdotes illustrating situations that teams could experience and the variations they could generate on projects. In round one,

the cards are played as drawn. In Round two, players are encouraged to mitigate the impact of variation through a collaborative "cyclical" planning mechanism, fostering discussion and group problem-solving through card exchanges. In the second round, the green cards can be traded between players by determining what is "best for the project" and/or for themselves, creating tension among players and promoting discussion about trade offs and their benefits. The red cards cannot be traded in either round, reinforcing the fact that not all sources of variation can be removed from the system. Figure 2 provides a small sample of the card deck.

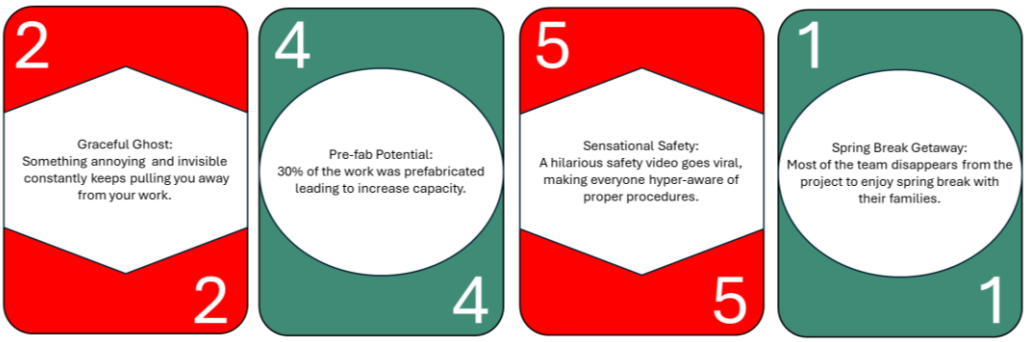

Figure 2: Sample of the card deck

Sync or Sink™ introduces a novel approach to help players connect with the resource productivity and process variability they experience in their day-to-day jobs. The game uses a deck of playing cards with anecdotes describing potential sources of variation. It contains 147 cards: 14 suites of 7 green cards with numbers ranging from 0 to 6, and 7 suites of 7 red cards with numbers ranging from 0 to 6. The average capacity of the deck is 3. Some cards require players to share their own anecdotes, increasing engagement, fostering team building, and encouraging the sharing of experiences. This mechanism engages participants in sharing lessons learned and highlighting project challenges, with the added benefit of triggering ideas for improvement through shared understanding of real-life situations. To tabulate overall capacity during a round, players hold on to their cards after each cycle. The sum of their capacity can be collected and compared between rounds, eliminating the need for a tally sheet. By comparing total card count to the number of chips passed, participants can evaluate the lost productivity and discuss the bullwhip effect. The number of chips can be easily adjusted based on the number of players available without impacting the mechanics. A time study performed by the authors while developing the game showed that it can be played in 35-40 minutes.

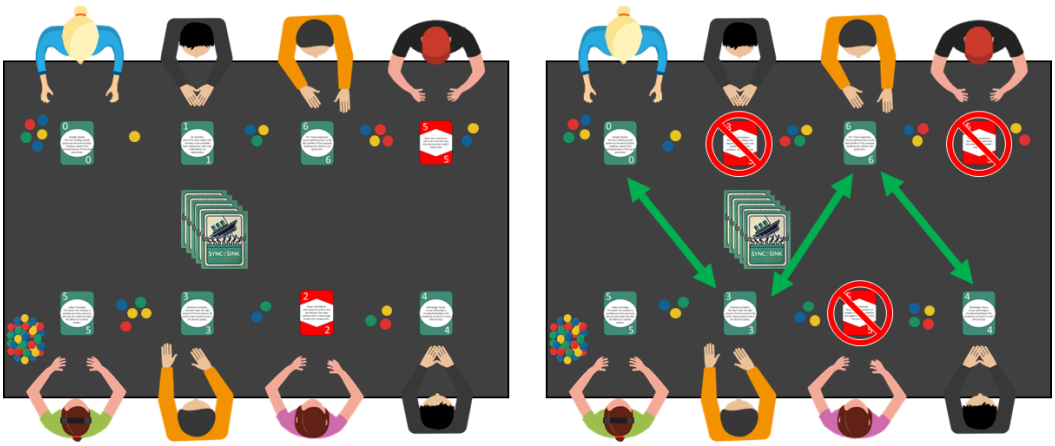

Figure 3: Illustration of round 1 (independent play, left) and round 2 (collaborative planning, right)

The initial prototype was tested internally by the authors through repeated playthroughs to evaluate the clarity and flow of the game mechanics. Early iterations included more complex game features, such as a central discard pile and separate card sets assigned to each role. However, these versions introduced too many steps and became confusing for players, reducing clarity of the intended learning outcomes. Based on these internal tests, several mechanics were simplified and certain ideas were intentionally removed to improve usability and maintain focus on the core lean concepts being taught.

PILOT GAME EVALUATION

To evaluate the effectiveness of the game, seven participants were recruited for a pilot evaluation. A facilitator was responsible for the debrief, highlighting key learning takeaways, while the other authors observed the playthrough and documented major observations. Following play, participants were asked to complete a survey. The survey consisted of demographic questions, items focusing on the game experience, and questions assessing perceived learning outcomes related to the lean concepts conveyed in the game. A 4-point Likert Scale was used to evaluate agreement with statements about game clarity, engagement, and mechanics, as well as to assess the game's effectiveness in demonstrating lean principles such as: (A) variability in construction, (B) collaboration among tasks, (C) differentiating between controllable and uncontrollable disruptions, (D) resource management, and (E) weekly work planning. In addition, two open-ended questions were used to collect qualitative feedback on the strengths and areas for improvement of the game.

The participants in the testing session had different educational and professional backgrounds. The assessment is based on a small sample size and is therefore exploratory in nature. Five out of the seven participants were construction professionals, while the remaining participants were from other industries. Participants spanned a wide age group, from 18-24 to 55 and above. Two participants reported being very familiar with lean construction principles, two reported being familiar, and three reported being somewhat familiar.

Overall, the feedback regarding gameplay mechanics and their role in supporting the understanding of key lean construction concepts was positive. In the preliminary pilot (n = 7), all participants reported that the game helped them understand the impact of variability in construction workflows and the importance of collaboration between tasks.

Figure 4 presents participants' Likert-scale responses evaluating their experience with the game. The statements address clarity, engagement, realism of the variation narratives, usefulness for learning lean construction concepts, and relevance to real-world experiences.

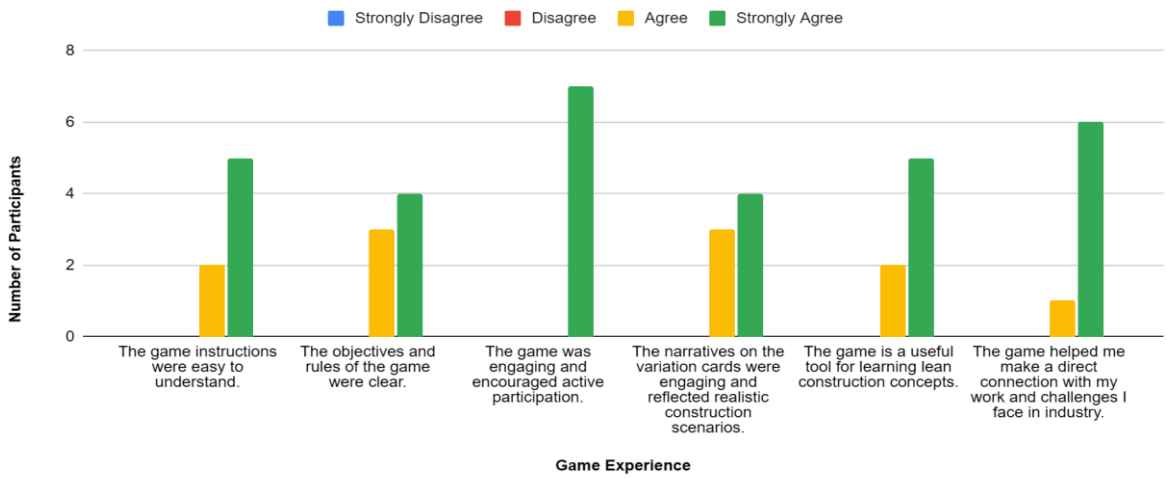

Figure 4: Participant perceptions of game experience

Figure 5 summarizes participants' ratings of the game's effectiveness in supporting understanding of key learning concepts, including variability in workflows, collaboration between tasks, differentiation between controllable disruptions, resource management and waste reduction, and weekly work planning.

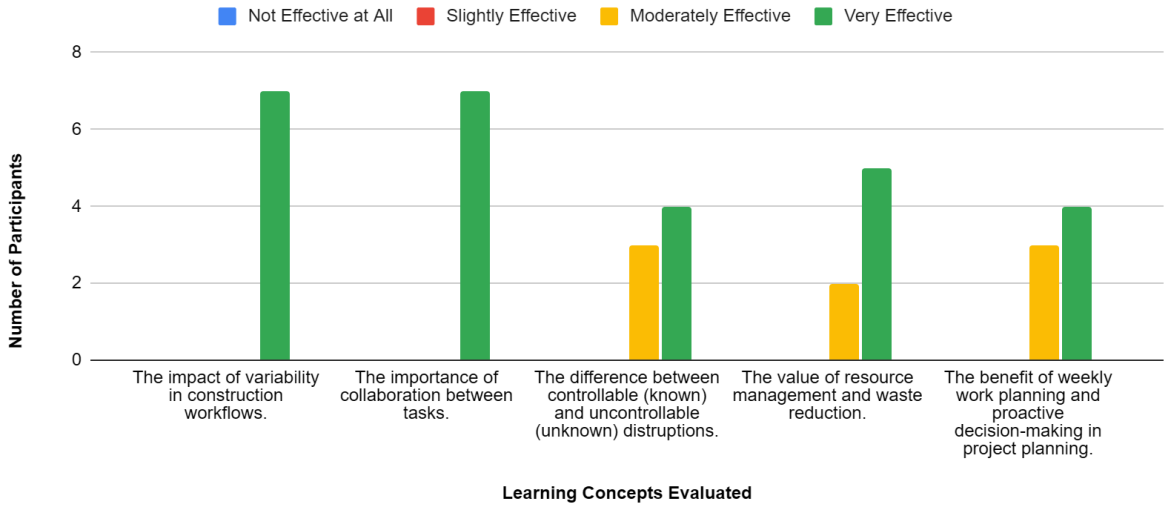

Figure 5: Participant ratings of learning effectiveness

In the open-ended responses, participants expressed that collaborating through card exchanges enhanced engagement and helped them understand the impact of resource allocation on project duration, with one participant specifically identifying "collaborative card swapping" as the most effective aspect of the game. Suggestions for improvement focused primarily on the need for clearer facilitation instructions. In addition, observations from the testing session provided valuable insights into players' behavior and overall game dynamics, including feedback on the card size and color, table setup, and opportunities to further optimize duration.

STUDY LIMITATIONS AND DISCUSSION

The game mechanics was evaluated with a small group sample, which limits the generalizability of the findings. Future studies should involve a large and more diverse pool of participants and include additional testing iterations. Moreover, the value and impact of the cards narrative should be further studied and should incorporate additional input from industry professionals. As part of an iterative design process, the game will continue to be developed and improved through ongoing testing and integration of participant feedback.

In reviewing existing lean simulation games and their documented challenges and limitations, including those associated with the Parade of Trades™, the study identified both the strengths of current approaches and opportunities for improvement. These insights informed the development of *Sync or Sink*™, which adopts a different mechanism and underlying intent. The game improves how people connect with the concept of variation by combining simple and humorous examples of productivity-related disruptions with interactive mechanisms that promote engagement, exchange, and collaborative decision-making to help address such issues. The first iteration of *Sync or Sink*™ sets the foundation for a new approach to expose variation using anecdotes as an engaging learning mechanism.

By maintaining a generic structure, the game allows for the development of future versions tailored to specific industry contexts. Future development could lead to the creation of multiple versions of the game using cards with narratives related to specific experiences across various delivery models, project phases, geographies, or sectors, among others. The game could also

evolve to allow adjustments to the distribution of controllable and uncontrollable variation cards. This flexibility enables facilitators to adapt the simulation to their specific context while supporting discussion grounded in participants' real-world experiences, distinguishing the game from existing lean simulations.

CONCLUSION

This paper presents the research conducted to develop a new lean simulation. Games have demonstrated their value in supporting participants' learning of new concepts. Simulation-based learning engages participants' capacity to do, think, and feel, while respecting their humanity. *Sync or Sink*™ is a new game that introduces anecdotes to enable participants to connect their own experiences to sources of variation in construction. The game's mechanics are intentionally generic and flexible and are designed to be easier to tabulate, supporting both participants and facilitators. Initial findings from a pilot test group (n = 7) indicated that the game is engaging and helps players connect the simulation to their work experiences and industry challenges. A key pedagogical contribution of *Sync or Sink*™ lies in its use of anecdotes and collaborative mechanics to help participants connect real-world experiences with the propagation of variability across interdependent workflows in construction. The narratives were engaging for industry participants; however, they could be further diversified to ensure relevance across a broader range of contexts.

Potential future improvements include the development of cards with anecdotes tailored to specific industry segments. Modifications to the task mechanics could be introduced to better represent the non-linear and iterative nature of design work. Future versions could also incorporate cards representing situations unique to different project delivery models.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the participants in the game testing session who contributed their time and provided valuable feedback. *Sync or Sink*™ is intended to reflect and celebrate the human moments encountered in the industry over the years, and it would not have been possible without the passion, care, and desire of those who seek to make this technically demanding industry a little bit more humane. This study was approved by the Research Ethics Board at the University of Alberta.

REFERENCES

Abbasian-Hosseini, S. A., Liu, M., & Howell, G. (2018). Investigating the cost-benefit trade-off of additional planning using parade game simulation. *Journal of Management in Engineering*, *34*(2), 04017066. https://doi.org/10.1061/(ASCE)ME.1943-5479.0000580

Ahmed, S., & Sobuz, M. H. R. (2019). Challenges of implementing lean construction in the construction industry in Bangladesh. *Smart and Sustainable Built Environment*, *9*(2), 174–207. https://doi.org/10.1108/SASBE-02-2019-0018

Alarcón, L. F., & Ashley, D. B. (1999). Playing games: Evaluating the impact of lean production strategies on project cost and schedule. *7th Annual Conference of the International Group for Lean Construction*. International Group for Lean Construction.

Ballard, G. (2000). *The last planner system of production control* [Doctoral Dissertation]. The University of Birmingham.

Barkokebas, B., Khalife, S., Al-Hussein, M., & Hamzeh, F. (2021). A BIM-lean framework for digitalisation of premanufacturing phases in offsite construction. *Engineering, Construction and Architectural Management*, *28*(8), 2155–2175. https://doi.org/10.1108/ECAM-11-2020-0986

Bhatnagar, S., Jacob, G., Devkar, G., Rybkowski, Z. K., Arefazar, Y., & 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

Bloom, B. S., Engelhart, M. D., Furst, E. J., Hill, W. H., & Krathwohl, D. R. (1956). *Taxonomy of educational objectives. Handbook 1: Cognitive domain*.

Brady, D., Tzortopoulos, P., & Rooke, J. (2011). An examination of the barriers to Last Planner implementation. *19th Annual Conference of the International Group for Lean Construction*. 19th Annual Conference of the International Group for Lean Construction. https://iglc.net/papers/Details/1109

Choo, H. J., & Tommelein, I. D. (1999). *Parade of trades: A game for understanding variability and dependence* (Nos. 99–1). Construction Engineering and Management Program, Civil and Environmental Engineering Department, University of California, Berkeley.

Daou, E., Gharzouzi, P., Sreih, E., & Hamzeh, F. (2015). Instantask: Designing a visual application for enabling agile planning response (Pt. 23-32). *23rd Annual Conference of the International Group for Lean Construction, Perth, Australia*. www.igle.net

Deming, W. E. (1982). *Out of the crisis*. The MIT Press.

Desmarais, D., & Alves, T. D. C. L. (2024). Target value delivery: A simulation. *Lean Construction Journal*, 41–81. https://doi.org/10.60164/ehgzibhh2

Eivazi Ziaei, P., Salhab, D., Ahuja, R., & Hamzeh, F. (2023). Lean health check framework. *31st Annual Conference of the International Group for Lean Construction*, 1498–1509. https://doi.org/10.24928/2023/0163

Hamzeh, F. (2009). *Improving construction workflow- The role of production planning and control* [Doctoral Dissertation, University of California, Berkeley]. https://doi.org/10.13140/RG.2.1.1182.9286

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

Han, S., & Park, M. (2011). Interactive parade game: Impact of managerial reactions to workflow variability. *Journal of Information Technology in Construction*, *16*, 104–117.

Hevner, A. R., March, S. T., Park, J., & Ram, S. (2004). Design Science in Information Systems Research. *MIS Quarterly*, *28*(1), 75–106. https://doi.org/10.2307/25148625

Ishikawa, K. (1987). *What is total quality control? The Japanese way* (6. print.). Prentice-Hall.

Khalife, S., & Hamzeh, F. (2023). How to navigate the dilemma of value delivery: A value identification game. *31st Annual Conference of the International Group for Lean Construction*, 663–673. https://doi.org/10.24928/2023/0235

Kondo, Y. (1991). *Human motivation: A key factor for management*. 3A Corporation.

Koskela, L. (2000). *An Exploration Towards a Production Theory and its Application to Construction*. Technical Research Centre of Finland.

Krafcik, J. F. (1988). Triumph of the lean production system. *Sloan Management Review*, *30*(1).

Kuhn, T. S., & Hacking, I. (2012). *The structure of scientific revolutions* (Fourth Edition). The University of Chicago Press.

Laamarti, F., Eid, M., & El Saddik, A. (2014). An overview of serious games. *International Journal of Computer Games Technology*, *2014*, 1–15. https://doi.org/10.1155/2014/358152

Michael, D., & Chen, S. (2006). *Serious games: Games that educate, train, and inform*. Muska & Lipman/Premier-Trade.

Ōno, T., & Mito, S. (1988). *Just-in-time for today and tomorrow: Taiichi Ohno with Setcuo Mito*. Productivity Press.

Ouma, L., Leicht, R., & Driver, D. (2024). A simulation for teaching set based design in architecture engineering and construction. *Lean Construction Journal*, 18–40. https://doi.org/10.60164/4ejs3ply3

Rybkowski, Z. K., Forbes, L. H., & Tsao, C. C. Y. (2018). The evolution of lean construction education (Part 1 of 2): At US-based universities. *26th Annual Conference of the International Group for Lean Construction*, 1013–1023. https://doi.org/10.24928/2018/0447

Sacks, R., Esquenazi, A., & Goldin, M. (2007). LEAPCON: Simulation of lean construction of high-rise apartment buildings. *Journal of Construction Engineering and Management*, *133*(7), 529–539. https://doi.org/10.1061/(ASCE)0733-9364(2007)133:7(529)

Shehab, L., Malaeb, Z., & Hamzeh, F. (2024). Harnessing LPS metrics for smarter resource allocation and project control through gamification. *Lean Construction Journal*, *2024*, 1–15. https://doi.org/10.60164/wxshl6tcv

Tommelein, I. (2024). Mistakeproofing! It's in the Cards: A Serious Game. *Lean Construction Journal*, 4–17. https://doi.org/10.60164/ql7dq3pty

Tommelein, I. D., David, R., & Howell, G. A. (1998). Parade game: Impact of work flow variability on succeeding trade performance. *6th Annual Conference of the International Group for Lean Construction*. International Group for Lean Construction.

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. https://doi.org/10.1061/(ASCE)0733-9364(1999)125:5(304)

Tsao, C. C. Y., Alves, T. da C. L., & Panagiotis, M. (2012). Different perspectives on teaching lean construction. *20th Annual Conference of the International Group for Lean Construction*. International Group for Lean Construction (IGLC). https://iglc.net/papers/Details/851

Tsao, C. C. Y., Azambuja, M., Hamzeh, F. R., Menches, C., & Rybkowski, Z. K. (2013). Teaching lean construction—Perspectives on theory and practice. *21st Annual Conference of the International Group for Lean Construction*. International Group for Lean Construction.

Tsao, C. C. Y., Draper, J., & Howell, G. A. (2014). An overview, analysis, and faciliation tips for simulations that support and simulate pull planning. *22nd Annual Conference of the International Group for Lean Construction*, 1483–1494.

Tsao, C. C. Y., & Howell, G. A. (2022). Development of simulations & pull planning for lean construction learning and implementation. *30th Annual Conference of the International Group for Lean Construction (IGLC)*, 1075–1086. https://doi.org/10.24928/2022/0216

Womack, J. P. (2007). *The machine that changed the world: The story of Lean Production*. Free Press.