Arefazar, Y. and Rybkowski, Z. K. (2022). Developing & Testing A Value Stream Map Simulation: Helping the Construction Industry Learn to See. *Proceedings of the 30th Annual Conference of the International Group for Lean Construction (IGLC30)*, 342-353. doi.org/10.24928/2022/0135

DEVELOPING & TESTING A VALUE STREAM MAP SIMULATION: HELPING THE CONSTRUCTION INDUSTRY LEARN TO SEE

Yasaman Arefazar [1] and Zofia K. Rybkowski [2]

ABSTRACT

Resources to interactively teach value stream mapping (VSM) to construction practitioners and students of lean are currently limited. While traditional value stream mapping methods make sense for those with a background in manufacturing or industrial engineering, they are arguably neither intuitive to construct nor easy to understand by those in the building industry. There is a need for a value stream mapping method that implements and communicates in ways that are already familiar to those in construction.

The objective of this research is to develop and test a VSM simulation as a preliminary study that makes intuitive sense for those in the construction industry and so can serve as a training method for the identification and removal of waste. A virtual simulation was developed and tested using a design research methodology to facilitate scalability and to enable on-line play.

KEYWORDS

Lean construction, value stream mapping, continuous improvement / kaizen, waste, workflow, lean simulation

INTRODUCTION

Value Stream Mapping (VSM) is a lean tool used for performance measurement and waste reduction. Rother and Shook (2009) entitled their book *Learning to See* because VSMs help visualize process flows in their entirety.

A VSM is a valuable tool for students taking lean courses because it enables them to identify the flow of processes, waste, and value. VSMs also help project managers develop an understanding of additional lean concepts such as takt time and value.

Construction engineering and management students sometimes find it challenging to grasp abstract concepts such as "waste," "value," "process," "conversion," and "flow" of processes common to Lean manufacturing. Because of this, experiential learning becomes essential for effective teaching and learning to occur in construction management programs (Ramalingam 2018). Unless the topic of VSM is presented correctly, practitioners may not be able to properly apply the technique to an actual situation.

A study conducted by Hamzeh et al. (2017) revealed that simulation games can be employed to facilitate classroom instruction, improve the learning experience, and

[1] Graduate Student, Department of Construction Science, Texas A&M University, College Station, TX, USA, o: (979) 422-6385, yasamanarefazar@tamu.edu, orcid.org/ 0000-0003-2827-572X

[2] Associate Professor, Department of Construction Science, Texas A&M University, College Station, TX, USA, o: (979) 845-43zrybkowski@tamu.edu, orcid.org/ 0000-0002-0683-5004

increase understanding of the theory behind lean construction and its real-world applications among engineering students. Additionally, simulation games align with student expectations that education should be enjoyable (Kapp 2012, Prensky 2007).

Research conducted by Brouwer-Hadzialic and Weigel (2016) and Oberhausen and Plapper (2015) demonstrated applications of VSM through laboratory experiments and student teams. Ramalingam (2018) mapped their BIM process when teaching Lean for one of the course modules on Lean Construction at a leading construction management institute in India. While valuable, such studies are limited, which triggers further interest in using the VSM technique as a demonstrative tool for teaching Lean.

VSM is process-oriented, and unless students and practitioners are included in the process, they may not be able to apply the technique to actual practice (Lobaugh 2008). Lean consultants such as Petruska (2014) created a VSM simulation, “The Pizza Game,” using poker chips and train tracks. Some of the tools discussed in this game included work balancing and spaghetti diagrams, where the team used a VSM to conceptually capture processes and improve them.

This research aims to develop a VSM to illustrate scenarios to observers where waste is embedded and needs to be eliminated. It enables students to learn by mapping current and future conditions, identifying wastes, and continually improving processes. This research intends to propose and test a graphical analysis method that is more understandable to construction practitioners to help them more intuitively understand opportunities to improve flow.

The proposed analysis method contains a Gantt Chart, timeline, and spaghetti diagram depicting processes and embedded wastes. The intent is to help construction practitioners to understand flow. Conventional VSM methods use flow charts for mapping the processes, which often require existing knowledge of VSM symbols. Since most construction practitioners do not already possess this knowledge, it can take substantial time and effort for an individual to read and understand the VSM and how to use it. Therefore, this research study proposes a more intuitive method for value stream mapping in construction.

VALUE STREAM MAPPING

The Value Stream Map (VSM) method originated from the Toyota Production System. It requires collaboration with the customer and a focus on their point of view with respect to process necessities (Haefner et al. 2014; Morlock & Meier 2015; Rahani & Al-Ashraf 2012).

The VSM was initially proposed to model production systems in a factory (Rother and Shook 2009) and then extended to supply chain modelling (Womack and Jones 1996). The process of value stream mapping can be categorized into six steps: 1) identify the process to improve; 2) create a current state map of the process; 3) determine an appropriate metric for improvement; 4) create a future state map of the process; 5) determine improvement methods to go from the current state to the future state that achieves the correct metric; and 6) initiate improvements (Lobaugh 2008). Simonsson et al. (2012) demonstrated that on-site practitioners can use VSMs to see the day-to-day flow of work, in order to understand the impact of improvements to workflow.

In the construction industry, VSMs can help identify the bottlenecks in the construction process and therefore minimize waste (Germano et al. 2017, Kanai and Fontanini 2020).

SIMULATIONS IN LEAN EDUCATION

According to Tsao and Howell (2015), serious games and simulations have traditionally played a critical role in teaching lean construction principles to outsiders. Experimenting with simulations began in the 1980s by lean pioneers Greg Howell and Glenn Ballard (Tsao and Howell 2015).

A simulation game supports teaching by mimicking miniature controlled experiments of actual processes that create opportunities for an “aha moment” among participants. In the world of lean, simulations are used to illustrate lean principles and create buy-in among those who will be implementing lean (Rybkowski et al. 2020). These games facilitate learning about the consequences of decisions and strategies through visual representation of processes and metrics (Shannon et al. 2010). This offers experiential learning of Lean principles in error-friendly, dynamic learning environments. Simulation games foster physical actions for learning by doing, which converts knowledge into a skill through the medium of realism (Galloway 2004). Maghool et al. (2018) stated that theorists such as Benjamin Bloom, David Kolb, Jean Piaget, John Dewey, and Paulo Freire believed that experiential learning should be integral to any educational system.

Moreover, according to a study by Bhatnagar & Devkar (2021), important themes such as waste reduction and value maximization are not key focus areas of existing lean simulation games. Games such as the Parade-of-Trades Simulation, LEAPCON, and Lego™ Airplane Game deal with waste along with various other learning objectives; however, they do not demonstrate waste reduction and analysis of value added / non-value added activities as the key learning outcomes (Pollesch et al. 2017).

In response to filling this gap, this research aimed to develop a VSM simulation that features a cook making spaghetti during two scenarios. A simulation video was developed to facilitate a participant’s recognition of the eight wastes, and analysis of value-added / non-value-added activities. The simulation facilitator is then encouraged to challenge players to brainstorm ways their newfound understanding can be applied to reduce wasteful activities in construction processes.

RESEARCH METHOD

This study reports on the development and testing of a lean simulation that focuses on value stream mapping for waste reduction and continuous improvement (kaizen). The simulation was inspired by the video “Toast Kaizen: An Introduction to Continuous Improvement & Lean Principles” by GBMP to introduce the concept of VSM and waste reduction to the simulation participants (Hamilton n.d.).

The study exposes to participants how they can efficiently and effectively map out current and future conditions that facilitate identifying wastes observed in the construction industry as a way to continually improve processes. This research aims to offer a VSM simulation that can help the simulation participants sharpen their intuition about waste identification, revise existing processes to eliminate waste, and quantify the impact of the newly revised processes.

For the simulation’s graphic design, Adobe Illustrator™ was used, and the animation was assembled in Microsoft PowerPoint™ and Adobe After Effects™.

This study used a design research methodology that involves iterative development and testing. The simulation was tested on: (i) 48 students without prior familiarity with VSMs during a course dedicated to lean construction in the Department of Construction Science at Texas A&M University; (ii) 9 experts from San Diego Community of Practice;

and (iii) 14 members of the Administrating and Playing Lean Simulations Online (APLSO) community where some of the participants were assumed to have prior familiarity with the concept of VSM.

Participants were asked to provide feedback on the VSM simulation. Modifications were made based on participant feedback.

DESCRIPTION OF THE SIMULATION

The simulation was designed to engage participants to watch a 7-minute-30-second long animated video that features a man cooking spaghetti for his girlfriend. The intent was to engage participants in a simple activity that is familiar to most, if not all, participants.

During his first attempt (Scenario I), the cook finishes within 4-minutes-12 seconds. The process intentionally consists of multiple types of waste such as unnecessary movement, material handling, and inefficient ordering of activities. Viewers are invited to actively identify these wastes. The eight wastes (Liker 2004, p. 28-29) depicted during Scenario I are shown in Figures 1, 2, 3, 4, 5 and 6. The first waste illustrated in the video depicts *unnecessary movement*, where the cook walks back and forth several times (Figure 1). For the second waste—*waiting*—the cook wasted time waiting for the water to boil, for the spaghetti to cook, and for the meatballs to grill (Figure 2).

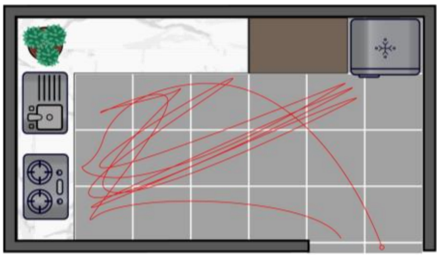

Figure 1. Unnecessary movement in Scenario I

Figure 2. Waiting

The third waste—*unnecessary transport or conveyance*—refers to the superfluous movements taken during handling of materials. The video depicts this waste by showing the cook walking back and forth to carry meatballs from the refrigerator to the stove and then back again to the refrigerator to return unused meatballs. The fourth waste is *overproduction*, which means producing more items than needed or sooner than necessary. During Scenario I, the spaghetti was cooked sooner than required, and as a result, extra food was stored in the sink and saved for further use (or disposal) becoming the fifth waste—*excess inventory*.

Figure 3. Unnecessary Transport

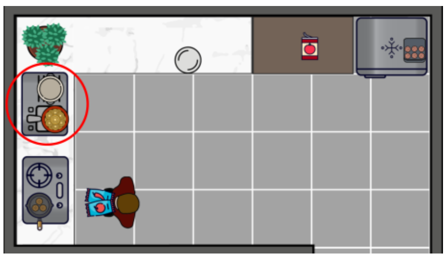

Figure 4. Overproduction and Inventory

For the sixth waste—*unused employee creativity*—the cook could have used his time more effectively by simultaneously engaging in another activity while waiting for the water to book and spaghetti to cook (Figure 5). Ironically, at the end, the completed spaghetti was discarded since the cook had neglected to first ask his girlfriend for her preferences before embarking on the task (i.e., she was allergic to spices in the spaghetti). This would be considered a *defect* (seventh waste) and was thrown into the trash (Figure 6). All the mentioned wastes comprise the eighth waste, *overprocessing or incorrect processing*, which is represented by redundant tasks that do not add value.

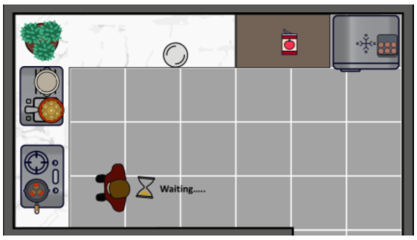

Figure 5. Unused employee creativity

Figure 6. Defect

In his second attempt (Scenario II), the man was able to cook the spaghetti within 2-minutes-32-seconds by removing extra movements and performing activities simultaneously (e.g., cleaning the countertop) during waiting times. Two variables that were changed in Scenario II were replacing the stove and using an electric kettle to expedite the boiling process (Figures 7 & 8).

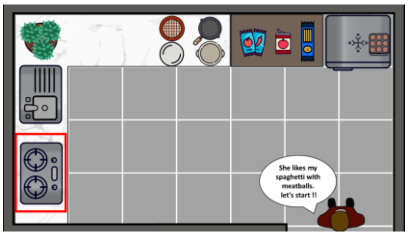

Figure 7. Scenario I Layout

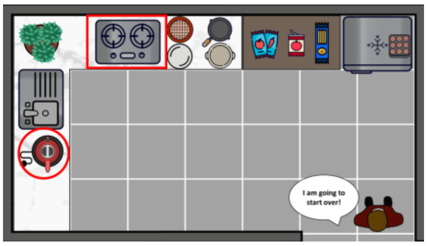

Figure 8. Scenario II Layout

As is apparent by the motion tracking during Scenario II, as shown in Figure 9, the amount of motion and waiting times were reduced by 39.7% compared to Scenario I. Also, overproduction and inventory wastes were removed by preparing the spaghetti only when needed (Figure 10).

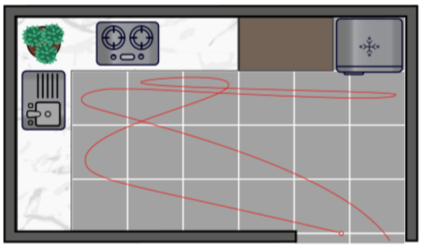

Figure 9. Motion Tracking (Scenario II)

Figure 10. Elimination of Overproduction

In the end, the cook's girlfriend was satisfied since he asked for her opinion about the spaghetti before beginning the process (e.g., conditions of satisfaction). Therefore, the result was satisfying, and no defects emerged during Scenario II. At this point, it is important for the facilitator to discuss with participants the need to define *conditions of satisfaction* at the beginning of any process because a product that is done quickly but that does not satisfy critical, stated needs is ultimately considered to be 100% waste.

Figure 11. Added Productivity

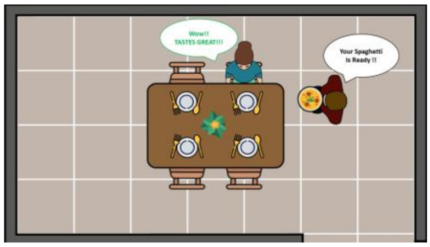

Figure 12. Satisfying Result

FACILITATING THE SIMULATION

To collect feedback from participants in the initial of three first run studies, the video was streamed to student laptops as an assignment a graduate level Advanced Productivity and Lean class in the Department of Construction Science at Texas A&M University. Students were requested to use graph paper, excel, etc., to graphically capture the flow of activities along a timeline: (a) *before* leaning the process, and (b) *after* leaning the process. Participants were then asked to respond to the following questions:

i. Which processes are waste? List them and/or circle them.
ii. What metrics could you use to quantify the improvement?
iii. If you were to design a Scenario III, can you think of any additional actions that could be taken? If so, what are they?

The intent of the assignment was to help students learn to see waste by communicating with simple graphics. The students were given 30 hours to complete this assignment. The authors of this paper discussed during the class some of the most interesting approaches submitted by the students. The authors also briefed the class about Value Stream Mapping, the eight wastes found in Scenario I, and improvements made during Scenario II. The authors of this paper presented opportunities to visually capture the processes in the form of a timeline, Gantt chart, and spaghetti diagram to map both scenarios. Ultimately, the students were asked to individually offer feedback on what they liked about the exercise (i.e., "plus") and what they thought could be improved ("delta"). The plus/deltas were collected anonymously to encourage frank responses.

For two additional first run studies, the authors of this paper ran the simulation during a Zoom meeting with 9 experts from the San Diego Community of Practice, and then later, with 14 Zoom participants during an APLSO (Administering and Playing Lean Simulations On-Line) meeting. Participants were asked to sketch a spaghetti diagram on top of provided kitchen floor plans which were sent out before the meeting and which participants could print. In addition, they were asked to respond to an online survey which asked about their education, current profession, past training regarding VSMs, and perceived effectiveness of Gantt Charts and Spaghetti Diagrams versus the conventional method of VSMs (i.e., ranking effectiveness along a 1-7 Likert scale). Respondents were also invited to share recommended plus/deltas and potential applications to construction.

EVALUATION AND RESULTS

Participants of the primary first run study included 48 graduate students taking an in-person lean construction course with no prior familiarity with the concept of VSM. Students came up with different ways to graphically represent their ideas and value stream map the processes portrayed in the video. They used a combination of tools to present their assignments. Most students used a table listing activities and their durations, a line chart, screenshots from the video, sketches, and bar charts / histograms to represent their observations. Others used color-coding, Gantt charts, and flow charts to visually capture and quantify differences between Scenarios I and II. A few students created spaghetti diagrams, conventional VSMs, AON diagrams, timelines, and other creative graphics (Figure 13). The authors of this paper selected several representative assignments and presented them in class for general discussion. The students discussed whether they would be persuaded by the chosen tool or graphic if they were the manager of a construction company and an analyst presented the visual to them to improve their decision-making.

The students mostly agreed that they could not immediately understand the data presented in the flow charts of conventional VSMs since they require a substantial understanding or prior training in VSM symbols.

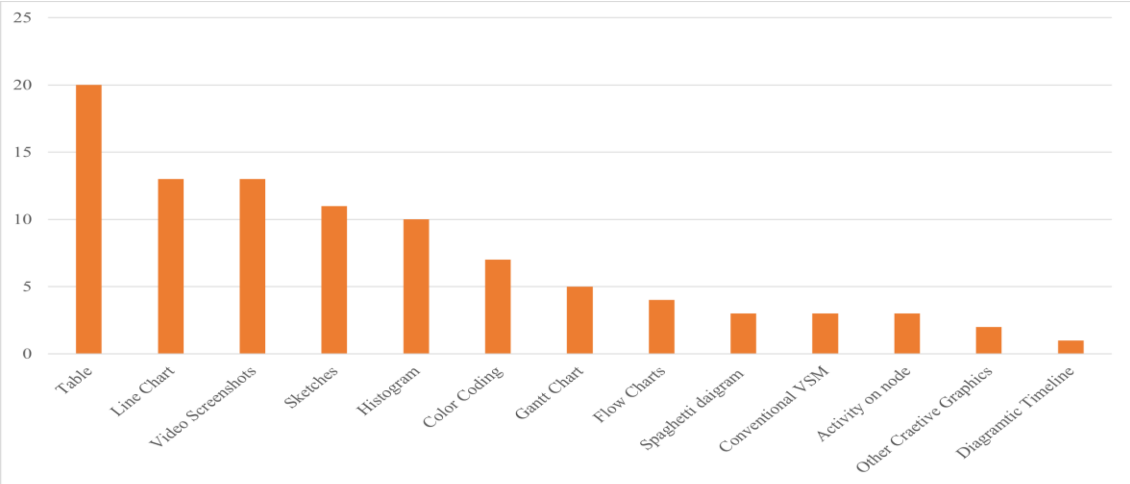

Figure 13. Frequency of the tools utilized by the students

By contrast, assignments that included tools such as tables, bar graphs, Gantt charts, color-coding, and timelines were more successful in being understood by construction management students who were new to the concept of VSMs.

Furthermore, the authors presented their diagnostic tool consisting of a timeline, Gantt chart, and spaghetti diagram for scenarios I and II (Figures 14, 15, and 16). Following class discussions, individual student feedback was collected via an online survey about what they felt worked with the given exercise (i.e., "plus") and what they thought could be improved (i.e., "delta"; Table 1).

To demonstrate that incremental improvements should be continual, the authors challenged participants to suggest an additional scenario. Based on collective feedback to include an island in the middle of the kitchen, movements were further reduced (Figures 15, 16, & 17), generating Scenario III—and time was further reduced by 10 seconds.

A modified version of the simulation representing Scenario III was then shown via Zoom to a group of 9 construction experts and they were asked to fill out a Google Form™ survey at the end of the session. Demographics from the survey reveal that 54.2% of the participants had a formal education in construction, 20.8% have a formal engineering education, 8.3% were educated in operations management, 8.3% in architecture, and 8.3% in technology and project delivery. Of the participants surveyed, 25% currently work in construction firms, 23.3% work as consultants, 8.4% in architectural and engineering firms, and the remaining are members of academic faculty or students. A large number of the participants (75%) stated that they were given prior training in VSM.

Respondents verbally expressed that the visual simulation was easy to understand. Of those surveyed, 91.7% assigned the proposed Gantt Chart and Spaghetti Diagram a Likert score of five and above (5, 6, &7) while 75% of participants gave the conventional VSM method a score of five and above (5, 6, & 7). Respondents also stated that they preferred the proposed VSM formats (Figure 15, 16, & 17) over the conventional form of VSMs (Figure 14). This is likely because constructors have more experience with Gantt charts.

Table 1. Plus & Delta on the VSM Exercise

Plus	Delta
• Simple / Easy to understand / Straightforward • Good graphical representation • Practical & Generic • Helps in critical thinking and problem solving • Good attention to details • Helps in deep understanding of value-added & non-value-added activities • Lucid and effective way to show continuous improvement • Shows application of learning in real life • Helps in raising a broader perspective / Brainstorm • To the point (Short video while delivering the concept) • Encourages student involvement in the class • Helps present different ideas graphically • Helps to think out-of-the-box • Explains the basics of lean using a simple example • It is a fun and innovative exercise for learning VSM • [It] encourages to learn more about how to better qualify [and] quantify specific metrics	• Commercial setting instead of a private setting • rearrange the kitchen for the optimized scenario • Give more instructions on the exercise • Use construction-oriented example • Use the real time needed for cooking activities • Distances should be calculated in both scenarios

Also, they noted that the Gantt Chart is understood with interrelated and multiple tasks that could have an impact on others. Besides, there was a consensus among the experts that the presented simulation is an excellent tool for teaching the fundamentals of Lean and introducing the concept to individuals unfamiliar with the idea of VSM. Furthermore, they mentioned that Value Stream Mapping could help streamline practices in the concrete construction activities, material delivery to the job site, logistics, area-based scheduling, manufacturing, process document management in the trailer, information management on the jobsite, and any repetitive tasks in construction.

RESEARCH SCOPE AND LIMITATIONS

The developed simulation is intended to help expose students and practitioners to VSM as a means to convey foundational Lean concepts such as waste, value, cycle time, takt time, and flow. The simulation is designed to depict processes and wastes graphically.

IMPLICATIONS

Value Stream Mapping is a tool used to think through a current situation, identify potential wastes in the process, and ultimately develop an improved future state map. The ultimate intended value of this work is to help users improve workflows.

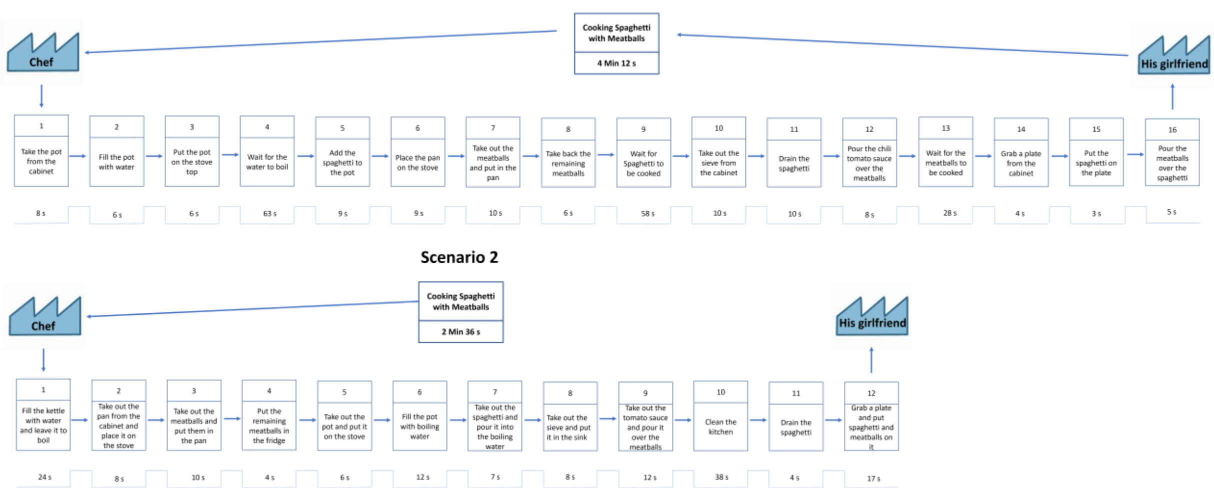

Figure 14. Conventional VSM for Spaghetti Making Process

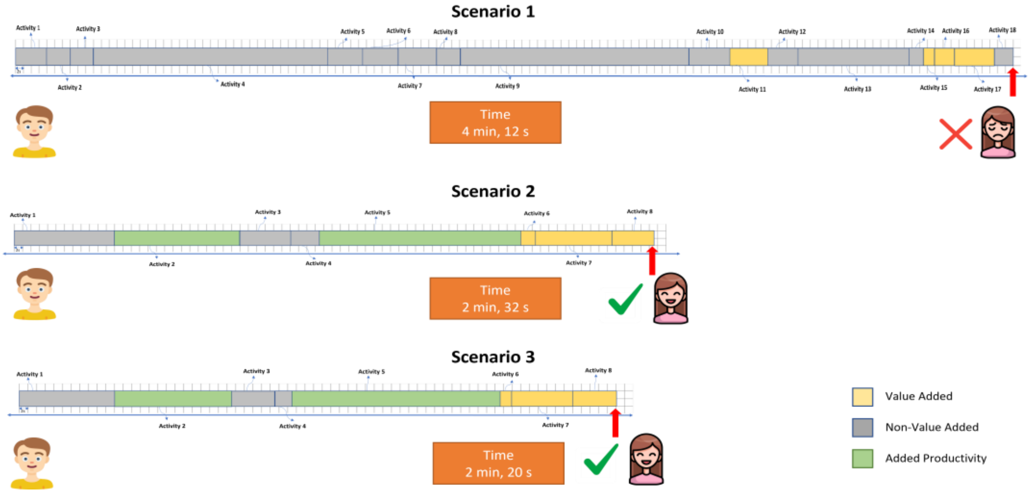

Figure 15. Comparison of Three Scenarios using Timeline

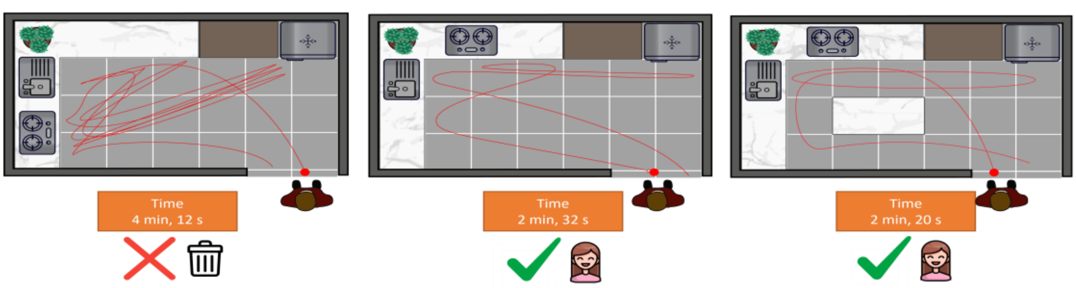

Figure 16. Spaghetti Diagrams for Three Scenarios

Figure 17. Comparison of the Scenarios Using Gantt Chart

CONCLUSION

This paper reports on the development and testing of a novel simulation as a preliminary study to expose participants to the utility of Value Stream Mapping as a means to identify and remove the eight wastes from processes. As part of the simulation, a graphic video was created to depict the process of making spaghetti. As a first run study, the simulation was tested on (i) 48 graduate students taking an advanced productivity and lean course in the Department of Construction Science at Texas A&M University; (ii) 9 experts from San Diego Community of Practice; and (iii) 14 participants at a meeting of the Administering and Playing Lean Simulations Online (APLSO) community.

Results from the first run studies showed that most participants liked the graphics of the videos, and found it simple and easy to understand. Additionally, there seemed to be a consensus that the designed exercise encourages participants to generate innovative ways represent process flow to the construction industry.

There also appeared to be general agreement among experts that the presented simulation is an excellent tool for teaching the fundamentals of lean and introducing the concept of VSM to individuals previously unfamiliar with the concept.

The authors of this paper observed that by sharing the simulation video and by implementing a Gantt chart to represent current and target conditions, students and practitioners trained in construction felt comfortable applying VSM to construction processes. While the conventional VSM format is perhaps well suited for many engineering and manufacturing applications—especially for those with prior VSM training—results from this research suggest there are additional and alternative ways to map construction processes that may be more aligned with the conventions of those trained in the construction industry.

AKNOWLEDGMENTS

The authors express their appreciation to the students of COSC 631 ("Advanced Productivity and Lean") at Texas A&M University, members from the San Diego Community of Practice, and the international research community of APLSO (Administering and Playing Lean Simulations On-Line) for their valuable feedback that helped in the continuous improvement process of the VSM simulation.

REFERENCES

Bhatnagar, S.,& Devkar, G. (2021). Development and Testing of a Simulation Game on Waste Elimination Using Lean Practices. *Proceedings of the 29th Annual Conference of the International Group for Lean Construction (IGLC).* Lima, Peru, 14-16 Jul 2021, 330-339.

Brouwer-Hadzialic, L., & Wiegel, V. (2016). Case study: Using value stream mapping in the educational process - How focusing on student actions can help depict the teaching process. *International Journal of Six Sigma and Competitive Advantage*, 10(1):50.

Germano, A. V., Fonseca, N. J. M., Melo, R. S., & Moura, A. (2017). Value stream mapping: Case study in columns concreting. *Proceedings of the 25th Annual Conference of the International Group for Lean Construction (IGLC)*. 9-12 July 2017, Heraklion, Greece.

Haefner, B., Kraemer, A., Stauss, T., & Lanza, G. (2014). Quality value stream mapping. *Procedia CIRP* (17), 254-259.

Hamilton, B. (n.d.). *Toast Kaizen: An introduction to Continuous Improvement & Lean Principles*. GBMP, Retrieved May 21, 2022, from <www.gbmp.org>

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.

Kapp, K. M. (2012). *The Gamification of Learning and Instruction: Game-based Methods and Strategies for Training and Education*, San Francisco, CA: Pfeiffer.

Kanai, J. & Fontanini, P. S. P. (2020). Value Stream Map and Visilean® for Prefabricated Concrete Panels Management. *Proceedings of the 28th Annual Conference of the International Group for Lean Construction (IGLC).* Berkeley, California, USA, 6-10 Jul 2020, 673-684.

Kavosa, M., & Lapiņa, I. (2020). Value Stream Mapping: Effective Process Improvement Tool in the Certification Process. *Proceedings of the 24th World Multi-Conference on Systemics, Cybernetics and Informatics (WMSCI 2020)*, 3, 59-64.

Liker, J., &

Meier, D. (2005). *The Toyota Way Field Book*, McGraw-Hill, New York.

Lobaugh, M. (2008). The value of value stream mapping to students," *2008 Annual Conference & Exposition,* American Society for Engineering Education. Session 2740.

Maghool, S. A. H., Moeini, S. H. I., & Arefazar, Y. (2018). An educational application based on virtual reality technology for learning architectural details: Challenges and benefits. *ArchNet-IJAR: International Journal of Architectural Research*, 12(3), 246.

Morlock, F., & Meier, H. (2015). Service value stream mapping in industrial product-service system performance management. *Procedia Cirp, 30,* 457-461.

Oberhausen, C. and Plapper, P. (2015). Value stream management in the lean manufacturing laboratory. *Procedia Cirp*, 32, 144-149.

Ohno, T. (1988). *Toyota Production System: Beyond Large-Scale Production*. Productivity Press, Cambridge, MA.

Pollesch, P., Rovinsky, A., Alvarado III, R., & Alves, T. C. L. (2017). House of cards–a simulation of lean construction principles. *Proceedings of the 25th Annual Conference of the International Group for Lean Construction (IGLC)*, 373-380.

Prensky, M. (2007). *Digital Game-Based Learning,* Paragon House Publishers, St Paul, MN.

Petruska, B. (2014). Pizza Game. <https://bobpetruska.com/pizza-game/> (May 21, 2022).

Rahani, A. R., & Al-Ashraf, M. (2012). Production flow analysis through value stream mapping: a lean manufacturing process case study. *Procedia Engineering, 41*, 1727-1734.

Ramalingam, S. (2018). Mapping of BIM process for teaching lean. *Proceedings of the 26th Annual Conference of the International. Group for Lean Construction (IGLC),* González, V.A. (ed.), Chennai, India, 1291– 1301.

Rother, M., & Shook, J. (2009). *Learning to See: Value Stream Mapping to Add Value and Eliminate Muda*, Lean Enterprise Institute, Cambridge, MA.

Rybkowski, Z. K., Forbes, L. H., and Tsao, C. Y. (2020). "Chapter 19: The evolution of lean construction education at US-based universities," *Lean Construction: 25 years of development*, edited by Patricia Tzortzopoulos, Mike Kagioglou, and Lauri Koskela, Taylor and Francis. 387-407.

Shannon, P. W., Krumwiede, K. R., & Street, J. N. (2010). Using simulation to explore lean manufacturing implementation strategies. *Journal of Management Education*, 34(2), 280-302.

Simonsson, P., Björnfot, A., Erikshammar, J., & Olofsson, T. (2012). Learning to see the effects of improved workflow in civil engineering projects. *Lean Construction Journal*, 35-48.

Tsao, C.C.Y. and Howell, G.A. (2015). A history of the use of simulations, the parade of trades, and the pull planning technique in lean construction learning and development. *White Paper,* March 03.

Womack, J. P., & Jones, D. T. (1996). Beyond Toyota: How to root out waste and pursue perfection. *Harvard Business Review,* 74(5), 140-172.