Obulam, R. and Rybkowski, Z. K. (2021). "Development and testing of the 5S puzzle game" *Proc. 29th Annual Conference of the International Group for Lean Construction (IGLC29)*, Alarcon, L.F. and González, V.A. (eds.), Lima, Peru, pp. 309–319, doi.org/10.24928/2021/0152, online at iglc.net.

DEVELOPMENT AND TESTING OF THE 5S PUZZLE GAME

Rajeswari Obulam[1] and Zofia K. Rybkowski[2]

ABSTRACT

Lean methods were originally developed in the manufacturing industry in the early 20th century to reduce the use of resources that did not contribute to added value. In the 1990's, there was steady growth in a movement to replicate the successes of manufacturing in the construction industry. By effectively deploying lean methods on the construction site, material and human labor that was expended with no increase in the value of the constructed work can either be reduced or reapplied to increase value.

The 5S methodology was originally developed in Japan and implemented by Toyota. The 5S system is a type of visual management tool used to handle and maintain workplace organization and efficiency. The 5S method has been adopted by lean thought leaders to improve productivity by more rigorously organizing the workplace via five sequential steps: sort, set in order, shine, standardize, and sustain.

Inspired by a popular participatory simulation to introduce players to 5S, this "5S Puzzle game" simulation was created to present the topic in a way that is more aligned with the way construction companies practice. This simulation was developed to be administered on-line in either of two ways: (1) with a single individual, or (2) with up to 4 players. The puzzle session consists of five rounds, each representing one of the S's that help a player progress from low levels of efficiency to maximally efficient processes. The stated goal of the simulation is to complete the puzzle. The actual goal is to help players experience an "aha" moment by quantifying the impact of each successive step as the player(s) progress through each round.

KEYWORDS

Construction sector, serious game, simulation, 5S, continuous improvement.

INTRODUCTION

Lean principles have been practiced in manufacturing in Japan because of observed results in enhanced performance; time to completion, cost, quality, safety, and employee morale have been shown to improve.

[1] Graduate student, Department of Construction Science, Texas A&M University, College Station, TX, 77843 USA, o: (979) 845-4354, raji.obulam@gmail.com, orcid.org/0000-0001-6739-9747

[2] Associate Professor, Department of Construction Science, Texas A&M University, College Station, TX, 77843 USA, o: (979) 845-4354, zrybkowski@tamu.edu, orcid.org/0000-0002-0683-5004

According to Womack and Jones (2003), the principles of Lean production can be summarized in the following manner:

- Specify the product's value;
- Identify the value stream;
- Create uninterrupted flow in the value stream;
- Pull to consumer demand; and
- Target perfection.

Lean thought has seeded the development of successful tools for organizations to overcome unpredictability which is present in various stages of projects in the industrial sector, especially when resources are restricted (Shah and Ward 2007). This has motivated other sectors to implement lean practices (Ohno, 1988).

Lean philosophy embraces continuous improvement. 5S methods are considered to be one of the essential pre-requisites for implementing lean and can act as an important tool to improve an organization by reducing waste and optimizing costs (Lake 2008). Rich et al. (2006) describe 5S as a visual management tool of lean implementation.

5S represents five main principles which phonetically begin with "S." The first "S" stands for *Seiri*, which means to *sort* by removing unnecessary elements; the second represents *Seito*, or to *set in order* by organizing all the elements based on their function; the third represents *Seiso*, shine or clean by removing sources of dirt; the fourth represents *Seiketsu*, or *standardize* by "freezing" a system; and finally the fifth "S" *Shitsuke*, refers to *sustain* to ensure the system is maintained (Osada 1991; Table 1).

Table 1: Explanation of 5S

Japanese words	English translation	Meaning
Seiri	Sort	Sort through all items and remove unnecessary items.
Seiton	Set in order	Place all items in an optimal position.
Seisō	Shine	Clean the workplace and all relevant materials on a regular basis.
Seiketsu	Standardize	Standardize the processes used to sort, order and shine.
Shitsuke	Sustain	Ensure that the progress is maintained.

It has been observed that number of companies prefer to start with 5S as an entry point to lean to offer an "easy win" (Anderson and Mitchell, 2005). A case study where the 5S method was implemented led to impressive improvements in a pharmaceutical plant. For example, mistakes made when picking up items for reuse were significantly reduced when dedicated transport carts were used. A template was created to indicate where specific parts should be stored (Bevilacqua et al. 2015).

Other case studies concluded that 5S, when applied to healthcare services and small-scale industries resulted in cleaner, more organized workplaces with increased safety and productivity, decreased inventory, supply costs and overhead costs (Young 2014; Khedkar et al. 2012).

This paper documents the development and testing of a new simulation to familiarize employees with the 5S method. The objective behind developing this simulation was to build up a simple yet scalable game that would empower a facilitator to lead a group of participants to instinctively understand the advantages of lean because of the progress achieved during the simulation. In this simulation, principles of 5S are used to achieve the target condition by slowly reducing waste and creating an sample template that helps maximize efficiency and productivity.

Although simulations have existed for some time, their application as a mode for training has not been fully explored. Simulations act as a visual tool to assist in decision-making and to help participants understand learning outcomes. In a typical lean simulation, participants are introduced to a challenge and invited to tackle it given a set of specified constraints (Rybkowski et al. 2020). Multi-player simulations also allow teammates to collaborate and communicate with other players.

The development of interactive, visual, computerized technology has contributed to the popularity of simulations by rendering them more realistic, relatable and interactive (Gouveia 2011). Arguably, the most effective teaching methods are those that encourage learners to objectively practice and to reflect (Bransford et al. 2003). Outcomes from some research suggest that using computer simulations may be a more effective way to teach than traditional forms (Cassidy 2003, Sacks et el 2007, Tommelein et el 1999 and Visionary Products Inc. 2008).

A 5S instructional simulation already exists and is widely played by lean educators (Figure 1) sequentially demonstrating the principles of continuous improvement through 5S (Super teams n.d.). It has since been adopted by those who teach lean construction as well. Despite the game's increasing popularity, a few gaps were found in the simulation and its design if transitioned to an on-line format—e.g. inability of players to visualize progress if played online/virtually, frustration in locating numbers of smaller font, and perhaps most importantly, difficulty in relating 5S to applications for those working in the construction sector. The purpose of developing and testing a new "puzzle" format of this simulation was to fill these gaps.

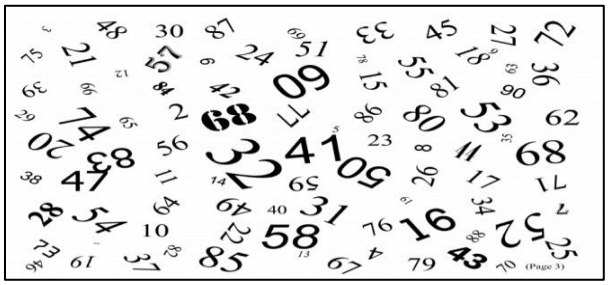

Figure 1. Reprinted from Super Teams 5S Game Handout.

METHODOLOGY

The 5S puzzle simulation presents five sequential steps of continuous improvement from a current state (worst-case scenario) to a target (ideal) state. The puzzle pieces were created using the website (TheJigsawPuzzles.com n.d.) where the depicted scene on the puzzle was purposely selected, under a creative commons license, to represent a scene from the built environment (Ratcliff). Reported results are from a first-run study with graduate students

from an introductory on-line lean construction course in the Spring of 2021 of 40 students where 3 individuals volunteered to play and 37 to observe and complete feedback forms. The semester-long course was administered on-line via Zoom™ due to COVID-19 and the simulation was facilitated using editable Google Slides™, while observers gave feedback via a link to a Google Form™ provided in the Zoom chat. Observers watched player performance using the "share screen" function of Zoom. Participants were informed at the start of play that the objective was to complete the puzzle as quickly as possible. The facilitation process is described in the following sections.

DESCRIPTION OF THE SIMULATION

A brief slideshow was presented comprising the rules before the simulation begins and questions from participants were clarified. Guidelines for the game were as follows:

- Each team has four players: three will assemble the puzzle and one will keep time;
- During a single round, each player is given 30 seconds to complete the puzzle as much as s/he can before passing on to the next player to take over, for a total of 1 minute 30 seconds;
- Players are instructed to not resize, rotate, or delete the pieces;
- There is to be no verbal communication between team members;
- There will be a brief discussion after each round.

FLOW OF THE SIMULATION

The simulation was facilitated using the following schedule and the sequence is as mentioned in Table 2:

Table 2: Flow of simulation and time taken.

Interval	Time (Minutes)	Description
1	10	Briefing
2	3	Game demonstration
3	1.5	*Round 1:* Simulation about the current condition.
4	1	Evaluation form for round 1
5	1.5	*Round 2:* Simulation with waste/unwanted materials removed from site.
6	1	Evaluation form for round 2
7	1.5	*Round 3:* Simulation with a template.
8	1	Evaluation form for round 3
9	1.5	*Round 4:* Simulation with a template containing the image and the materials arranged.
10	1	Evaluation form for round 4
11	1.5	*Round 5:* Simulation at target condition.
12	1	Final Evaluation form
13	10	Final explanation and Q&A
	35.5	Total time required (minimum)

SIMULATION SEQUENCE

Round 1 exemplified a worst-case scenario with the presence of unwanted materials on a construction site, as well as a complete lack of organization. It was observed that players tended to try to complete the puzzle by searching for relevant puzzle pieces scattered among unwanted pieces; they typically separated them, and then placed them in what they perceived to be their correct positions within their given 30 seconds. The game was completed when each of the three players sequentially had a chance to play and a total time of one minute thirty seconds was reached. A screenshot of the 5S Puzzle simulation during Round 1 is shown in Figure 2. The number of correctly joined puzzle pieces was recorded at the end of each round after time is up.

The players were not permitted to verbally communicate or help one other in any way. This round has typically been shown to be the least efficient in terms of performance and was purposely designed to frustrate players by the inclusion of unwanted pieces in disarray. These conditions resulted in players considering ways to improve efficiency and productivity in the limited time. In this trial first-run-study, players were on average able to fit 7 pieces out of 20 correctly.

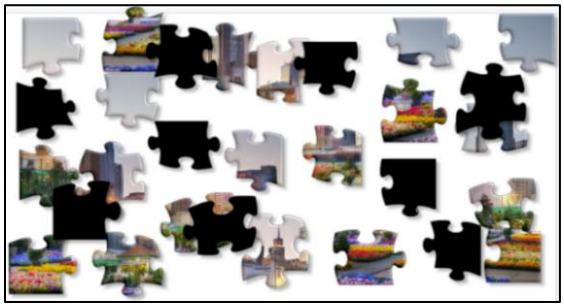

Figure 2: Round 1 of the 5S puzzle game.

Figure 3: Round 2 of the 5S puzzle game.

During round 2 (Figure 3), players proceeded to a modified slide where *sorting* had already been completed, and waste/unwanted (black pieces) materials had been removed (improved site conditions). This revised gameboard represented a more orderly workspace where only relevant materials were included. In the experimental trial, players improved their performance by fitting on average 12 pieces out of 20 correctly. This is 5 more correct placements than during Round 1.

Round 3 (Figure 4) built upon improvements previously made; however, a template was also introduced. The template gave players an idea of the size of the puzzle and acted as a guide for the precise positioning of each piece. During Round 3 of the experimental trial, players were able to improve upon their performance of previous rounds, fitting 16 pieces out of 20 correctly—4 more than during Round 2. This round represents the second "S"—*set in order*.

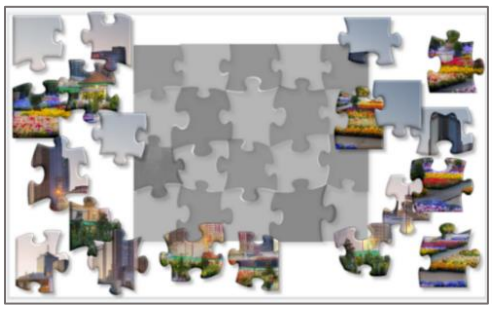

Figure 4: Round 3 of the 5S puzzle game.

Figure 5: Round 4 of the 5S puzzle game.

During Round 4, to improve upon the immediately previous performance, the same template now included a superimposed watermark of the puzzle image (Figure 5). A table was created on either side of the template and all the pieces were displayed in the table—although out of order. In this round the players were able to fit 17 pieces out of 20 correctly. The intent of this round was to help quantify impacts of the third "S"— *shine*.

In the final round, the side tables had been additionally numbered, as was the template, and all the pieces were arranged and placed methodologically and in order within the side tables (Figure 6). This appeared to significantly increase the players' ease in finding pieces and completing the puzzle. This was the most efficient round, as the players were able to fit all the pieces of the puzzle correctly within the first 30-seconds of the game.

Figure 6: Round 5 of the 5S puzzle game.

EVALUATION AND RESULTS

Participants of this primary first run study included a group of 40 graduate students taking an on-line Lean Construction course using Zoom. The simulation was played using editable Google Slides. Before the simulation began the students were shown a brief presentation explaining the rules of the game. The facilitator enlisted the help of three volunteers who moved the puzzle pieces during each timed round, while the rest of the class observed using the "screen share" function of Zoom. Observers were sent a link in the Zoom chat box to an on-line random number generator so researchers could link participant comments between rounds while maintaining participant anonymity. At the end of each round observers were sent links to an evaluation form using Google Forms and asked to complete the forms anonymously by consistently inputting the same random number that was personally generated by them at the start of the game.

The full set of questions asked in the evaluation form at end of each round were:

- Please enter the three-digit number you got at the random number generator.
- What appeared to get in the way of achieving a higher score?
- How do you feel about the score?

Participants were asked to input the same random number in each successive evaluation form and the number was only known to the participant. All responses were collected and tabulated in a spreadsheet. The questions in the evaluation form were chosen to assess whether the game was intuitive and helped participants understand the 5S method. At the end of play, observers were then introduced to the 5S numbers game by Superteams (n.d.). Since the 5S Numbers game already existed and was being widely played by educators and consultants in the lean construction community, the purpose of facilitating the 5S Numbers Games as well with the same participants was to determine whether or not it made sense to continue developing and improving the new "puzzle" version of the simulation.

Therefore, in the final evaluation form, participants were asked two additional questions:

- In what ways was the PUZZLE GAME especially helpful in illustrating 5S?
- In what ways was the NUMBERS GAME especially helpful in illustrating 5S?
- If you could recommend only one game for further development, which one would it be? (choose one):→5S Puzzle Game →5S Number Game

All the evaluation forms were collected anonymously, and the data tabulated in a spreadsheet for later analysis (Appendix).

The number of puzzle pieces that were correctly placed at end of each round was recorded to determine the efficiency and productivity rate in each round. The percentage of the puzzle completed was calculated by dividing the number of puzzle pieces placed correctly by the total number of puzzle pieces. This helped quantify the impact of each intervention as the game progressed. The data collected during the trial with the graduate students is shown in Table 2.

Eighty five percent (85%) of observer respondents agreed that the game demonstrated positive learning outcomes (Table 3). This suggests that the simulation creates an environment corresponding to its intended goal. They also agreed that the game allowed them to better understand the 5S method as applied to construction. This may be in part, because the *5S Numbers Game* requires participants to cross out numbers, while the 5S puzzle game more accurately replicates the process of active movement of objects required on an actual construction job site.

After completing the questionnaires, participants also gave verbal feedback. During a debrief, the facilitator engaged players in discussion about the logic of the ordering of the 5S's to minimize wasted labor; for example, the facilitator explained why *sort* should come before *set-in-order*; and *set-in-order* before *shine, etc.* Participants were also shown before and after photographs of 5S as applied to actual construction processes.

At a minimum, the simulation may take between 20 to 35 minutes to play with an additional 10 minutes at the beginning of the game for explanation of rules. Realistically, however, facilitators should allocate at least 90 minutes to include feedback and discussion.

Table 3: Percentage completion/ efficiency as the rounds progress

Round #	Total number of puzzle pieces placed correctly (out of 20)	Percentage completion/ efficiency of the round
1	7	35%
2	12	60%
3	16	80%
4	17	85%
5	20	100%

Table 4: Evaluation of the 5S puzzle game versus the 5S number game

Name of simulation	Total number of volunteers selecting the simulation	Percentage of volunteers selecting the simulation
5S puzzle game	34/40	85%
5S number game	6/40	15%

LIMITATIONS

One limitation of this simulation as played was that the sequential process meant participants also learned the intended location of various puzzle pieces, meaning a learning curve was likely also responsible for the improved performance. It is recommended that future experiments be conducted where different teams play only one step and results are aggregated. Also, this was a first run-study; more definitive tests need to be conducted on a statistically significant sample size.

CONCLUSION

This paper reports on the development and testing of a new on-line simulation with the primary goal of developing an understanding by participants of the principles of 5S. It represents a perceived improvement, based on preliminary data, on the 5S Numbers game, which is becoming increasingly popular with lean construction educators.

According to our first-run study, this simulation (the 5S Puzzle game) appears to overcome the limitations sometimes observed in the 5S Numbers game by providing a board on which pieces are actively moved. The original contribution of this research is that it demonstrates that creating pieces that move make it easier for those learning 5S to make the mental link between 5S principles and their manifestation on an actual job site. Additional experimentation is necessary to eliminate improvements likely caused by learning curve in addition to the 5S interventions.

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APPENDIX: TABULATED RESULTS COLLECTED FROM OBSERVERS' GOOGLE FORMS.

Three-digit random number	In what ways was the PUZZLE GAME especially helpful in illustrating 5S?	In what ways was the NUMBERS GAME especially helpful in illustrating 5S?	If you could recommend only one game for further development, which one would it be?
155	*	*	5S Puzzle Game
158	It helped us understand the importance of organization	*	5S Puzzle Game
167	To understand and practically explain how 5S can be implemented	To understand how sorting and ordering can help you at its best.	5S Puzzle Game
219	gradual application was good	easier than the puzzle game	5S Puzzle Game
250	It shows that order helps a lot in efficiency	It shows that organization helps seed up the process with organization	5S Puzzle Game
253	It showed us the various steps of the 5S we needed to learn	how a random and reversed and different numbers can be confusing	5S Puzzle Game
263	Team work, improving productivity, follow the basic system	To standardize the process	5S Puzzle Game, 5S Numbers Game
295	Recognition.	organization	5S Puzzle Game
328	organized	it actually was not helpful.	5S Puzzle Game
397	Very helpful	Ok	5S Puzzle Game
453	shine	order	5S Numbers Game
519	The S's were followed by the distinction of colors	The players had to focus on the size and rotation to be able to get them in order.	5S Puzzle Game
534	Yes	Practical Experiment	5S Puzzle Game
547	yes		5S Numbers Game
578	understanding that black pieces were causing distraction.	Knowing that order really matters	5S Puzzle Game
583	Helped by eliminating the defect in the system represented by the black pieces		5S Numbers Game
611	It helped in the way by providing with each S as the game proceeded to the next round	Similar to the Puzzle game, with the increase in the level the organization also increased.	5S Puzzle Game
624	Puzzle game showed how eliminating waste first is the best way to start	Numbers game was helpful in learning how to look ahead and plan what is coming next	5S Puzzle Game
639	Illustrating the order of the 5S does matter and gives a easy example to follow	It can illustrate sorting and setting in order is important	5S Puzzle Game
647	We learn how to put things in proper way	proper functioning	5S Puzzle Game
648	Increase in score shows how the performance was improved in the puzzle game following the 5S .	It helped in sorting and, better visualization of the numbers	5S Puzzle Game

657	after sorting the unwanted pieces, it saves it and I think 5S will help a lot if followed	after setting the numbers in order it really easy because we are more familiar with numbers than the picture we have seen for the first time	5S Puzzle Game
Three-digit random number	In what ways was the PUZZLE GAME especially helpful in illustrating 5S?	In what ways was the NUMBERS GAME especially helpful in illustrating 5S?	If you could recommend only one game for further development, which one would it be?
659	*	It showcased the order clearly	5S Puzzle Game
661	sorting, shine	set in order, sort, standardize	5S Puzzle Game
694	The time management is the key to have good productivity and we could exactly done work on this thing with the help of these 5S.	The puzzle one is better.	5S Puzzle Game
748	It showed you how the order can improve efficiency.	It promotes order	5S Puzzle Game
777	The vivid hints allow for lucidly differentiating between the all the 5s	Less helpful	5S Puzzle Game
810	walked us through the steps	*	5S Puzzle Game
837	It followed the sequence. All aspects were covered while playing the game. It was seen how each S was represented in each round.	We had the time to play R1 and R4 only. But it sort of represented the order of the 5S's. That's good.	5S Puzzle Game
840	Direct application of the concepts	Order of things	5S Numbers Game
863	Yes	Yes	5S Puzzle Game
880	sorting - it helps showing you how sorting can be really important to fit the puzzle pieces together.	again, it helps to see how sorting between the numbers can have a big impact because once you have spotted and sort out the number, you can continue to the next sequence. the only problem is that you would have to be able to identify where the numbers are first.	5S Numbers Game
880	to organize things in a quick manner	if we can follow a set of principles will arrange it would make the work easy	5S Puzzle Game
912	The puzzle game was helpful in illustrating 5S because it included the extra black pieces which helped to show that distractions and waste can exist and it is important to identify them.	It helped to keep you on your toes and really solidified the sort aspect of 5S.	5S Puzzle Game
951	Puzzle Game	Sorting and setting order	5S Puzzle Game
982	each round explained clearly the aim of the game	each round made it easier to understand 5S	5S Numbers Game
992	Sorting and standardizing were easy to observe	Was more challenging, Sorting and standardizing were easy to observe	5S Puzzle Game

*respondent left the question blank.