Ng, M.S. & Chen, Q. (2025). Perceptions of lean concepts from Japan: using an interactive game to teach lean terminology. In O. Seppänen, L. Koskela, & K. Murata (Eds.), *Proceedings of the 33rd Annual Conference of the International Group for Lean Construction* (IGLC33) (pp. 1506–1515). https://doi.org/10.24928/2025/0194

# PERCEPTIONS OF LEAN CONCEPTS FROM JAPAN: USING AN INTERACTIVE GAME TO TEACH LEAN TERMINOLOGY

**Ming Shan Ng [1] and Qian Chen [2]**

## ABSTRACT

Lean terminology is commonly used and taught in the construction industry within the context of a production factory scenario, which could limit the perception of lean concept. This makes it challenging for industry practitioners, researchers and students to fully understand and implement these concepts in practice. Nevertheless, many lean concepts such as *kanban* that translates to "visual signage" in English are deeply rooted in daily scenarios in Japan. A comprehensive perception of lean concepts can potentially assist in thorough lean adoption beyond the production lines. However, there is little research that studies the perception of lean concepts in scenarios other than that in the typical production factory. To address this gap, this study presents the research titled "Beyond production lines: Perceptions of lean terminology from Japan" using an interactive game to teach lean terminology through relatable daily scenarios. The main purpose of this work is to investigate the perceptions. In the first phase of this study, 16 lean concepts were selected; four rounds of simulations were conducted involving 61 industry practitioners and students from diverse global backgrounds. The results reveal varied perceptions of lean concepts. The findings provide valuable insights and lay the groundwork for future research on lean education.

## KEYWORDS

Lean education, simulation, lean game, communication.

## INTRODUCTION

Lean terminology and concepts were established and originated in the Toyota Production System from Japan (Ohno, 1988). Industry practitioners and researchers in the manufacturing industry, the automobile industry and the construction industry etc. have been looking for ways to apply lean concepts in organisation settings (Macomber & Howell, 2004). They still use the original lean terms in the Japanese language when referring to some lean terminology. For example, *kanban* has been more widely used than its English term "visual signage" in lean practice; *jidoka* has been more commonly used than its English term "autonomation". Generally, these "lean terms" are being used in everyday life in Japan and they are associated with the culture in Japan to different extents. However, outside of Japan, these terms in Japanese are merely being used and taught within the context of a production factory scenario.

[1] Professor, Center for the Possible Futures, Kyoto Institute of Technology, Matsugasaki Hashikamicho, Sakyo-ku, Kyoto, 606-8585, Japan, ng@kit.ac.jp, orcid.org/0000-0003-2610-3561.

[2] Assistant Professor, Construction Integration and Digitalization (CID) Lab, Faculty of Applied Science, School of Engineering, The University of British Columbia, 1137 Alumni Ave, Kelowna BC, V1V 1V7 Canada, qian.chen@ubc.ca, orcid.org/0000-0002-5899-9342.

In the construction industry, lean concepts have been gradually adopted from the manufacturing industry and the automobile industry (Common et al., 2000). Recently, the industry has been moving towards the manufacturing industry partly due to the adoption of industrialised construction with standardisation, modularisation and prefabrication, as well as innovative business models such as “Building as a Product” and “Building as a Service” (Ng et al., 2023). Also, construction processes have been adopting digitalisation and automation to boost productivity and efficiency (Chen et al. 2018). To efficiently manage the adoption of industrialised construction, innovative business models, digitalisation and automation, lean concepts are emerging in the industry to ensure value adding and waste reduction to different extents (Macomber & Howell, 2004; Ng and Hall 2019).

In current practice, lean education has been emerging amongst industry practitioners and at universities. For example, lean workshops are included in continuous professional development (CPD) to assist individual professionals, such as engineers and construction managers, and corporations to understand lean concepts and implement them on construction projects. Also, lean in construction is one popular topic in research in construction management; very recently, lean implementation to manage digitalisation and automation has been emerging in academia to bridge the gap between technology and project management (Chen, 2020; González. et al., 2022; Ng, 2022). At universities, lean is one core topic in construction management classes; promotion of lean education can improve management knowledge in a lean business system (Pearce et al. 2023); students learn lean concepts such as Target Value Design with interactive games (Rybkowski et al., 2016; Ng & Hall, 2021). In many cases, lean terminology is introduced to industry practitioners and students within the context of a production factory scenario. However, this limits perceptions of lean concepts beyond specified production lines, hinders practitioners and students from thinking out of the box to spur innovations in lean implementation. Also, this makes it challenging for industry practitioners, researchers and students to fully understand and implement these concepts agilely in practice for dynamic scenarios, which commonly happen in the construction industry.

Furthermore, recent scholarship studies perceptions in lean education to different extents. For example, Lodgaard et al. (2016) and Pearce et al. (2023) investigated lean perceptions in the manufacturing industry; Common et al. (2000) tested the transfer of lean principles to construction by studying the penetration into large construction companies; Salling et al. (2023) surveyed to understand the level of job satisfaction to identify the perception of project management amongst construction workers, so as to improve the efficiency in the construction industry. However, no research understands the perceptions of lean concepts in the construction industry. Also, there are few approaches to teach lean terminology with easy-to-understand daily scenarios beyond the production lines that could assist them in implementing lean concepts in construction.

To fill the research gaps, this study presents an original work of an interactive game titled “Beyond production lines: Perceptions of lean terminology from Japan” invented by the authors of this work. This answers the research question of how participants can understand lean terminology using easy-to-understand daily scenarios beyond the production lines. This article presents the first phase of the study. The learning objective of the game is to enhance participants’ understanding by connecting lean concepts to examples in everyday life. The purpose of this study is to investigate the perceptions of lean concepts beyond the production lines in typical lean education, which teaches lean within the context of a production factory scenario. The paper is structured as follows. The next secion presents the methodology and game description; this is followed by a section that presents the results of a case study of five rounds of five rounds of game simulations. The authors hence discuss the results and propose future research and conclude the work.

This study contributes to the field of knowledge in lean education with a study of the perceptions using an interactive game. Both the perception study and the game are original and have never been developed based on the authors' knowledge. This research of perceptions and the interactive game are both original and there is no precedent in using a game simulation approach to teach lean terminology and investigate the perception of lean concepts in architecture, engineering and construction fields. This study presents a hands-on teaching approach, with which the participants engage in the educational process to understand lean concepts using examples that can happen in everyday life. This study demonstrates how the popular lean concepts are being perceived in the industry and lays the groundwork for future research directions in lean education and implementation in practice. The results of this work can be further studied in future research to improve lean education in academia and practice.

# METHODOLOGY

This study aims to investigate the perceptions of lean concepts beyond the production lines using daily scenarios that can be commonly found in everyday life in Japan. In the first phase of the study, the authors selected 16 commonly-known lean concepts and conveyed them through relatable daily scenarios in everyday life in Japan and relatable culture in Japan to different extents. These concepts were selected because the terms have been commonly used in many lean classes and coaching sessions. Furthermore, the game presents 17 daily scenarios, which can be commonly experienced in everyday life in Japan and other countries. They are explained in details in the next section. This work shows the results of the first phase of the study, in which 61 industry practitioners and students from diverse global backgrounds participated in the game in person and online in five rounds respectively. The learning objective of the game is to enhance participants' understanding by connecting lean concepts to examples in everyday life. This study aims to investigate perception of lean concepts through the game.

## GAME DESCRIPTION

The game takes approximately 90 minutes. The interactive game in this work uses Google Slides (or slides in pdf format) to present the selected scenarios and the online platform – Slido$^{TM}$ –to collect and present real-time feedback provided by participants during the game simulation. Other software can also be used. At the beginning of the game, one moderator introduces lean and the history of lean originated from the Toyota Production System from Japan. The game has a pre-requisite that participants have a basic understanding of the presented lean concepts to reduce time spent on explaining the terminology. The moderator(s) then present a list of 18 choices that include the selected 16 lean terms listed in both English and Japanese, as well as "nothing to do with lean" and "I do not know/decline to answer". For each scenario, each participant is asked to select one choice from the list that best suits the scenario based on their perceptions of lean concepts; the moderators then present real-time the votes on Slido$^{TM}$ and discuss with the participants what lean concepts are associated with the scenario and why the participants selected their choices items from the list. The authors collected quantitative data from Slido$^{TM}$ and the discussions qualitatively for each scenario. The game ends with a reflection discussion with examples of the lean concepts in current practice in the construction industry, followed by a debriefing session to receive plus and delta from participants for the authors to further improve the teaching approach.

## 16 LEAN TERMS IN THE GAME

In the game, participants can select one out of the 18 choices which include 16 lean terms as follows. (L1)"Just in time" and (L6) "just right in amount (*pokkiri*)" refer to the delivery of work or inventory at the right time and in the right amount respectively (Tommelein & Li, 1999; Arbulu et al., 2003). (L2) "Pull system" refers to a thing that is produced or delivered only when it is needed and in the right amount (Tommelein, 1998). (L3) "Two-bin system (*nitanahou*)" refers to a system with two containers (bins) where one is drawn down of components and the other one is full acting as a buffer; when all components in one bin are used up, the empty bin serves as a "visual signal (*kanban*) to replenish. (L4) "Takt time" refers to work package or team size optimisation to fit the preferred rate of production (Vatne & Drevland, 2016). (L5) "Levelling (*heijunka*)" refers to adjusting and smoothing out inconsistencies in quantity such as time or manpower (Binninger et al., 2016). (L7) "Set-Based Design" refers to a design approach that allows decision-makers to review sets of design alternatives and integrate positive aspects of each set to look for design improvement (Parrish et al., 2008). (L8) "Target Value Design (*genka kikaku*)" refers to a design management approach to design based on detailed cost estimates (Ng & Hall 2021). (L9)"Visual signage (*kanban*)" refers to a visual control system that signals when to pull the upcoming procedure at the right time (Arbulu et al., 2003). (L10) "Visual alert system (*andon*)" refers to a visual system to highlight an alarming status of the operations (Biotto et al., 2014). (L11) "Mistake-proof (*poka-yoke*)" refers to a design that eliminates the possibility of making a mistake. (L12) "Autonomation (*jidoka*)" refers to machinery that detects problems and stops by itself for inspection and problem-solving (Tommelein, 2008). (L13) "5S – Sort (*seiri*), Set in order (*seiton*), Shine (*seisō*), Standardise (*seiketsu*), Sustain (*shitsuke*)" refers to an order and cleaning principle that is applied to any workplace like shops, services, manufacturing, warehouses and offices (Sowards, 2012). (L14) "Overburdern (*muri*)", (L15) "unevenness (*mura*)" and (L16) "waste (*muda*)" refer to unwanted steps and outcomes in a process (Koskela, 1992). These "lean terms" can refer to all kinds of scenarios including those in a production factory and in everyday life. Most of the time, the concepts are adopted jointly in a lean process. Also, through the adoption of one concept could achieve other concepts simultaneously.

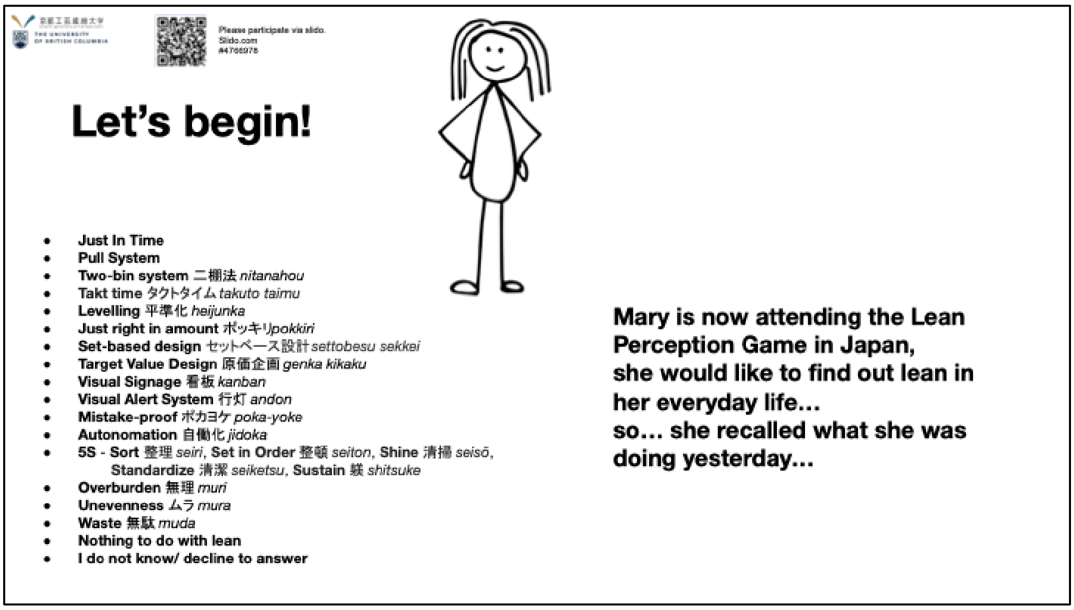


Figure 1: The game presents a list of 18 choices for selection and the beginning of the 17 scenarios in Mary's everyday life in Japan.

## 17 SCENARIOS OF LEAN CONCEPTS IN EVERYDAY LIFE

The authors of this work selected 17 scenarios that can be found in everyday life in Japan and other countries. The game presents Mary's life in a day. Figure 1 shows the slide that begins the 17 scenarios presented one by one during the game. Each scenario can refer to one or more than one lean concept to different extents as shown in Table 1. The game is designed that there is no definite right or wrong answer to the choice in each scenario.

Table 1: Most votes lean terms in each scenario by industry partitioners and researchers in four rounds of workshops and by students in the class at the university respectively.

L1 - Just in time, L2 - Pull System, L3 - Two-bin system, L4 - Takt time, L5 - Levelling, L6 - Just right in amount, L7 - Set-based design, L8 - Target Value Design, L9 - Visual signage, L10 - Visual Alert System, L11 - Mistake-proof, L12 - Autonomation, L13 - 5S, L14 – Overburden, L15 – Unevenness, L16 – Waste; N/A – Nothing to do with lean

| Scenario | | Most relevant | Most-voted at workshops | Most-voted in class |
|---|---|---|---|---|
| 1 | Mary taking the right amount of breakfast according to exactly how hungry she feels in response to her stomach growling | L2 | L2 (28%); L13 (27%) | L2 (57%); L6 (13%) |
| 2 | Mary takes a train to the station named “Sakurajima”, she sees a circle for the destination on the digital signage and hence queues at the circle floor mark | L9 | L9 (79%) | L9 (56%); L10 (11%) |
| 3 | Mary and her colleagues at work put and move a sticker of a certain task from the column “doing” to “done” when she has finished the task the day before | L9 | L9 (18%); L5 (14%); L11 (13%) | L11 (25%); L7 (17%); L9 (17%); L13 (17%) |
| 4 | a notch design on a typical whole milk bottle in Japan, with which Mary understands this is the right type of milk that she wants; and the location of the notch indicates that she should open the bottle from the other side | L11 | L11 (43%); L7 (22%) | L11 (56%); L7 (16%); L10 (16%) |
| 5 | a wall of tools, where Mary takes a cleaning tool off from a hook that has been designated to hang that tool after use | L13 | L13 (79%): L5 (13%) | L13 (69%) |
| 6 | Mary takes a seat by looking at the digital signboard that indicates which seats are occupied or not at a ramen restaurant | L9 | L10 (51%); L9 (34%) | L10 (38%); L9 (21%) |
| 7 | a ramen chef who collects and hangs the ramen ticket from Mary after her order to indicate the sequence of orders from all customers | L2 | L2 (43%); L3 (15%) | L1 (21%); L8 (16%) |
| 8 | the ramen chef serving each bowl of ramen to fit the specified rate of pulling each ingredient step by step | L4 | L1 (31%); L4 (25%) | L4 (35%) |
| 9 | a long and unproductive meeting Mary and her colleagues take after lunch | L16 | L14 (46%); L16 (41%) | L16 (76%) |
| 10 | two toilet rolls are placed in a way that they are available for usage at the same time in the office restroom | N/A | L3 (57%) | L3 (61%) |
| 11 | Mary queues at the taxi stands at which multiple taxis are queueing | N/A | N/A (25%); L1 (14%) | L5 (29%); L15 (14%) |
| 12 | Mary calls a taxi with a mobile app at the moment she needs and a taxi comes upon receiving the booking | L2 | L2 (28%); L6 (26%); L1 (23%) | L2 (75%); L8 (25%) |
| 13 | Mary mixes and matches ingredients from the burger selections on the menu and asks for a seafood tempura with a burger bun at a restaurant. | L7 | L7 (48%); L6 (16%) | L7 (50%); L8 (20%); L13 (20%) |
| 14 | Mary's friend tells Mary to buy a set with a beef burger, a deep-fried chicken snack and a salad with a fixed budget of $500; if the purchase is over budget, Mary should top up from her pocket; if the purchase is under $500, Mary can keep the rest | L8 | L8 (80%) | L8 (80%) |

Table 1 (continued)

L1 - Just in time, L2 - Pull System, L3 - Two-bin system, L4 - Takt time, L5 - Levelling, L6 - Just right in amount, L7 - Set-based design, L8 - Target Value Design, L9 - Visual signage, L10 - Visual Alert System, L11 - Mistake-proof, L12 - Autonomation, L13 - 5S, L14 – Overburden, L15 – Unevenness, L16 – Waste; N/A – Nothing to do with lean

| | | | | |
|---|---|---|---|---|
| 15 | Mary asks for a matcha ice cream at a shop with a robot stewardess; when the robot is serving a pistachio ice cream instead of a matcha one, the robot stops and corrects the flavour | L12 | L12 (62%); L11 (28%) | L12 (50%); L11 (30%) |
| 16 | two cold beers being served at the same time in a bar; Mary drinks one glass after another; when one glass is empty, the empty glass signals the bartender to refill while Mary is drinking from another glass | L3 | L3 (59%); L16 (17%) | L3 (100%) |
| 17 | an automated bathtub system that can be remote-controlled to prepare a bath at the right time | L1 | L1 (65%); L12 (14%); L2 (13%) | L1 (57%); L10 (29%) |

# CASE STUDY RESULTS

## DATA COLLECTION

The game was first presented at the International Group of Lean Construction (IGLC) conference in 2023 in Lille, France. Responses from 61 participants were collected in five rounds of simulation, including four rounds with 31 industry participants, professors and researchers in one in-person workshop and three online workshops, as well as one in-person class with 30 civil engineering master's students at an university in Canada. The authors integrated the data from the first four rounds of workshops and the data from the master's class and conducted a comparative analysis. The following paragraphs summarise the findings of this work based on the five rounds of simulations

## FINDINGS REGARDING THE PERCEPTIONS OF LEAN CONCEPTS

Table 1 presents the direct responses from the 61 participants collected in the five rounds of simulations. This work differentiates the responses and consensuses amongst the participants regarding the relevant lean concepts to each scenario and lays the ground for further analysis. Scenarios 2, 5, 14-17 received significant consensuses respectively from the participants from both the workshops and the class that their responses aligned with the most relevant lean concepts intended to be present in the scenarios. For example, Scenarios 2,5 and 14 received the votes for “visual signage”, "5S” and “Target Value Design” respectively from over 50% of the participants from both the workshops and the class. This shows that the scenarios that can happen in everyday life aligns with the participants' understandings of the corresponding lean terms. For example, Scenario 2 shows a typical digital sign board in a train station in Japan, it was mentioned in the discussion that a sign board can relate to a production factory scenario; discussions regarding Scenario 14 include the concept of Target Value Design with a target cost set in the scenario makes it very obvious to be related to the intended lean term; it was discussed that the robot in Scenario 15 makes the scenario obvious to be related to “autonomation”.

Scenarios 1, 4, 8, 9, 12 and 13 received marginal consensus respectively. In all of these six scenarios, over 50% of the participants in the class voted for the most relevant lean concepts, for which the majority but less than 50% of those at the workshops voted. For example, 57% of the students in the class voted for “pull system”, which is the most relevant lean concept for the scenario; while only 28% of the participants at the workshops voted for this and yet 27% voted for 5S, which is not relevant. For Scenario 12, 75% of the students in the class voted for “pull system”, for which only 28% of the participants at the workshop voted; while 26% voted for “just right in amount” and 23% voted for “just in time”, which are relevant but not the most relevant one intended in the game. The responses in these two scenarios show that "pull system" could be perceived in relation to some other concepts such as "just in time". In the case, "pull system" can help to achieve "just in time" to different extents. Students and industry practitioner also have divergent votes. For example, practitioners with years of field experience associate "takt time" with a practical scheduling tool that may focus on the scenarios involving time management, workflow balance, or labor pacing across construction phases. Students, especially those with limited practical exposure, perceive "takt time" as a theoretical concept learned in class and they may confuse it with other terms when there are potential overlapping applications.

Scenarios 3, 7 and 8 show relatively little consensus because the majorities of the votes from the participants from both the workshops and the class are not solely referring to the most relevant lean concepts as intended. For example, Scenario 3 has only 18% and 17% of the participants at the workshop and students from the class voted for "visual signage" respectively, while 25% of the students voted for mistake-proof, which is irrelevant. Moreover, Scenarios 6,10 and 11 show significantly misconceptions of the corresponding lean concepts. For example, the majority of the participants at both workshops and in the class Scenario 6 voted for "visual alarm system", which is irrelevant to the scenario. The deviations of perceptions of lean concepts in daily life show further studies are needed to explore the causation and lean education in correspondence to the perception studies.Based on the preliminary findings, a few implicative findings from the lean workshops versus university lecture session are presented below:

- **Well-understood lean terms:** Scenario 2 shows a significant consensus from the workshop participants (79%) to understand the meaning and application of "visual signage". This implies that participants generally understand its role in displaying operational statuses. Scenario 5 also shows that workshop participants (79%) exhibit a strong understanding of the "5S" concepts through the tool management example, which draws parallels between a clean workplace and work areas clear of hazards in a more complex construction site. Also, Scenario 14 shows that the participants have a consistent votes for "Target Value Design". These three terms received the similar consensus in perceptions from students in the classroom, indicating that they are well-understood concepts to resonate with experts and students.
- **Ambiguous lean terms:** The term "Set-Based Design" and "takt time" receive a diverse understanding across scenarios, suggesting they may be less understood or more context-dependent in their application. Student participants associated Scenarios 3, 4, 5, 6, 7, 10, 11, 13 and 14 with the "Set-Based Design" concepts, while workshop participants associated specific different Scenarios 1, 2, 3, 4, 10 and 13 with the same concepts. The application of "Set-Based Design" involves creating and evaluating multiple design options (meal options Scenario 13) simultaneously to select the most desired design option. It's a more abstract concept that requires participants to understand iterative design and decision-making process. "Takt time" also shows low response rates across the 17 Scenarios, implying participants do not have consistent votes for these from related terms like "two-bin system" and "pull system". Its application is often context-dependent and tied to well-coordinated production environments, which may not be familiar to many participants, especially if they lack experience in manufacturing or highly structured workflows. A scenario involving time optimisation may not sufficiently emphasise how "takt time" coordinates production pace. Therefore "takt time" could be confused with other scheduling or efficiency-related lean tools like "just in time" or "pull system".
- **Terms with overlapping interpretations:** For Scenario 6, responses from workshops and classroom were widely spread across multiple terms such as "visual alert system"

and "visual signage", suggesting that participants may interpret these concepts as related in some contexts. Scenario 7 also receives overlaps in responses with the the terms "just in time", "pull system" and "takt time", "levelling" and "two-bin system" etc.

# DISCUSSION

## LIMITATIONS AND OPPORTUNITIES FOR IMPROVEMENT

This research in lean perception study leads to several recommendation in learning and teaching lean. The work shows lean can be perceived or applied in everyday life. Through a thorough understanding of the concepts, lean practitioners can think out of the box and spur innovation with lean concepts beyond a standard production line scenario. There is no precedent for using a game simulation approach to teach lean terminology and investigate the perception of lean concepts in the industry. This game and the simulation offer a hands-on approach, with which the participants engage in the educational process to understand lean concepts using examples that can happen in everyday life. Industry practitioners, lean coaches, professors, researchers and students are encouraged to present this open-access game for lean education or take the same approach and develop their own games with other scenarios. This work presents an exploratory perception studies to identify potential future research that can be further investigate in future research.

Nevertheless, the resultant perceptions studied in this work are restricted by the selected 17 scenarios, which reflect real-world scenarios of everyday life in Japan to different extents. There are a couple of scenarios amongst the 17 ones refer to the same lean concepts. However, the participants did not get the same answers for various scenarios correctly. This requires further research to investigate how and why the perceptions vary in different scenarios, so as to improve lean education. For example, "visual signage" is the mostly relevant lean concept to Scenarios 2,3 and 6. There was a significant consensus for Scenario 2, a marginal consensus for Scenario 6 and a misconception for Scenario 3. It is questionable in what extent the perceptions for "visual signage" vary significantly. Future research can explore how perceptions of lean concepts differ in different scenarios to improve understanding of the concepts so that they can be adopted appropriately in different applications. More scenarios and lean concepts can be included in later studies using the same teaching approach.

Also, the results are limited to the 61 sample participants and their understandings of the presented lean concepts to different extents. Despite the prerequisite, Further studies with larger sample sizes can be conducted to generalize the results. Statistical analysis can be conducted to explore the perceptions and find out the causation of misconception to improve lean education and hence implementation through correcting misconceptions so that lean concepts can be adopted in, for example, a completely new scenarios such as a human robot on-site scenario. Moreover, validations with, for example, focus group interviews with lean experts can be conducted in future research. This research and the interactive game are original.

## FUTURE RESEARCH DIRECTIONS

Based on limitations of this current study, future research will focus on the depth of participants' insight by integrating qualitative methods such as pre/post assessments interviews and participant reflections to understand the reasoning behind lean concept selection. This is particularly important for terms such as "takt time," where voting patterns suggest potential confusion or overlap with related concepts such as "just in time" or "pull system." To more directly assess learning outcomes, future iterations of the game will incorporate educational components to assess the learning outcomes. We will also focus on a comparative analysis between students and industry professionals to identify how professional experience influences lean terminology interpretation. For example, practitioners may associate lean terms with on-site tools and practices, while students may rely on academic definitions. Scenarios will also be revised in our future work to more explicitly reflect real-world construction-related situations, which provides better contextual interpretation of lean concepts and improved engagement with them relevant to construction workflows..

# CONCLUSIONS

This study presents an interactive game to explore the perceptions of 17 selected lean concepts through relatable daily scenarios with 61 industry practitioners, researchers and students from diverse global backgrounds. The results reveal varied perceptions of lean concepts. The lean concepts of "visual signage", "5S" and "Target Value Design" are identified to receive majority votes amongst the participants. "Set-Based Design" and "takt time" are found to be relatively ambiguous and receive diverse perceptions to different extents. "Takt time" is relatively less familiar to the participants and can be easily confused with other closely related concepts such as "just in time" and "pull system". The game also shows that several lean concepts have overlapping interpretations. For example, "visual signal" and "visual alert system" appear to be interpreted as related in some contexts. Although this study provides initial exploration and direct observations of participants' perceptions on lean concepts, limitations exist about why participants perceived certain terms or whether they found them confusing. Future research directions include in-depth interviews to collect feedback from participants to understand why the divergent views of lean concepts exist and a revised lean game with an educational focus to assist stakeholders' effective understanding and engagement for lean implementation, as well as interpretive studies for lean implementations in real construction scenarios.

# REFERENCES


Arbulu, R., Ballard, G. & Harper, N. (2003). Kanban in Construction, *Proceedings of 11th Annual Conference of the International Group for Lean Construction*.

Binninger, M., Dlouhy, J., Oprach, S. & Haghsheno, S. (2016). Methods for Production Leveling – Transfer From Lean Production to Lean Construction, *Proceedings of 24th Annual Conference of the International Group for Lean Construction.*

Biotto, C., Mota, B., Araújo, L., Barbosa, G. & Andrade, F. (2014). Adapted Use of Andon in a Horizontal Residential Construction Project, *Proceeding of the 22nd Annual Conference of the International Group for Lean Construction*, 1295-1305.

Chen, Q., B. García de Soto & B. T. Adey (2018). Construction automation: Research areas, industry concerns and suggestions for advancement. *Automation in Construction*, 94 (Oct): 22–38. doi.org/10.1016/j.autcon.2018.05.028.

Chen, Q. (2020). *A systematic approach to enabling digital supply chain coordination in construction projects*. Diss. Zurich: ETH Zurich. doi.org/10.3929/ethz-b-000458752.

Common, G., Johansen, E. & Greenwood, D. (2000). A Survey of the Take-Up of Lean Concepts Among UK Construction Companies, *Proceedings of the 8th Annual Conference of the International Group for Lean Construction*.

González, V. A., Hamzeh, F., and Alarcón, L. F. (2022). *Lean construction 4.0: driving a digital revolution of production management in the AEC industry*, Taylor & Francis. doi.org/10.1201/9781003150930H.

Koskela, L. (1992). *Application of the New Production Philosophy to Construction*; Centre for Integrated Facility Engineering Technical Report No. 72; Stanford University: Stanford, CA, USA.

Lodgaard, E., Ingvaldsen, J.A., Gamme, I. & Aschehough, S. (2016). Barriers to lean implementation: perceptions of top managers, middle managers and workers. *Proceedings of 49th CIRP Conference on Manufacturing Systems (CIRP-CMS 2016)*. Procedia CIRP 57 (2016), 595-600.

Macomber, H., & Howell, G. (2004). Two great wastes in organizations: A typology for addressing the concerns for the underutilisation of human potential. *Proceedings of the 12th Annual Conference for Lean Construction*.

Ng, M.S. & Hall, D.M. (2021). Teaching Target Value Design for digital fabrication in an online game: overview and case study. *Proceedings of the 29th Annual Conf. of the Intl. Group for Lean Construction*, pp. 249–258. doi 10.24928/2021/0117.

Ng, M.S. (2022). *Design for Digital Fabrication (DfDFAB): management for sustainable adoption of emerging technologies and innovations*. Diss. Zurich: ETH Zurich. isbn: 978-3-907363-06-5. doi.org/10.3929/ethzb- 000578446.

Ng, M.S., Graser, K. & Hall, D.M. (2023). Digital fabrication, BIM and early contractor involvement in design in construction projects: a comparative case study. *Journal of Architectural Engineering and Design Management*, vol 19(1), pp. 39-55. doi 10.1080/17452007.2021.1956417.

Ohno, Taiichi (1988). *Toyota Production System: Beyond Large-Scale Production* (English translation ed.). Portland, Oregon: Productivity Press. pp. 75–76.

Parrish, K., Wong, J., Tommelein, I. D. & Stojadinovic, B. (2008). Set-Based Design: Case Study on Innovative Hospital Design, *Proceedings of 16th Annual Conference of the International Group for Lean Construction*, 413-424.

Pearce, Antony, Dirk Pons and Thomas Neitzert (2023). Understanding Lean—Statistical Analysis of Perceptions and Self-Deception Regarding Lean Management. *Operations Research Forum*, 4:28. doi.org/10.1007/s43069-023-00198-4.

Rybkowski, Z. K., Munankami, M. B., Shepley, M. M., & Fernández-Solis, J. L. (2016). “Development and testing of a lean simulation to illustrate key principles of target value design: A first run study.” *24th Ann. Conf. IGLC 2016*., 133–142.

Salling, S. T. , Pérez, C. T. & Wandahl, S. (2023). Perception of Project Management Among Construction Workers: A Survey in Denmark, *Proceedings of the 31st Annual Conference of the International Group for Lean Construction*, 882-893. doi.org/10.24928/2023/0124.

Sowards, D. (2012). *Lean Construction Pocket Guide*. MiniBuk, Mesa, AZ.

Tommelein, I. D. & Li, A. E. Y. 1999. Just-in-Time Concrete Delivery: Mapping Alternatives for Vertical Supply Chain Integration, *Proceeding of the 7th Annual Conference of the International Group for Lean Construction*, 97-108.

Tommelein, I.D. (1998). “Pull-driven Scheduling for Pipe-Spool Installation: Simulation of Lean Construction Technique.” *ASCE JCEM*, 124 (4) 279-288.

Tommelein, I. D. (2008). ‘Poka Yoke’ or Quality by Mistake Proofing Design and Construction Systems, *16th Annual Conference of the International Group for Lean Construction* , 195-205.

Vatne, M. E. & Drevland, F. (2016). Practical Benefits of Using Takt Time Planning: A Case Study, *Proceedings of 24th Annual Conference of the International Group for Lean Construction*.