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# THE REPAIR-CO GAME: A ROADMAP TO DEMONSTRATE THE IMPORTANCE OF PROBLEM-SOLVING CAPABILITIES OF LEAN TOOLS

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## ABSTRACT

Lean Construction facilitators use the Repair-Co Game to introduce new stakeholders to the need for Lean. The game heightens participant awareness of the futility of impulsive finger-pointing to individual workers when an existing management system may instead be principally responsible for a company's inability to reach its expressed goals. Although this current gaming approach has been shown to be effective, the authors of this paper observed that the Repair-Co Game can also be expanded to introduce players to the usefulness of Lean tools that can identify root causes and effective countermeasures. These tools include the Ishikawa Fishbone Diagram, Pareto Chart, 5 Whys Root Cause Analysis, Big Room Meetings, and Collective Kaizen, which are implemented during Big Room meetings. This expanded version of the Repair-Co Simulation has been tested with 35 graduate students at Texas A&M University, 45 students at CEPT University, and 33 members of the URC construction company. Despite the different locations of the test grounds and make-up of players, results from initial experimental sessions have been shown to be remarkably similar in some ways but also different in others, demonstrating the important nuances of an individual context. Qualitative feedback from participants demonstrate the potential of the game in helping participants solve problems at their root cause.

## KEYWORDS

Lean Simulations, Repair-Co Game, Ishikawa Fishbone (Cause-and-Effect) Diagram, Pareto Chart, 5-Whys Root Cause Analysis, Continuous Improvement (PDCA).

## INTRODUCTION

In contrast to manufacturing, the construction industry is widely recognized for its fragmentation, silo-ization of OAEC[5] (Owner, Architecture, Engineering, and Construction)

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[5] This paper uses the acronym OAEC to signify Owner – Architect – Engineer – Constructor, where the Owner is placed in the primary position to remind other stakeholders that fulfilling the Owner's conditions of satisfaction is paramount in Lean.

stakeholders and high levels of variability. Prabaharan and Shanmugapriya (2022) investigated barriers to adopting Lean in Indian construction industries. They discovered that one of the critical barriers to the implementation of Lean is the "perceived complexity of learning and implementing Lean concepts" (p. 11). Furthermore, similar findings can be found throughout the literature, indicating that a "lack of knowledge and understanding of Lean principles and the intricacy of Lean philosophy and terminology" persists as a potential hindrance to the incorporation of Lean practices within the construction industry (Demirkesen et al. 2019, p. 7-8).

Lean simulation games serve as highly reliable training tools to help professionals learn Lean concepts through hands-on experiences. Lean games help bridge the gap between a concept and its application (Bhatnagar and Devkar 2021). Lean simulation games serve a pivotal role in helping OAEC professionals to dispel misconceptions and enhance their understanding of Lean concepts (Rybkowski et al. 2021). Lean simulation games are regarded as an influential way to teach Lean concepts clearly and effectively (Hamzeh et al. 2017; Rybkowski et al. 2018). Over the past decade, there has been a steady rise in the adoption of Lean simulation games within the OAEC industry (Bhatnagar et al. 2022). As firms progress in their Lean initiatives, they can incorporate a training program with simulation games targeted to address specific Lean processes and tools. For Lean training workshops, especially those catering to working professionals, specific Lean simulation games must be designed and tested to ensure that they are effective in communicating desired objectives.

This research paper reports on results from implementing the Repair-Co Game in three different locations with different populations,[6] namely: (i) graduate students of construction engineering and management at CEPT University in Ahmedabad, India, (ii) graduate students of construction science at Texas A&M University in College Station, Texas, USA, and (iii) URC Construction[7] practitioners, including craftworkers, and licensed engineers and architects in Chennai, India. Because so much of Lean arguably reflects common sense, students may initially question the need for Lean principles at the beginning of a course on Lean. Therefore, it is helpful to share evidence of the poor performance of the OAEC sector, but also how Lean has been shown to help (McKinsey 2017). Prior to the rounds of play described in this paper, the Repair-Co Game had already been facilitated in its original incarnation in numerous settings and in various locations. However, results from the Repair-Co Game have not been published in peer-reviewed literature in either its (a) original or (b) extended versions, which offers additional lessons. The intent of this paper is to fill this gap.

# LITERATURE REVIEW

## PART I: THE GENESIS OF THE REPAIR-CO GAME

The Repair-Co Game is popularly used in the classroom and professional training programs to open the minds of students and professionals about the challenges the construction industry faces, and the need for a better approach such as Lean. This simulation game is relatively simple to administer in diverse settings thanks to limited physical demands. The authors of this paper have used the Repair-Co Game in the classroom setting for several years. The version played is based on a PowerPoint™ instructional guide prepared and openly shared by Alan Mossman (2020). In this guide, Mossman credits John Seddon, Vanguard Consulting, UK, for inspiring the game (Seddon n.d.). The authors of this paper searched for the roots of this game and discovered that the stated mission of the consulting firm echoes the spirit of the Repair-Co Game. The website title, "Bursting bureaucracy in home repairs," provided contextual

[6] Readers may wish to contact the authors of this paper to learn specifics about facilitation of Repair-Co in multiple settings.
[7] URC Construction is a general contractor headquartered in Erode, India, specializing in infrastructure construction with approximately 2,000 employees.

information about the Repair-Co Game. A 20-minute podcast by Seddon (2020) was transcribed by the authors to understand the genesis of the Repair-Co Game. In his podcast, John Seddon argues that “95% of the influences on performance are in the system, and only 5% are due to the people who actually serve customers” (Seddon 2020). This is the fundamental message conveyed by the Repair-Co Game. To illustrate his point, Seddon used the example of a repair person who is called to fix washing machines. He chose repair companies as examples of service organizations because most people can readily relate to them (Seddon 2020).

Mossman developed the Repair-Co Game from Seddon’s exercise. The game starts with a narrative about a Repair-Company’s call centre that receives service requests from customers. The call centre personnel notifies a repairperson who is then dispatched throughout a specified geographic area according to logistics established by the call centre. The repairperson travels the route dictated by the logistics map. The repairperson’s sequence of daily activities is informed by individuals such as the call centre receptionist, logistics personnel, and a manager. Mossman’s graphics support Seddon’s vision that helps players focus on the facts of the narrative (Figure 1).

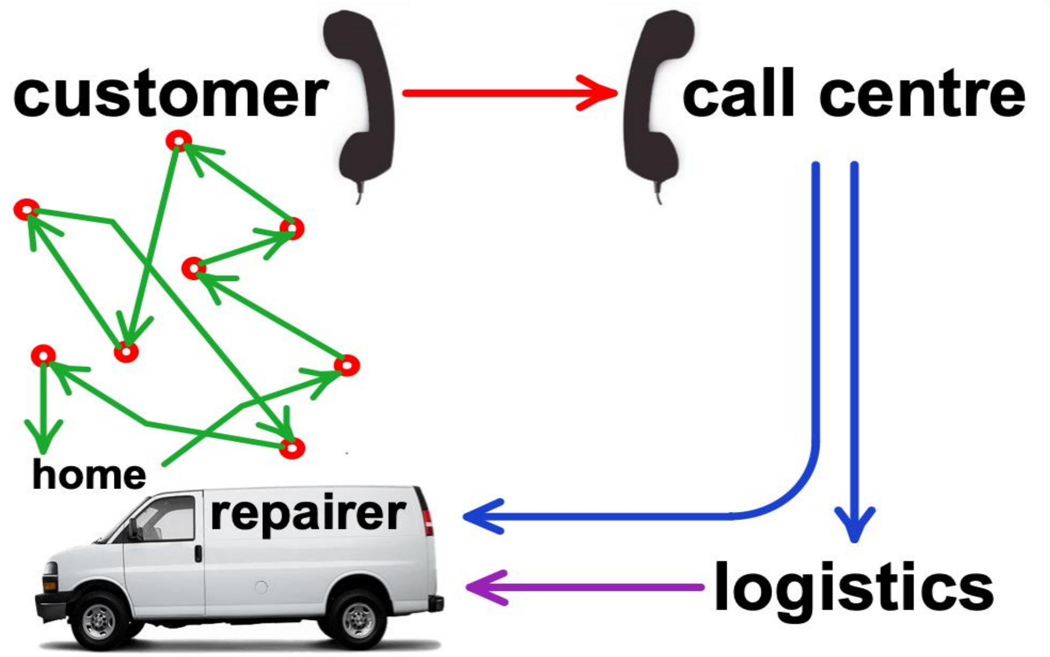


Figure 1: Repair-Co Game setup.
Graphic reprinted from Mossman (2020), with permission.

Once a facilitator describes the scenario, participants are shown the diagram in Figure 2 and asked the following questions: According to the manager’s weekly schedule, how many daily repair visits are expected during a typical workweek? (e.g. 8). How many visits, on average, are actually made each day during a typical week? (e.g. 5.5). Once participants openly respond to these two questions, they are invited to individually, and then collectively in a group, brainstorm possible reasons the repairperson’s schedule varies. The facilitator projects an Excel spreadsheet onto a wall for all to see; a hand-drawn table on a whiteboard or flip chart also works. In the left-hand column, the facilitator lists each brainstormed response separately. While the group is asked to collectively share at least ten possible reasons for the variability, a large and/or highly engaged group may generate quite a few more. With brainstorming complete, the facilitator writes “repairperson” in the heading of the column to the immediate right of the potential “reasons” column and “system” atop the farthest right-hand column. The facilitator then directs participant attention to the table and then asks: “What is the main cause of the variation? Is it primarily the fault of the repairperson or the system?" After moving down the list and marking participant responses, the facilitator then asks: "Yet where is the blame often placed?" While some variation is arguably due to the person or both the person and the system, most reasons for varied performance are discovered to be outside the control of the repairperson and are instead due to a fault of the system. In the Seddon version of the Repair-Co Game, the game stops here. The original intent is to give participants an "aha" realization that it is often not the individual alone who is the main culprit. In other words, the game convincingly demonstrates that it is often the *system* that first and foremost needs to be fixed with the help of those performing the work.

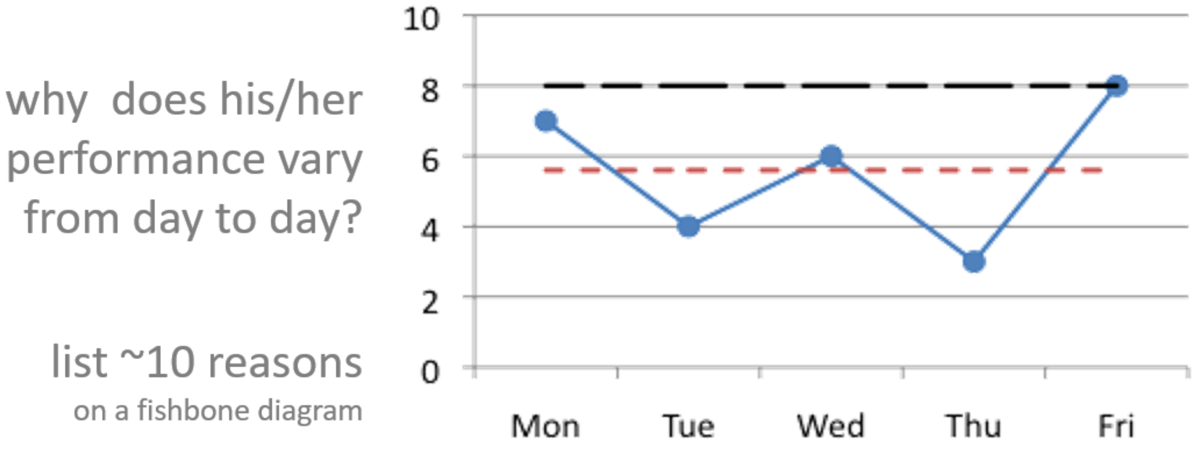


Figure 2: Performance characteristics of the repair person during a typical workweek. The graphic is reprinted from Mossman (2020) with permission.

Individuals can be myopic. One takeaway of the Repair-Co Game is that collective brainstorming during a Big Room meeting can help a manager identify numerous potential causes of a challenging problem s/he may not have considered when contemplating the problem alone. Brainstorming with others within an organization often helps ideas emerge that might otherwise be overlooked.

## PART II. EXTENDING REPAIR-CO: THE POTENCY OF THREE LEAN TOOLS

The original intent of playing the Repair-Co Game has been to heighten participant awareness of the need for Lean to fix an organization's system with the help of the people in the organization. While the game continues to serve effectively in this capacity, it can further be used as an illustration to show how three additional Lean tools can be used to solve an organization's challenges. These three tools are the Ishikawa Fish Bone (cause and effect) diagram, the Pareto Chart, and the Five-Whys Root Cause Analysis.

Following Part I, which helps participants to appreciate the system as a key area of improvement rather than primarily blaming the repairperson, the facilitator invites participants to consider two different contexts: a large city and a small town. Participants are then provided with a blank template of Ishikawa Fish Bone diagram showing different "bones," that can be used to organize various causes under six categories: measurement, manpower, environment, machines, methods, and materials. The participants are then asked to insert the "reasons for varied performance" they had previously brainstormed into the Ishikawa Fish Bone diagram. One advantage of the fishbone structure is that the categories can help prompt participants to identify causes they may not have previously considered. For example, under "measurement," did the group give thought to the possibility that the repair person's daily performance may not have been accurately measured and recorded? The Ishikawa Diagram reminds us to consider this, as one of the six categorical "bones" of the "fish." To help identify additional causes, the facilitator can also invite participants to assume different roles such as customer, call centre personnel, repairperson, manager, etc. (Bono n.d.).

In reality, not all potential reasons shown in the fishbone diagram are equally responsible for a problem. Typically, a small proportion of causes (i.e. 20%) create the lion's share (80%) of a problem/effect. The identified causes by the participants are entered into a spreadsheet, and the participants are asked to consider the likelihood of the occurrence of each of these causes. The participants are asked to raise their hands if they feel a possible cause can occur in the context of a specific large city—and subsequently—a small town. The raised hands are counted by the facilitator, and this number is entered into the spreadsheet. This process is repeated for each brainstormed reason. This tabulated information is then graphed in the spreadsheet and depicted as a Pareto Chart (i.e., the frequency of reasons is sequenced from left to right, from largest to smallest). As this process of seeking inputs is conducted for both big cities and small towns, two Pareto Charts should be separately generated by the end of this exercise. The ranked histogram format of a Pareto Chart helps viewers readily identify primary culprits (i.e. reasons for performance variability) and focus on a countermeasure to resolve the primary cause(s) first.

The final step is to subject the primary cause(s) identified on the Pareto Chart to a Five-Whys Root Cause Analysis (Liker 2004). The Five-Whys process aims to systematically drill down to identify the ultimate root cause of a problem to ensure that a selected countermeasure will solve the problem permanently. In Five-Whys, a manager sequentially asks, "Why?" a problem has occurred until s/he reaches the last actionable cause. In the Five Whys table of *The Toyota Way* (Liker 2004), the investigator begins with the puddle of oil on the shop floor and asks why it occurred. If one simply wipes up the puddle, the problem will reoccur. However, by repeatedly asking "Why?" the manager discovers the leak is due to a gasket made of inferior material. Why? The purchasing agent is evaluated on short-term cost savings. Once the last actionable cause is identified, the problem can permanently be resolved at its underlying root by applying a countermeasure to change the evaluation policy for purchasing agents. In a similar manner, when participants start their journey to investigate the root cause and develop a countermeasure, they experience, again with greater clarity, that it is typically a "system" that is at fault for the poor performance of the repairman. The process also helps to appreciate one of the key principles of the Toyota Production System (TPS), which is to make decisions slowly by consensus because time taken during collaborative decision-making enables fast, efficient, and often error-free implementation. While conducting the 5 Whys Analysis, participants are urged to avoid arriving at immediate conclusions. Instead, they are invited to delve more deeply into the brainstorming process to identify with fellow participants the final actionable root cause and to suggest a viable countermeasure.

These three simple tools, the Ishikawa Fish Bone Diagram, the Pareto Chart, and the 5-Whys Root Cause Analysis—when implemented during a Big Room Meeting—help Lean managers engage in the plan-do-check-act (PDCA) cycle of continuous improvement where countermeasures to root causes are used to permanently resolve a problem at its core. Using PDCA, the effects of the change are measured, and if successful, the change is standardized. This is the stairstep of continuous improvement (Figure 3). The extended version of the Repair-Co Game also highlights to the managers that during their journey of continuous process improvement, it is important to judiciously select and apply relevant Lean tools during the process of building consensus. For instance, there is a sound rationale for applying the earlier-mentioned Lean tools in a specific sequence.

## REPAIR-CO: FIRST RUN STUDIES OF THE THREE LEAN TOOLS

To test the progressive application of the three tools mentioned above in our first-run studies, the authors played the Repair-Co Game with three different audiences in three separate locations. The participants were asked to imagine the Repair-Co scenario in two different contexts: one in a large city with significant urban sprawl and the other in a small town. The purpose of introducing two locations was to help illustrate how problems and their solutions are context-dependent. In other words, the manager must systematically investigate causes for poor performance in a given context rather than arriving at unfounded conclusions and suggesting remedies as a "one size fits all" approach. The rationale behind the addition of these processes is to help students and professionals understand how Lean tools can be helpful for not only analyzing the causes of poor performance but also for suggesting routes to continuous improvement while collaboratively engaging the members of an organization. Images of these tools and processes are depicted in Figure 4.

# RESEARCH METHODOLOGY

## INDUSTRY WORKSHOP SETUP

Although there are slight variations in how the Repair-Co Game is facilitated, one example for each of the three settings will be presented and discussed for clarity.

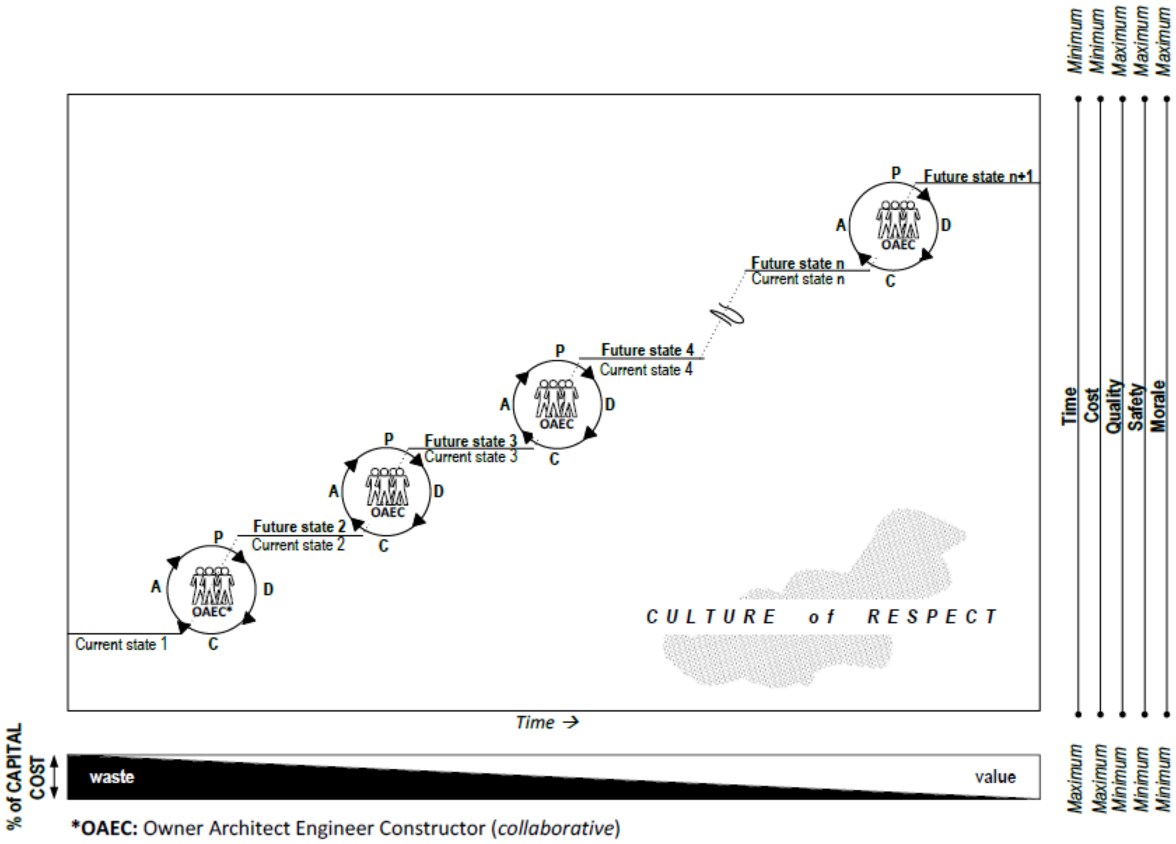


Figure 3: Lean's stairstep of Continuous Improvement (Rybkowski 2013).

The first research setting was a general contractor in India. This company began its Lean transformation journey in 2012 with the support of the Institute for Lean Construction Excellence (ILCE). The contractor had joined ILCE as a chartered member. The human resources department for this contracting organization went through extensive capacity upgrading sessions in the form of training programs and on-site guidance focusing on Lean concepts, principles, and tools. The sessions resulted in the implementation of Lean principles on several projects, with wide-scale adoption of the Last Planner® System of Production

Control (LPS), Value Stream Mapping (VSM), 5S, Work Sampling, and Big Room Meetings. The organization experienced impressive results with the application of Lean concepts and tools in the execution stage of its projects. In the recent past, the organization won prominent Engineering, Procurement, and Construction (EPC) projects, and there was a growing realization that it needed to align its design teams with the growing Lean ethos of the organization. The senior management became aware that Lean principles would reap fruits in a true sense most effectively when the seeds of Lean principles are sown in the early stages of a project's lifecycle, which was the design phase in this organization. The company's Research and Development (R&D) personnel were tasked with disseminating Lean principles and tools to the functional departments involved in the design process. The design departments included: Structural, Architectural, and MEPF. In addition to being applied to construction activities, Lean principles can and should be implemented throughout all phases of project delivery, including design, project accounting, etc. The R&D division crafted a roadmap to align with this goal. The first step involved a brainstorming session with functional heads of the design departments focusing on the identification of current design challenges. Based on these interactions, the organization reached out to CEPT University to help conduct research on the identified challenges and to guide the organization in ways to streamline its design processes. "Lean Champions" were identified from each design department (Architecture, Structural, and MEPF) to facilitate the dissemination and application of Lean principles and tools to their respective departments. The R&D Team conducted a one-day workshop with the theme of "Lean Design." Two authors of this paper served as facilitators and designed and conducted the workshop targeted to specifically assist the organization's design professionals. Because the event marked an important milestone for the organization, the facilitators carefully tailored the workshop agenda to align with the organization's expressed needs. The program was designed by interconnecting two components: Discussion about Lean principles in design processes and facilitation of Lean simulation games.  The managing director was especially keen to engage young professionals in the company's design departments. The workshop was held during a weekend (Saturday) in a conference room that enabled participants to sit in groups around tables; the flexibility of the selected space was conducive to keeping participants engaged and focused.

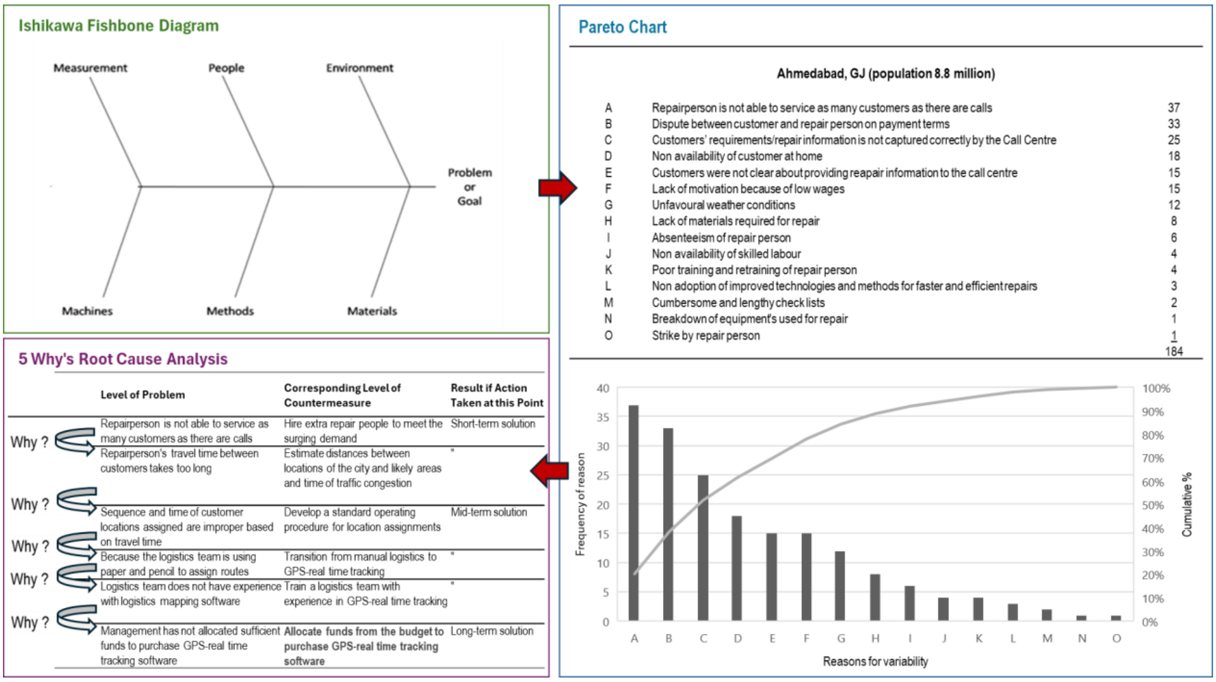


Figure 4: Sequencing of tool application runs clockwise, starting from upper left
(in order: Ishikawa Fishbone Diagram, Pareto Chart, 5-Whys Root Cause Analysis table).

### ACADEMIC INSTITUTES

In addition to Lean champions in practice and industry, Lean simulation games have been used worldwide by those in academia to impart knowledge of Lean principles to students. The academic settings described in this paper comprised two graduate-level courses focusing on Lean Construction: one in India and one in the US. The co-authors of this paper have been using Lean simulation games as an integral part of their teaching pedagogy in their courses on Lean Construction for a number of years.

## FACILITATION OF THE REPAIR-CO-GAME

### INDUSTRY WORKSHOP

On the day of the workshop, 33 design personnel in total came to participate. This number was encouraging given the hectic schedule of construction industry professionals. Included in these 33 participants were three (3) heads of each department, two (2) R&D team members, the Managing Director of the approximately 1500-member organization, and the Technical Secretary of ILCE.

The workshop was attended by professionals from multiple disciplines and departments: Architecture (3 No.), Structural (16 No.), MEPF (mechanical, electrical, plumbing, and fire protection) (11 No.), Research and Development (2 No.), and Human Resources (1 No.). The workshop began with self-introductions by participants and facilitators, followed by a playing of the Repair-Co Game in its extended version. The workshop facilitators identified two cities – one large and one small from the state where the headquarters of this organization was located. The purpose of choosing specific cities was to help the participants easily connect with the context. The steps described earlier about the Repair-Co Game in its extended version were followed, and the participants were requested to give their feedback digitally using a Plus-Delta form (Google Form®) at the end of the workshop (LCI 2024).

### ACADEMIC INSTITUTES

Out of two academic settings for the facilitation of the extended Repair-Co Game, one consisted of 45 graduate students of the Construction Engineering and Management Program at CEPT University in India while the second involved 35 graduate students of a Construction Science program at Texas A&M University in the US. Before the facilitation of this simulation, the authors collected data on the demographic background of the students. In both settings, most of the students had previously experienced large and small cities. In the Indian University, approximately 20% of the students held an undergraduate qualification in Architecture while 80% of the students held an undergraduate qualification in Civil Engineering. Several had prior work experience as well. In the US-based university, approximately 95% of the graduate students had previously earned undergraduate degrees in Civil / Construction Engineering and had experienced both large and small cities. Facilitation steps described in an earlier section were followed. After finishing the facilitation of the Repair-Co simulation game, post-simulation discussions focused on lessons learned from playing the game.

## RESULTS & DISCUSSION

The underlying common thread in the three settings where the Repair-Co Game was facilitated was the context of a large city versus a small town. In the case of the workshop facilitated for URC Construction Company, the large city was Chennai, Tamil Nadu State, India, and the small town was Coimbatore, located in Tamil Nadu State. The academic setting in India considered Ahmedabad and Morbi as large and small cities, respectively, located in the Gujarat State. Houston and College Station in the state of Texas were considered as large and small cities, respectively, for the academic setting in the US. These settings provided fertile grounds to compare and analyse potential causes of variability in the performance of the repairperson in different contexts. It was interesting to observe how game participants primarily attributed their brainstormed causes to the "management system" instead of the "repairperson" during the first phase of the game as was the intent of the original version of the Repair-Co Game. In the extended version of the Repair-Co Game, participants appeared to develop an understanding of the usefulness and interconnectedness of Lean tools as a means to analyse root causes and develop effective countermeasures to address underperformance. In the process of identification of potential reasons for poor performance, suggested causes in the context of a large city were identified, followed by suggested potential causes in a small town.

An analysis of reasons behind variable performance indicated a similarity in the identification of "traffic" as a likely primary cause for the repairperson's variable performance in large cities. After their identification of this potential cause, participants were shown a Google Map™ screenshot with traffic patterns during rush hour (i.e. 5:00 pm; Figure 5). These screenshots supported participant hunches that traffic may indeed represent a key inhibiting factor in large cities. It also strengthened the case that the causes identified by the game participants are not random, but informed by the participants' prior experience with large cities. The students also felt that with the advent of innovative technologies such as GPS and other forms of transport scheduling software, traffic challenges could potentially be addressed by generating more efficient routing of repair calls. Additional suggestions included making repair calls outside of rush hour or hiring and stationing additional repairpersons to service geographically defined zones of a city. "Traffic" did not appear in the list of potential causes for variable performance in small towns, likely because of the lower populations and more sparse distribution of occupants in these regions. The students were shown traffic maps of screen prints during rush hour in smaller towns, indicating significantly lower levels of congestion. The intent of sharing these maps was to impress upon participants the importance of not only generating a hunch but also of seeking evidence to validate the hunch before implementing a countermeasure to resolve the suspected problem.

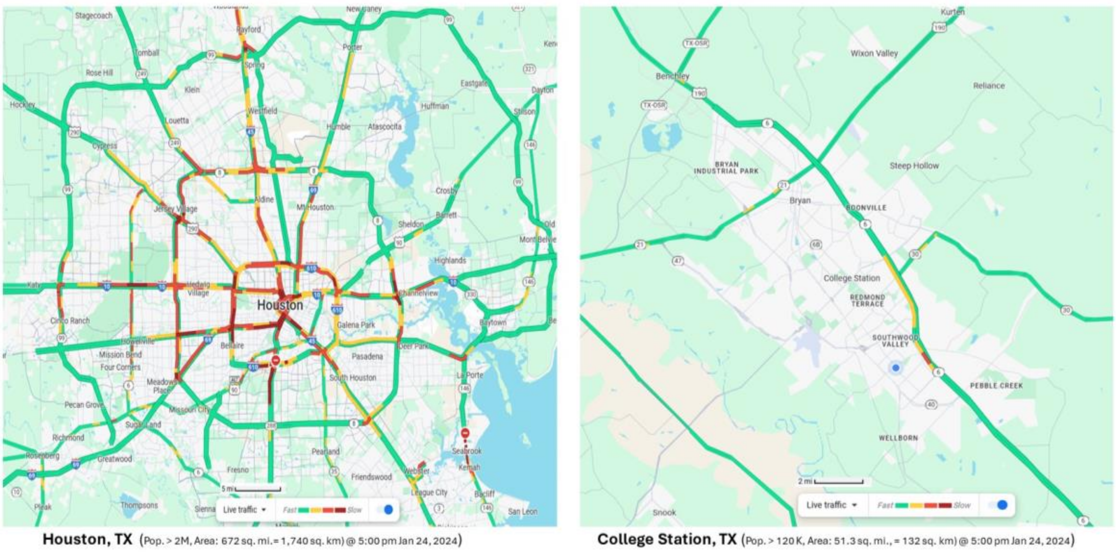


Figure 5: Traffic Pattern in Houston (left) and College Station (right) shown to participants during a trial playing of the Repair-Co Game in the US. Screenshots were taken from Google Maps™ at 5:00 pm in both locations.

For the three smaller cities, "insufficient customer demand" and "non-availability of skilled manpower" for repair work emerged as prominent proposed causes in all three test settings.

These outcomes indicated a commonality in the thought process among the game participants across three different settings. The purpose of presenting the context of two cities, both large and small, within the extended Repair-Co Game, was to impress upon participants that the context surrounding an activity plays an influencing role. Therefore, managers should make systematic efforts to decipher a context and identify “causes” behind poor performance within that given context. In other words, there is no “one size fits all” when seeking solutions to a problem. After all, implementing a countermeasure to post employees in different locations throughout a region or servicing customers outside of rush hour makes sense for large cities where heavy traffic is a primary constraint. However, a different countermeasure for a company to add additional capabilities to their repertoire would make sense for a small town where there is limited need for washing machine repair. Finally, when a manager invites diverse and multiple members within an organization to brainstorm potential causes of a problem that needs to be resolved, the probability that primary causes will be identified increases—reinforcing the importance of implementing these tools during Big Room Meetings with those who do the work.

In both the original and extended versions of the Repair-Co simulation, game participants expressed appreciation that Lean principles not only offer opportunities for systematically analysing causes but also for arriving at potential solutions. During the game, participants embraced the collaborative spirit required to brainstorm potential causes. They also appeared to respond to the thoroughness provided by categorizing causes under different arms (Manpower, Machines, Methods, Measurement, Materials, and Environment) in the Ishikawa Diagram. As managers often have limited resources to improve a given problem context, there is a need to focus on resolving the primary causes for maximum benefit. Generating Pareto Charts for each of the two cities helped participants (and ultimately managers) prioritize their efforts on the most impactful causes. Finally, using a 5-Why analysis to identify a root cause ensures a problem does not recur once resolved.

During the conduct of these three workshops, the work facilitators keenly observed the interactions and behaviour of game participants. As the game participants were seated in groups, the workshop facilitators reached out to members surrounding each table and listened to the conversation of participants over the course of this game. It appeared that improvements occurred through a social process, facilitated by interactions and diverse perspectives. Additionally, their responses suggest that participants experienced a desired “aha” moment in terms of analysis of “system” vs “person,” as well as an understanding of the importance of prioritizing the “vital few” versus “trivial many” causes revealed by a Pareto Chart analysis. Importantly, participants experienced how Lean philosophy and principles have given rise to practical analysis and process improvements armed with Lean tools.

It should also be acknowledged that the Repair-Co game is typically facilitated within a larger context which can affect participant receptivity to specific ideas. For example, to motivate participation in these sessions, participants were often awarded plastic tokens that could be converted to book prizes or grades at the end of the workshop and academic courses, respectively. These sessions were considered effective based on “plus-delta” feedback from participants and students. However, one limitation of this research is that a separate rating for the Repair-Co Game was never asked of participants. Future research should be done to consider what works well and what could be improved, if anything, to the structure of the Repair-Co Game.

# CONCLUSION

The Repair-Co Game appears to serve as a valuable tool for introducing stakeholders to the principles of Lean Construction. By highlighting the systemic nature of inefficiencies and the need for collective problem-solving, the game effectively demonstrates the usefulness of Lean methodologies. Moreover, its adaptability allows for expansion to incorporate additional Lean tools such as the Ishikawa Fishbone Diagram, Pareto Chart, and 5 Whys Root Cause Analysis, further enhancing participants' understanding of Lean concepts. Testing the extended version of the game across different locations and participant groups yielded consistent results, indicating its potential for widespread application. However, feedback from participants still suggests areas for improvement, including the need for clearer communication and the inclusion of more design-related examples. In general, the Repair-Co Game presents a promising avenue for promoting Lean practices within the construction industry, facilitating continuous improvement and problem-solving at its core. Finally, the extended version of the Repair-Co simulation further enhanced learning outcomes and helped to drive home a message about the need for a systematic approach to consistent improvement in organizational systems with the collaborative application of selected Lean tools.

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