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APPLICATION OF CAUSE MAPPING METHOD IN A BUILDING PROJECT WITH PREFABRICATED SLABS

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ABSTRACT

This paper explores the application of the Cause Mapping method in a building project with prefabricated slabs in Lima, Peru. Cause Mapping is a root cause analysis technique based on the principle that a "root cause" is typically a system of interconnected factors rather than a single issue. In this case study, the method is used to identify, analyze, and propose solutions to the most recurrent quality defects observed in prefabricated slabs. Common defects identified are fissures in the slabs, misalignments in the modulation with respect to the plans, and incorrectly positioned or non-existent installation points. The study uses interviews and documentary analysis in projects of the construction company under study. The results show that many of the defects arise from discrepancies in the design drawings, manual processes in non-mechanized plants and communication problems between the parties involved. As a response, the study proposes optimizing preconstruction processes, strengthening design review protocols, and promoting the adoption of advanced technologies. A noted limitation of the study is that quality defect data were sourced from company records, which may contain inaccuracies or incomplete information. Future research could benefit from broader data samples and an expanded focus to include other scopes of work.

KEYWORDS

Cause Mapping, prefabrication, root cause analysis, defects, quality issues.

INTRODUCTION

The construction sector is one of the most relevant economic sectors globally (Sarmiento-Rojas et al. 2020). Despite its importance, construction projects face many challenges to get completed within the scheduled time, cost, and required quality standards (Shafiei et al. 2023; Khadim et al. 2021). Faced with these problems, lean construction appeared with the aim of minimizing waste and increasing value (Koskela et al., 1992). In this context, many of the goals of lean construction resulted to be achieved with prefabrication, as it permits to reduce waste on site in terms of labour and materials, increase quality and reduce uncertainty (Mawdesley and Long, 2002).

Prefabrication represents a form of industrialization in which certain stages of a construction project are transferred from the field to off-site specialized facilities (Wang and Hu, 2018). In terms of quality, the prefabricated buildings turn the traditional single-site quality management into the current two including factory and site, which makes the quality management more complex, but it is also expected to achieve better quality performance than traditional cast-in-

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situ construction because the prefabrication components manufactured in factories enables to achieve better quality control (Jiang et al. 2018; Li et al. 2016). While quality seems more reliable with prefabrication, quality issues might arise in different fabrication stages, including the design, production, transportation and site installation (Jaillon and Poon 2010). Poor oversight at each stage yields substantial economic losses by risking issues (Li et al. 2022) like improper component lifting, weak connections, lax acceptance scrutiny, among others (Chai et al. 2023).

Different tools and technologies are used in prefabrication to achieve quality, such as BIM (Murray et al. 2003), RFID (Motamedi and Hammad 2009), etc. Nevertheless, in recent years, scholars have shifted their focus from just the technologies and tools to exploring management practices to ensure quality in prefabricated construction. For example, Chai et al. (2023) analyzed the factors influencing the construction quality of prefabricated buildings through a literature review, questionnaires and using Structural Equation Modeling (SEM), getting as results the importance in quality the construction organization and management have. Similarly, Jaillon and Poon (2010) studied quality defects in prefabricated buildings in Hong Kong using questionnaires and case studies, highlighting that a lack of design expertise is a key barrier to the development of prefabricated housing in the region.

From these studies, it is evident that internationally, several tools and methods have been used to identify root causes of defects in prefabrication. However, these tools/methods provide generic causes and do not show the cause-and-effect relations between them, which would enhance problem solving. This can be achieved with Cause Mapping, a root cause analysis method that consists in a simple three-step process for defining, analyzing, and solving problems (Think Reliability 2024). Thus, the present study aims to fill the research gap by applying Cause Mapping to a building project with prefabricated slabs.

The research objectives are: 1) identify the most frequent defects in prefabricated slabs and 2) apply the Cause Mapping method to identify causes and their countermeasures. This study could help project managers develop quality management plans and mitigate losses from potential risks, allowing professionals to concentrate on the most critical stages and factors to implement effective quality control actions.

BACKGROUND

QUALITY AND PREFABRICATION

Quality management of prefabricated buildings must differ from traditional models (Yu et al. 2019). Additionally, producing components demands industrialization, advanced technology, and robust management (Deng and Liu 2020). Prefabricated buildings also involve complex logistics, and poor transportation plans or inadequate protection can compromise quality (Xia et al. 2021). Furthermore, on-site assembly is more intricate than traditional construction, and poorly defined processes or weak personnel management can negatively affect quality (Yuan et al. 2020). In conclusion, high-quality management is essential at every stage of prefabricated construction to meet required standards within project timelines.

CAUSE MAPPING

Root Cause Analysis (RCA) is a collective term that describes a wide range of approaches, tools, and methods that branch out to expose the root cause finally (Rosenfeld 2013). RCA was used as the American Society of Quality (ASQ) adopted the approach that all problems were preceded by an event that caused it (Wilson et al. 1993). It is strongly related to lean, as it has been effectively used with lean tools as kaizen (Kapuria et al., 2017) and value stream mapping (Zahoor et al., 2019). Some of its tools include fishbone diagrams, mind mapping, pareto analysis, causal tree, brainstorming, nominal group technique, metaphorical thinking, 5-Why analysis, among others (Ahmed and Rezouki 2020).

Cause Mapping is an RCA method developed by ThinkReliability, categorised as a cause-and-effect diagram. Unlike other methods, it operates on the idea that a "root cause" is a system of multiple causes rather than a single factor (Zhu 2008). Cause Mapping follows three key principles (Think Reliability 2024):

1. A systems approach, which emphasizes mapping the system of causes to reduce risk.
2. Visual communication, using words, images, and shapes to illustrate relationships between causes, effects, and solutions.
3. Simplicity and effectiveness, avoiding overly complex tools and jargon that often confuse problem-solving processes.

Functionally, Cause Mapping consists of three steps (Think Reliability 2024):

1. Define the problem by outlining what, when, where, and how goals were affected.
2. Analyze the issue by constructing a Cause Map that starts with the impact on goals and moves from left to right, asking "why?" and "what caused this effect?" to form cause-and-effect links while documenting supporting evidence.
3. Develop solutions by first exploring what's possible, selecting the best option, and creating an action plan that assigns tasks, ownership, and deadlines.

METHODOLOGY

A case study methodology will be carried out, since it offers distinct advantages when a researcher is investigating the 'how and why' of a set of events (Yin 1994). The case study consists of a building in Lima, Peru; where Cause Mapping was applied to the defects in prefabricated slabs.

The research's unit of analysis will be the most common quality defects in precast slabs in a construction company which is positioned in the Top 5 of the real estate ranking of the Peruvian Association of Real Estate Companies (ASEI), and the process of applying Cause Mapping to find the root causes of such defects in one project. The data analysis will focus on (1) the description of the projects' context, (2) the identification of the most common quality defects of the precast concrete elements, and (3) the application process of the Cause Mapping method, which includes the problem definition, the identification of the root causes and their solutions.

The methodology is structured in two stages. The first stage will consist on extracting the company's quality defects in prefabricated slabs in the last six building projects from the defects reports in Autodesk Construction Cloud software, using as filter the prefabricated slabs work packages. Then, the information will be standardized to obtain a list of defects with their frequency, and the two most frequent defects will be selected for the cause mapping application in a chosen project. The second stage will consist on applying Cause Mapping by doing semistructured interviews with the contractor's resident engineer, quality engineer and building information management engineer; and with two of the pre-manufacturer's project managers, which were directly involved with the prefabricated slabs work packages in the project chosen for analysis. The information provided will then be validated with project documentation.

RESULTS

CASE STUDIES DESCRIPTION

Seven projects were considered to analyze the defects found inside each project's documentation. Their details are analyzed in Table 1, where the prefabricated slab corresponds to a 5 cm thick concrete panel, structural reinforcement and steel beam “tralicho” of reinforcements, to be completed on site with the remaining pouring with a compression layer.

Table 1: Profile of the company’s construction projects considered in the study.

ID	Project description	Prefabrication description	Number of defects in precast slabs	Structural shell construction period
CS1	22-story residential building + rooftop and 6 basements, with a total area of 25,160 m2	589 post-tensioned prefabricated slabs were produced for the basement’s floor, and 1358 traditional prefabricated slabs for the tower	39	December 2023 – Today
CS2	18-story residential building + rooftop and 6 basements, with a total area of 24,287 m2	617 post-tensioned prefabricated slabs were produced for the basement’s floor, and 1110 traditional prefabricated slabs for the tower	5	January 2024 – Today
CS3	13-story residential building + rooftop and 5 basements, with a total area of 15,300 m2	409 traditional prefabricated slabs were produced for basement, and 767 were for the tower	5	April 2023 – April 2024
CS4	13-story residential building + rooftop and 5 basements, with a total area of 16,129 m2	445 traditional prefabricated slabs were produced for basement, and 805 were for the tower	10	August 2022 – July 2023
CS5	13-story residential building with 1 semi-basement and 3 basements, with a total area of 9,533 m2	298 traditional prefabricated slabs were produced for basement, and 542 were for the tower	3	November 2022 – October 2023
CS6	17-story residential building + rooftop and 6 basements, with a total area of m2	315 traditional prefabricated slabs were produced for basement, and 549 were for the tower	3	September 2021 – October 2022

The project chosen for applying the Cause Mapping method is CS1, because most defects were found there, and it is an ongoing project. This happened because new technology was used: post-tensioned prefabricated slabs. The pre-manufacturer had no previous experience producing this type of prefabricated slab, an+

d they could not use their mechanized plant to produce them. This meant they used the traditional plant with manual tasks, increasing the probability of human error.

The rest of the projects do not have as many defects as CS1 because traditional prefabricated slabs were used, or it was the second time using post-tensioned prefabricated (CS2). Therefore, the company had already experienced a learning curve with each technology and/or were able to use the mechanized plant, resulting in less defects. Moreover, the data was collected from the projects’ documentation, so minor defects that could have happened might not have been registered. And, the construction company used to do a manual registration until July 2023, so they did not have an integrated system of information that allowed the standardization of the defects registry.

MOST COMMON QUALITY DEFECTS IN PRECAST SLAB

The projects' quality defects extracted from documentation were analyzed in detail and then the twelve most frequent were organized as in Table 2. Out of the 12 quality defects identified, the three most frequent are shown in Figure 1: prefabricated slabs with fissures (D1), prefabricated slabs not modulated according to the plans (D2), and incorrectly positioned or non-existent installations (D3).

D1 consists of a visible line or opening in the surface of the slab. According to the pre-manufacturer documents and unstructured interviews, this defect does not have a real impact in CS1, as the cracks were not a structural issue. Furthermore, the pre-manufacturer was responsible for correcting these cracks, so this rework did not take man-hours from the contractor. Additionally, as of the date of data collection, the fissures were observed exclusively in vehicle-accessible basements, where their impact was minimal. This contrasts with the potential consequences if such defects appeared in the tower, which could significantly affect costs and timelines by delaying subsequent activities, such as painting. For these reasons, this defect was not analyzed using the Cause Mapping method.

D2 consists in the pre-manufacturer delivering a prefabricated slab with different lengths from the ones that were agreed. This results in slabs not fitting together on site.

D3 consists of differences between the mechanical, sanitary and electrical installation points' position pre-manufacturer produces for the prefabricated slab, and the ones the contractor needs.

Table 2: Quality defects in precast slabs of the company's construction projects considered in the study.

ID	Quality defects in precast slabs	Frequency	Percentage
D1	Prefabricated slabs with fissures	11	16.92
D2	Prefabricated slabs not modulated according to the plans	10	15.38
D3	Incorrectly positioned or non-existent installation points	6	9.23
D4	Prefabricated slab with edge breakage	5	7.69
D5	Prefabricated slab reinforcement poorly positioned	5	7.69
D6	Lack of pass for sanitary installations in prefabricated slab	4	6.15
D7	Prefabricated slab with porous finish	4	6.15
D8	Lack of slab reinforcement	3	4.62
D9	Joints between slabs	2	3.08
D10	Prefabricated slab with bundle of height not in accordance with tendon profile	2	3.08
D11	Slabs with out-of-round and missing baskets	2	3.08
D12	Rust spot in slab finish	2	3.08

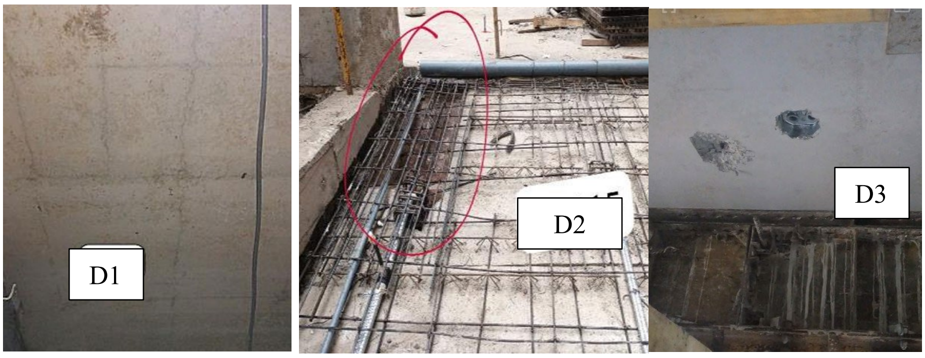

Figure 1: The three most frequent defects in prefabricated slabs: D1, D2 and D3 respectively.

APPLICATION PROCESS OF THE CAUSE MAPPING METHOD

In order to apply Cause Mapping, the three steps must be followed: define the problem, analysis, and solution.

Define the problem

The first step of the Cause Mapping method is to do a proper definition of the problem, as described in Table 3. As noted by Galley (2008), each participant can define a problem differently, but they agree if the investigation starts by focusing on the impact to overall goals, so the authors asked each one what the problem was according to them, what the overall goals of the project were, and why these were impacted by the problem. Moreover, the method requires pinpointing a date to see if something changed as a starting point of the incident and a place where the case study happens. For this reason, these questions were asked to EX2, who has been working in the contractor company for 15 years.

Table 3: Problem outline.

Topic		Description
Problems		Rework due to defect, Man-hours spent on correcting defects in slabs, Slabs not modulated according to validated modulation plans, Incorrect or non-existent installations, Incorrect modulation of slabs
When		The company has been having these defects since 2015 when they started using prefabricated elements
Where		Metropolitan Lima, Peru
Goals Impacted	**Cost**	• Unplanned man-hours spent on correcting the defects • Investment in material to correct the defect
	Time	• Correcting the defect requires conventional formwork and manual rebar placement, which takes more time than placing the precast slab. • Modification of the sectorization, which impacts the schedule

Analysis

The analysis of the problem is shown in Figure 2. As mentioned above, it starts by writing down goals. From there, the key is to ask why something happened so the incident's causes can be traced. After analyzing the issues D2 y D3 with the participants, the authors discovered they both were root causes of the real issue: rework on prefabricated slabs, which directly impacts on the project goal of less time and cost. The rework can be adding formwork and steel mesh in areas without prefabricated slab and chopping the slab to change installation points or add one.

Then, when the participants from the contractor were asked why D2 and D3 happened, they mentioned that the engineering drawings the pre-manufacturer uses to produce the slabs, are different from the ones they use to build. From the contractor side, they admit they might sometimes approve incorrect pre-manufacturer's drawings. The BIM area sends the technical office the validation of the structural drawing, sectorization, installation points and passes, and modulation. But, due to the repetition of this process, this area might get overconfident and not perform a detailed review as it should.

After the semistructured interviews with the contractor's participants, the data was processed, and a draft of the Cause Map was developed. It was then shown to the pre-manufacturer participants, and they were asked why questions to complete it. They mentioned that, after the contractor approves the prefabricator's drawings, there are often changes in the drawings from the contractor because of situations like interferences that are constantly being identified and corrected, or late consults to the structural engineer, among others. And the problem is that those changes are not mentioned to the pre-manufacturer. In addition, they admit that human errors can happen in the premanufacturing plant, but only when they use the non-mechanized plant, because the mechanized plant has the whole process automated. They used the non-mechanized plant essentially for two reasons. The first one was the prefabricated post-tensioned slabs used for the basement of the project, because it was the first time the pre-manufacturer created this type of technology. The second one was the overproduction in the mechanized plant, which forced the use of the other plant. This overproduction usually happened because of machines breaking down, crane being stopped, power outage, and internet connection being cut off.

Proposed Solutions

The causes found in the analysis, their respective evidence according to the participants, and the proposed solutions are described in Table 4. The solutions were developed by doing unstructured interviews with project's participants after the cause map was finished.

Solution S1 tries to include in the contractor's change procedures clauses for notifying the pre-manufacturer of any changes to the plan that are made, and to do so in the shortest possible time. On the other hand, S2 tries to review whether the function of reviewing the prefabricator's plans should be carried out by the BIM area and not by another person in charge in the technical office, to balance the workload. In addition, training in Trimble Connect is recommended, as it is a common cloud environment platform that facilitates the exchange of information, promotes collaboration and reduces response times for any observations.

S3 recommends implementing collaborative work with 3D plans and scale prototypes in the pre-construction stage, seeking a better understanding of the new system. This will reduce costs and times so that, in this case, solutions in the basement can be found in preference to post-tensioned prefabricated slabs, which do not have an automated production process in the mechanized plant. However, S4 mentions that this plant could not always be used due to overproduction in it, so it is recommended to evaluate production plans of the plant to produce based on demand. Moreover, S5, S6 and S7 refer to problems of management of the machinery and services in this mechanized plant, so solutions for this management are proposed.

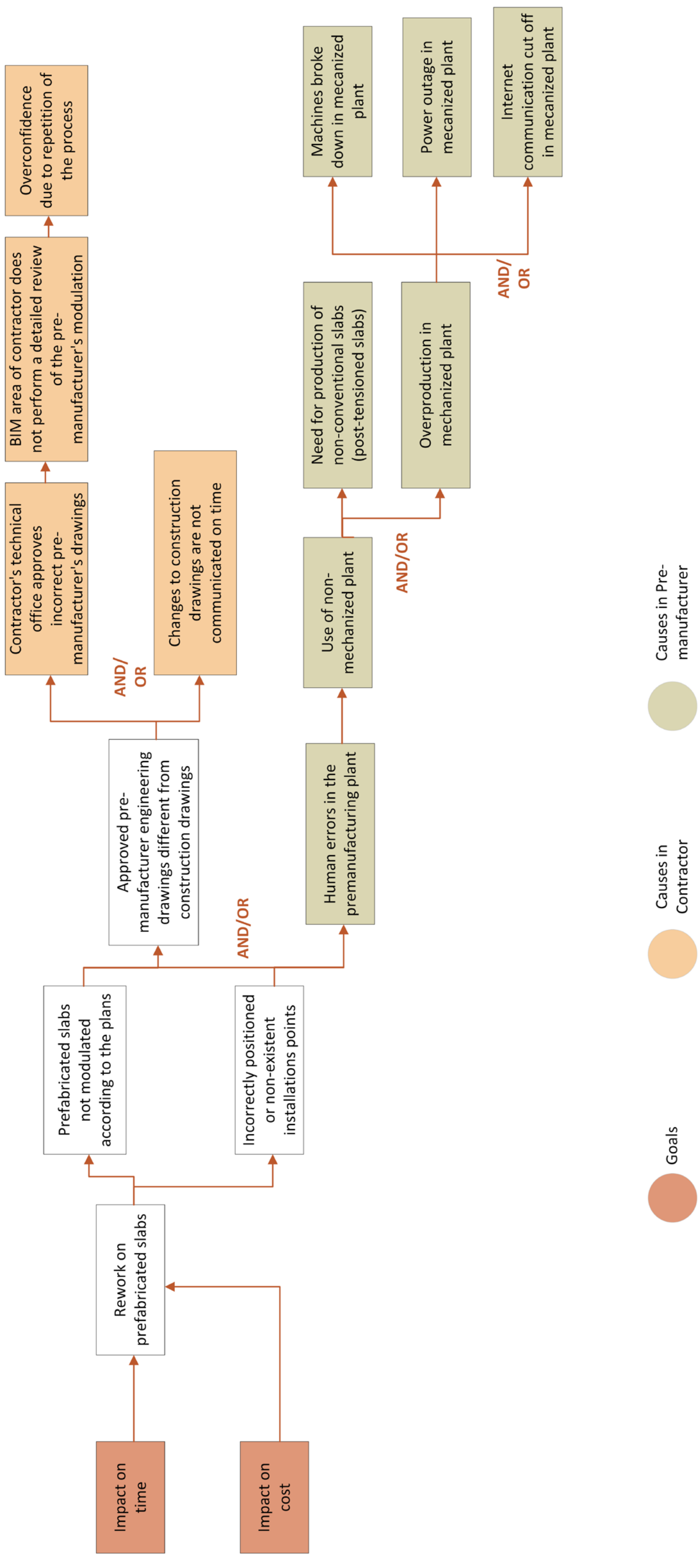

Figure 2: Cause Map of the defects in prefabricated slabs.

Table 4: Evidence and solutions for each cause identified.

ID	Causes	Evidence	Proposed Solutions
S1	Changes to construction drawings are not communicated on time	Contractor's drawings before pre-manufacturer's approval are different from their drawings after the approval	Define procedures for changes, establishing the minimum time required
S2	BIM area of contractor does not perform a detailed review of the pre-manufacturer's modulatio n	Drawings sent by pre-manufacturer that are approved are different from drawings from contractor	Review workload, define functions and distribute tasks. Train in the use of the Trimble Connect tool to better assist in revisions.
S3	Need for production of non-conventional slabs (post-tensioned slabs)	Approved drawings of the technical file	Develop collaborative work in Preconstruction with 3D detailing models Develop prototypes to scale.
S4	Overproduction in mechanized plant	Slab production program in pre-manufacturer	Pre-manufacturer must adjust production according to demand.
S5	Machines broke down in mechanized plant	Current operating certificates	Maintenance plan review and strict compliance
S6	Power outage in mechanized plant	Incident report from plant administrator and security	Evaluate the purchase or rental of a generator set Review of the electrical installations with a specialist Meeting with management of the electrical concessionaire
S7	Internet communication cut off in mechanized plant	Incident report from the plant manager and plant safety	Evaluate the use of fiber optics for the area.

DISCUSSION

Cause Mapping contribution in the case study was that it let the practitioners know the-most frequent defects in prefabricated slabs for the contractor and of what root causes should be mitigated so they do not appear again. Moreover, solutions were proposed so that if they are implemented, the frequency of the analyzed defects should be reduced. This measurement is beyond the paper’s scope, but it is proposed as future research.

From the literature, the quality defect of prefabricated slabs not modulated according to the plans is also described by Kim et al. (2016), where they propose a dimensional assurance quality technique with laser scanning and BIM to avoid this defect. Moreover, Deng et al. (2023) described the quality defect of fissures, explaining that the slabs are susceptible to this during transportation and hoisting, due to the low tensile performance of normal concrete.

Comparing the causes from the literature with the present study, the causes found with Cause Mapping are more particular to the specific case, but they can still be compared. Production of non-conventional slabs could have been avoided with preconstruction training, which is strongly related to the cause found by Chai et al. (2023) where they specify that preconstruction training plays a significant role in the quality of prefabricated slabs. Moreover, the lack of the required technology in non-mechanized plant resulted in human errors, which is in concordance with Liu et al. (2020) and Faridah et al. (2012), where they specified that there is an insufficient grasp of advanced technology that meets production needs. Furthermore, the lack of communication of construction drawings’ changes aligns with the absence of effective communication channels among the actors (Faridah et al., 2012). On the other hand, some of the study's causes were not found in the literature as they are particular to this case, like the contractor's BIM area not performing a detailed review of the pre-manufacturer's modulation.

The proposed method in the study for applying Cause Mapping was found intuitive and easy to use by practitioners, which could promote its use and therefore its benefits. Furthermore, it can be very well mixed with kaizen in construction companies, as it helps to identify where to focus the efforts for continuous improvement. However, more research is needed to find if it is applicable in other contexts like different types of projects, with other technologies apart from prefabrication, and if it can be mixed with managerial practices like the last planner system.

As a limitation in the methodology, the first stage relies heavily on project documentation, which may contain inaccuracies, while the second stage involves interviews where participants protect their own interests, hindering discussion. Additionally, no validation method was used in this study. To improve reliability, future research should involve on-site data collection by a team under the author's guidance, conduct a workshop to develop a cause map with most participants, and validate results through expert judgment.

CONCLUSIONS

The most common quality defects in the prefabricated slabs of the building projects studied include fissures, prefabricated slabs not modulated according to the plans, and incorrectly positioned or non-existent installations. The fissures in prefabricated slabs are a defect that is not considered for this case study because they appeared only in the basement, so it does not affect a future activity like painting. It is recommended as a future study to review the root causes of this defect in a project where this defect appears in the tower.

From the quality defects register, the project in analysis has more defects than the rest of projects because of the new technology used, where the pre-manufacturer had no experience and could not produce the slabs with an automated process. Therefore, it might be concluded that working with a pre-manufacturer with experience and a mechanized plant greatly reduces quality defects.

The Cause Mapping method was applied, and the most important root causes and solutions were found. The results show that many of the defects arise from discrepancies in the design drawings, manual processes in non-mechanized plants and problems in communication between the parties involved. As a solution, it is proposed to optimize preconstruction processes, implement more rigorous reviews and encourage the use of advanced technology.

The study's proposed method for applying Cause Mapping was deemed intuitive and user-friendly by practitioners, potentially encouraging its adoption and maximizing its advantages. Additionally, it integrates effectively with kaizen practices in construction companies, aiding in pinpointing areas for targeted continuous improvement efforts.

The solutions found with the method are meant to reduce the frequency of the quality defects identified, but this was not measured in the present study. Furthermore, problems in the methodology used for conducting separate interviews were found, such as the fact that each one tends to protect their own interests, and there could not be a discussion among the participants to reach agreements. As future research, it is recommended to conduct a study that implements the solutions proposed with Cause Mapping and measure the new frequency of defects and improve the methodology with a workshop involving all these participants to obtain better results. As limitations of the study, the data collected on defects are those that the construction company has been able to record, so other minor problems that could have occurred have not been taken into consideration. In addition, the projects prior to July 2023 had a manual recording of defects, without an integrated information system that would allow the standardization of the quality record. Therefore, it is proposed as future research, to involve the researcher in the project to perform more reliable data collection.

REFERENCES

Ahmed, M. I., and S. E. Rezouki. 2020. “Application of Root Causes Analysis Techniques in the Contractor Selection for Highway Projects.” *IOP Conf Ser Mater Sci Eng*. IOP Publishing Ltd.

Chai, Y., X. Liang, and Y. Liu. 2023. “Construction Quality of Prefabricated Buildings Using Structural Equation Modeling.” *Applied Sciences (Switzerland)*, 13 (17). Multidisciplinary Digital Publishing Institute (MDPI). https://doi.org/10.3390/app13179629.

Deng, B.-Y., Tan, D., Li, L.-Z., Zhang, Z., Cai, Z.-W., & Yu, K.-Q. (2023). Flexural behavior of precast ultra-lightweight ECC-concrete composite slab with lattice girders. Engineering Structures, 279, 115553. doi:10.1016/j.engstruct.2022.115553

Deng, H., and J. Liu. 2020. “Research on PC Component Quality Risk Evaluation Based on Intuitionistic Fuzzy Analytic Hierarchy Process.” *IOP Conf Ser Earth Environ Sci*. IOP Publishing Ltd.

Galley, M. 2008. “Basic Elements of a Comprehensive Investigation”. *ThinkReliability*.

Gibb, A. 1999. *Off-site Fabrication: Prefabrication, Pre-assembly and Modularisation*. Scotland: Whittles Publishing.

Jaillon, L., and C. S. Poon. 2010. “Design issues of using prefabrication in hong kong building construction.” *Construction Management and Economics*, 28 (10): 1025–1042. https://doi.org/10.1080/01446193.2010.498481.

Jiang, R., C. Mao, L. Hou, C. Wu, and J. Tan. 2018. “A SWOT analysis for promoting off-site construction under the backdrop of China’s new urbanisation.” *J Clean Prod*, 173: 225–234. Elsevier Ltd. https://doi.org/10.1016/j.jclepro.2017.06.147.

Kapuria, T. K. , Rahman, M. and Haldar, S. (2017). Root Cause Analysis and Productivity Improvement Of An Apparel Industry In Bangladesh Through Kaizen Implementation. *Journal of Applied Research on Industrial Engineering*, *4*(4), 227-239. doi: 10.22105/jarie.2017.108637.1025

Khadim, N., S. Taseer, M. Musarat, and U. Ilyas. 2021. “Effects of Corruption on Infrastructure Projects in Developing Countries.” *International Journal on Emerging Technologies*, 12 (1): 284–295.

Kim, M. K., Wang, Q., Park, J. W., Cheng, J. C. P., Sohn, H., & Chang, C.-C. (2016). Automated dimensional quality assurance of full-scale precast concrete elements using laser scanning and BIM. Automation in Construction, 72, 102–114. doi:10.1016/j.autcon.2016.08.035

Koskela, L. (1992). Application of the New Production Philosophy to Construction. Technical Report # 72. Center for Integrated Facility Engineering. Department of Civil Engineering. Stanford University.

Li, C., H. Yao, and P. Jin. 2022. “Identification and control of influencing factors of assembly building construction quality.” *Urban Build Space*, 29: 356–357.

Li, C. Z., J. Hong, F. Xue, G. Q. Shen, X. Xu, and M. K. Mok. 2016. “Schedule risks in prefabrication housing production in Hong Kong: a social network analysis.” *J Clean Prod*, 134 (Part B): 482–494. Elsevier Ltd. https://doi.org/10.1016/j.jclepro.2016.02.123.

Moody, D. L., and G. G. Shanks. 2003. *Improving the quality of data models: empirical validation of a quality management framework $. Inf Syst*.

Motamedi, A., and A. Hammad. 2009. *RFID-Assisted Lifecycle Management of Building Components Using BIM Data*.

Murray, N., T. Fernando, and G. Aouad. 2003. “A Virtual Environment for the Design and Simulated Construction of Prefabricated Buildings.” *Virtual Real*, 6 (4): 244–256. https://doi.org/10.1007/s10055-003-0107-8.

Mawdesley, M. J., & Long, G. (2002). Prefabrication for Lean Building Services Distribution. In C. T. Formoso & G. Ballard (Eds.), 10th Annual Conference of the International Group for Lean Construction

Ng, T., E. Palaneeswaran, and M. Kumaraswamy. 2012. "Costs and Benefits of ISO9000-based Quality Management Systems to Construction Contractors." *Construction Economics and Building*, 8 (2): 23–29. University of Technology, Sydney (UTS). https://doi.org/10.5130/ajceb.v8i2.3003.

Qi, B., Y. Zhu, and W. Fan. 2016. "Risk factor identification method of the whole life cycle in prefabricated construction." *J. Shenyang Jianzhu Univ. (Soc. Sci.)*, 18 (3): 257–261.

Rosenfeld, Y. 2013. "Root-Cause Analysis of Construction-Cost Overruns." https://doi.org/10.1061/(ASCE)CO.

Sarmiento-Rojas, J. A., J. S. Gonzalez-Sanabria, and C. G. Hernández Carrillo. 2020. "Analysis of the impact of the construction sector on Colombian economy." *Tecnura*, 24 (66): 109–118. https://doi.org/10.14483/22487638.16194.

Shafiei, I., E. Eshtehardian, F. Nasirzadeh, and S. Arabi. 2023. "Dynamic modeling to reduce the cost of quality in construction projects." *International Journal of Construction Management*, 23 (1): 24–37. Taylor and Francis Ltd. https://doi.org/10.1080/15623599.2020.1845425.

Think Reliability. 2024. "Cause Mapping®." *https://thinkreliability.com/cause-mapping/*.

Wang, Z., and H. Hu. 2018. "Dynamic response to demand variability for precast production rescheduling with multiple lines." *Int J Prod Res*, 56 (16): 5386–5401. Taylor and Francis Ltd. https://doi.org/10.1080/00207543.2017.1414970.

Wilson, P., L. Dell, and G. Anderson. 1993. *Root Cause Analysis: A Tool for Total Quality Management*. American Society for Quality.

Xia, M., L. Zhao, Y. Qiao, Z. Yuan, Y. Cui, L. Zhao, and J. Li. 2021. "Analysis of Factors Affecting the Quality of Precast Components Based on Structural Equation Modeling." *Arab J Sci Eng*, 47 (4): 4171–4185. Springer Science and Business Media Deutschland GmbH. https://doi.org/10.1007/s13369-021-05991-z.

Xue, H., S. Zhang, Y. Su, Z. Wu, and R. J. Yang. 2018. "Effect of stakeholder collaborative management on off-site construction cost performance." *J Clean Prod*, 184: 490–502. Elsevier Ltd. https://doi.org/10.1016/j.jclepro.2018.02.258.

Yin, R. 1994. *Case study research: design and methods*. California: Sage Publications.

Yu, T., Q. Man, Y. Wang, G. Q. Shen, J. Hong, J. Zhang, and J. Zhong. 2019. "Evaluating different stakeholder impacts on the occurrence of quality defects in offsite construction projects: A Bayesian-network-based model." *J Clean Prod*, 241. Elsevier Ltd. https://doi.org/10.1016/j.jclepro.2019.118390.

Yuan, Z., Z. Zhang, G. Ni, C. Chen, W. Wang, and J. Hong. 2020. "Cause Analysis of Hindering On-Site Lean Construction for Prefabricated Buildings and Corresponding Organizational Capability Evaluation." *Advances in Civil Engineering*, 2020. Hindawi Limited. https://doi.org/10.1155/2020/8876102.

Zahoor, Sadaf & Abdul-Kader, Walid & Ijaz, Hamza & Khan, Atif & Saeed, Zeeshan & Muzaffar, Shoaib. (2019). A Combined VSM and Kaizen Approach for Sustainable Continuous Process Improvement. International Journal of Industrial Engineering and Operations Management. 01. 10.46254/j.ieom.20190203.

Zheng, S., D. Wang, Q. Zuo, and X. Feng. 2016. "SEM-based research on the quality and safety factors of prefabricated components." *Journal of Engineering and Management*, 30 (6): 112–117.

Zhu, Q. 2008. "Goal trees and fault trees for root cause analysis." *2008 IEEE International Conference on Software Maintenance*, 436–439.