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# Lean Practice Techniques for Safer Offsite Construction in Malawi

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**Abstract:** Within offsite construction (OSC), lean practice is one of the philosophies used for improving safety performance. While lean practice is recognized as an important mechanism for addressing poor safety performance, limited empirical insight is available on lean practice techniques (LPTs) implemented by OSC contractors in developing countries. This study investigated the LPTs implemented by OSC contractors for safety improvement in Malawi. The qualitative data were collected using semi-structured interviews conducted with thirteen OSC contractors in Malawi. Thematic analysis was used for data analysis with 'summative' approach used partially for quantitative counting and comparison of the keywords or phrases. Overall, 30 LPTs were identified as being implemented by OSC contractors in Malawi. Out of the 30 LPTs, only six LPTs reached the 46.15% cut-off point of significantly implemented LPTs. Such LPTs included 'use of personal protective equipment (PPE)', 'providing necessary working equipment', 'shining' (n = 13, 100%), 'use of visual tools' (n = 10, 76.92%), 'use of safeguards' (n = 7, 53.85%), and 'use of visual safety demarcations and borders' (n = 6, 46.15%). The implication of the study lies in the use of LPTs that improve construction safety, both in developed and developing countries such as Malawi. Lean improvement efforts would need to focus on the LPTs with low implementation, and initiatives that help organisations improve their lean practices. The study findings also present an opportunity for project actors to develop interventions for supporting implementation of LPTs to improve construction safety performance.

**Keywords:** Contractors, lean practice techniques, offsite construction, safety.


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## 1. Introduction

The construction industry has one of the highest rates of fatalities, averaging 1.7 fatalities per 100,000 workers in developed countries (Tyler, 2020), i.e., United Kingdom (UK), and 21.0 per 100,000 workers in developing regions, i.e., sub–Saharan Africa (SSA) (Construction industry development board, 2016). Improper workplace safety conditions have been blamed for site showdown in the construction industry. Despite global efforts to improve safety performance through implementation of safety legislation and programmes, the International Labour Office (2003) estimates that 60,000 workers are fatally injured around the world annually. Such statistics, including those that show the mortality rate in the construction sector is three times the mortality rate of the manufacturing sector (Ghosh and Young-Corbett (2009), encourage the need for interventions to reverse the trajectory.

Within the sustainable construction philosophical worldview, the construction industry is transiting towards the adoption of offsite construction (OSC) as a mechanism for resolving the ailing safety performance in the construction sector. Lean practice is employed as a production philosophy to reduce wastes, i.e., accidents, during manufacture and assembly of OSC components. Lean practice is characterised as a philosophy for identifying and eliminating waste in construction processes as a way of mitigating the risk of workplace accidents that cause injuries, illnesses, and fatalities. According to Dermikesen (2020), lean practices have shown the ability to positively affect safety performance and sustainability indicators including social, environmental, and economic. A lean tool is a methodology that is adopted to establish reliable manufacturing or construction activities that minimize process and production wastes. A lean practice technique (LPT) is a specific qualitative feature or practice within lean construction tool that defines how a certain activity should be executed in order to eliminate processes that are not valuable. LPTs are, therefore, subsets of lean tools (Bashir, 2013). The following is a brief introduction of the synthesis of literature relating to six lean construction tools and techniques illustrating their relationship to safety.

5S housekeeping is described as management of various factors on construction sites, including people, materials, and machines (Wu et al., 2019). The main aim of the 5S management tool is to optimize the arrangement and formation of various offsite/onsite factors to improve efficiency and eliminate waste (Wu et al., 2019). It is intended to systematically keep the workplace well-organized through cleanliness, orderliness, and standardization (Bashir et al., 2011). This is achieved through simplification of production flow, elimination of emplacements of materials/equipment, and minimization of movement and displacement of employees (Bajjou et al., 2017; Bashir et al., 2011). It provides basic rules for workplace organization aimed at minimizing waste and creating a conducive working environment (Aisheh et al., 2012). By providing a conducive workplace, 5S provides a platform for effective implementation of all other lean management tools (Aisheh et al., 2012). The 5S process comprises five levels of onsite management interventions aimed at keeping the construction process well organized for the uninterrupted value-adding construction operations (Bashir, 2011; Bajjou et al., 2017). They include organising, i.e., removing unnecessary or lesser-used materials and tools to avoid condensation and improve circulation and safety conditions at the workplace (Mohammad et al., 2013), orderliness, i.e., arranging materials and tools in a defined manner (Gambatese and Pestana, 2014), cleaning, i.e., removing all emplacements and keeping only materials and tools required for a specific task around the workstation, thereby avoiding obstructions and unnecessary congestion caused by bulky or unwanted items (Ingle et al., 2015), standardizing i.e., defining a standard working procedure to maintain the workplace cleanliness and organization (Bashir, 2011), and sustaining, i.e., maintaining a culture of continuous improvement among workers (Aisheh et al., 2012). Recently, a sixth S, i.e., 5S + safety) has been introduced to create a conducive working environment dedicated to safety (Aisheh et al., 2012; Ingle et al., 2015).

Visualization management (VM) is a lean tool used in communicating specific instructions to workers or detecting deviations from standard working procedures (Saurin et al. 2006). It involves the use of visual devices to disclose or display safety information through safety signs and labels, visual demarcations and boards, and digital billboards and dashboard graphics (Saurin et al., 2006; Bajjou et al., 2017; Wu et al., 2019). The overt display of the information allows a wide range of users to access the required information in real time. For example, frequent visualization of the information allows workers to remember what their work demands, such as performance and safety targets, workflow schedule, and quality requirements (Bashir, 2013). Incorporating visual tools in the working process also allows easy communication of safety information, identification of hazardous work areas, and motivation of workers (Bajjou et al., 207; Saurin et al., 2006). VM brings awareness to workers who lack safety consciousness and judgment (Wu et al., 2019; Aisheh et al., 2012).

Mistake proofing is a lean tool for proactively checking the construction process ahead of time to prevent free flow of errors in the construction process (Gambatese and Pestana, 2014). In fact, the approach employs various forms of interventions aimed at preventing errors or defects from flowing through the manufacturing and construction processes or detecting migration from standard working procedures (Saurin et al., 2006). The specific lean practices include equipment failure alert or warning systems, personal protective equipment (PPE), visual inspection devices, and safeguards (Bashir, 2011; Saurin et al., 2006). Among others, interventions make use of audible or visual tools such as hazard warnings or equipment failure alert gadgets to warn workers against imminent danger or crossing unsafe boundary guards (Bashir et al., 2017; Bajjou et al., 2017).

The Last Planner System (LPS) is a concept that was developed by Glen Ballard in 2000 based on principles of lean production (Bashir et al., 2011). Ballard describes LPS as "the most completely developed lean construction tool" (Ogunbiyi et al., 2012). The last planners are site supervisors who are usually close to the realities and constraints of the execution of the work (Bajjou et al., 2017). LPS minimizes waste and improves reliability in production flow through robust planning, control, scheduling, and mutual coordination among project stakeholders (Bajjou et al., 2017; Bashir et al., 2011). It advances a tectonic shift from traditional and optimistic planning systems of construction processes to a more realistic approach that is based on workers' ability to achieve performance in a safe way. LPS techniques include empowering and involving workers in safety planning, correlation of workers skills and abilities with work methods, pre-task hazard analysis, weekly work plan, plan for supervision, and providing employees with safety equipment (Bashir et al., 2011; Enshassi et al., 2019).

Daily huddle meetings (DHM) provide a platform for brief daily start-up meetings of project stakeholders to review previous work and methods, discuss both good and bad aspects and suggest ways of improving performance (Bashir, 2013; Aziz and Hafez, 2013). For example, DHM provides an avenue where last planners and workers discuss safety rules, anticipated safety hazards, mitigation measures, and review the previous tasks (Enshassi et al., 2019). Thus, it provides an opportunity to review how tasks should, can, and will be done to achieve safety improvements in workstations (James et al. 2014). It requires involvement and two-way communication between managers and employees to encourage a coordinated approach to tackling production challenges, increase productivity, and job satisfaction (Saurin et al., 2006).

Enshassi et al. (2019) describe First Run Studies (FRS) as a systematic method for critically analysing work methods in order to identify the most appropriate and safest method that matches the ability and skills of the worker. It uses video files, photos, and illustrations to describe work methods to the workers (Bashir, 2013). FRS comprises techniques such as planning for the critical tasks and illustration of work methods using videos photos (Enshassi et al., 2019). It involves modelling of construction processes to demonstrate how tasks must be performed safely. It also includes investigation of accidents and thorough scrutinization of operations and exploration of alternative approaches to doing tasks.

Overall, the application of LPTs in OSC is reported to minimise accidents caused by inter alia excessive stress, human error, organisational pressure, and poorly organised workplaces (Carvajal-Arango et al., 2021; Bashir et al., 2011; Bajjou et al. 2017). However, there are limited empirical studies that identify the extent of LPTs implementation by contracting organisations involved in OSC in developing countries. The dearth of literature on lean management practices implemented by contracting organisations involved in OSC in developing regions, including sub–Saharan Africa (SSA) and countries such as Malawi, add to the ambiguity about occupational health and safety (OHS) challenges in developing countries. Some studies have attributed the problem of poor safety performance to 'pseudo-lean', i.e., selective, schematic and incomplete implementation of LPTs in various lean tools (Tezel et al., 2017). Hence, the focus of this study is identification of LPTs implemented by contracting organisations for safety improvement in Malawi in order to unpack implementation issues that need attention.

## 2. Method

The study adopted a method appropriate for identifying LPTs applied in OSC. The five steps involved in carrying out this qualitative study are captured in a framework illustrated in Figure 1.

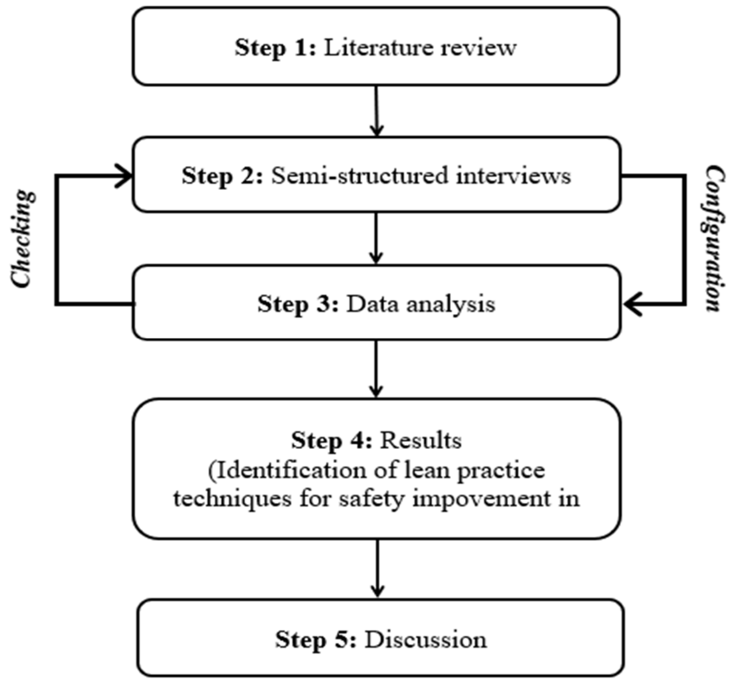


**Fig. 1.** The research framework (Adapted from Chileshe et al., 2016)

### 2.1. Research Design

The study adopted a qualitative data collection method using semi-structured interviews. Due to their flexibility and adaptability, semi-structured interviews produce in-depth information that leads to the discovery of new frontiers never pre-conceived. Furthermore, semi-structured interviews are effective when the research is premised on seeking to understand attitudinal aspects such as people's opinions regarding a subject matter (Denscombe, 2014; Axinn and Pearce (2006). The approach has earlier been used in construction management research, i.e., Kavishe and Chileshe (2020).

### 2.2. Selection of Respondents

Since knowledge of OSC was critical to the study, purposive and snowballing sampling techniques were used to select interviewees with experience in OSC. These techniques were deemed appropriate because OSC is still in its early stages of adoption in developing countries. The list of participating contracting organisations was downloaded from the website of National Construction Industry Council (NCIC) of Malawi. NCIC is an organisation that issues operational licenses to construction companies in Malawi. The council maintains a list of licenced contractors that was accessed on its websites. However, the list does not provide details regarding the actual nature of the work in which the companies are engaged. As a result, preliminary inquiries were made to ascertain the companies' involvement in OSC. The potential interviewees were asked if they were aware of OSC or if they use components from any OSC production systems such as modular building, or construction, volumetric pre-assembly (VP), or non-volumetric pre-assembly (NVP). Where it was feasible, site visits were conducted to inspect the nature of work in which contracting organisations were engaged. However, most of the contractors that were contacted and whose work was inspected were not engaged in OSC. Only eight contractors were identified as fitting the sample requirements. In order to increase the sample size and improve the response rate, snowball sampling was adopted. Thus, purposively sampled interviewees were requested to refer the researcher to other contracting organisations engaged in OSC operations. A further five contractors were identified, making a total of thirteen respondents. Nine interviews were conducted face-to-face, and four were conducted virtually.

The sample size of thirteen was considered adequate for this study. According to Patton (2002), the threshold of between five and 50 is considered adequate for the purpose of reaching saturation. The idea of supporting data saturation as a guide to adequate sample size in qualitative research was espoused by Boddy (2016), who asserts that once saturation is reached, the findings could be generalised to the entire population. Furthermore, the depth of the collected data supported by the principle of saturation is more important in qualitative research than the size of the sample (Burmester and Aitken, 2012). Consequently, with thirteen interviewees, the results generated from the study could provide in-depth insights into the issue under investigation. Further, the results could provide some degree of analytic generalisation. An analytical generalisation based on qualitative data yields ideas pertaining to newer situations that serve as a basis for developing or testing theories and conclusions with wider implications for contexts that are far more similar (Yin, 2014; Halkier, 2011; Yin, 2013). Low response rates with qualitative questionnaires are not a new thing in construction management research. Previous studies are replete with similar response rates, i.e., twelve PPP experts (Kavishe and Chileshe, 2020) and eleven experts (Tengan and Aigbavboa, 2018), whose results were extrapolated to similar situations and contexts. As such, the collected data was considered suitable for further analysis.

### 2.3. Data Collection

As illustrated in Figure 1, semi-structured interviews with open-ended questions were used to collect data from interviewees. Based on the research questions, the interview guide contained a set of 23 pre-determined questions, which were discussed with a degree of flexibility and adaptability. The qualitative interview guide was designed and applied using standard best practices as suggested by Young et al. (2017), Moser and Korstjens (2018), and McGrath et al. (2019). The interview guide was divided into four sections. Section A sought information about individual and organisational characteristics of the interviewees. Section B probed for information regarding LPTs applied by interviewees' organisations, while the impact of the techniques on safety and their implementation challenges were sought in sections C and D, respectively. However, this paper is limited to the identification of LPTs applied by OSC contractors in Malawi.

Semi-structured interviews were preferable because they allow the researchers to probe, prompt and pursue issues of interest, and the respondents have the liberty to speak widely about issues (Young et al., 2017). The process is an interactional event where the researcher and the interviewee discuss the questions in an iterative manner. Furthermore, interviews can investigate complex and sensitive issues and navigate any form of limitation in the sample population (Young et al., 2017). However, in order to obtain quality and in-depth information from the interviewees, interviewers must possess skills for crafting questions and following interesting issues with supplementary questions.

### 2.4. Thematic Analysis and Trustworthiness in Qualitative Research

Thematic analysis (TA) was used as the main approach for data analysis with 'summative' approach used partially for quantitative counting and comparison of the keywords or phrases for qualitative analysis of the data. A combination of qualitative data analysis methods has been used in previous studies (Kavishe and Chileshe, 2020; Liu and Wilkinson, 2011). TA was used to develop a story from the texts of interest by noting patterns and themes to structure a compendium of codes that included a description of how such codes are interrelated (Brough, 2019). In the current study, the process involved six iterative phases, as suggested by Braun and Clarke (2012) and shown in Figure 2. The researchers familiarised themselves with the datasets through active, critical, and analytical reading of the transcripts of the interviews to identify items of potential interest. Codes were generated to provide a summary of portions of data related to specific research questions. In qualitative studies, the initial coding commences from a theory that is, just as in this study, based on the previous findings. The generated codes were clustered and collapsed into themes which represented important topical issues in relation to the dataset. This process was conducted repeatedly until the researchers were convinced that the themes conveyed a coherent story in relation to the overall dataset and research questions. Furthermore, the themes were refined and renamed to ensure that they had a clear focus, purpose, and scope to convey a story. Based on the recommendation of Creswell (2014), the process flowchart for qualitative data analysis included a step for a validity and reliability check in qualitative data. Qualitative validity entails checking the accuracy of the results from the standpoint of the researcher, participants, and readers by employing certain procedures (Creswell, 2014). Qualitative reliability examines the consistency of the researcher's approach by relating it to the approach of different researchers and studies in the same scholarly field, among others. The concern is whether the findings are comprehensive, accurate, and trustworthy (Moon, 2019). In this study, the strategies for validity and reliability checks included obtaining interviewees consent, triangulation of the data, seeking clarity in descriptions, agreement of the exactness of their responses, documentation of the research process, and references to extant literature. Triangulation of data entails converging several data sources, i.e., different construction professionals, to ensure that data, analysis, and conclusions were credible, dependable, confirmable, and transferable (Moon, 2019). It also entails using clear descriptions of the setting and themes to make the findings more realistic and richer. The researchers must also document their study protocol clearly, i.e., every step of the procedure used in the study, which other researchers can follow easily. In the current study, qualitative reliability checks included checking and eliminating obvious mistakes made during the transcription of the data and avoiding drift in the definition and meanings of the codes through a recursive process of reviewing datasets against the codes and the themes. Additionally, every step of the research process was well documented and was consistent with previous studies in construction management research.

However, as shown in Figure 1, another strategy used for ensuring validation of the research process was that of member checking, which according to Kavishe and Chileshe (2020) verifies the accuracy of the data collected through an iterative loop of checking and confirming. In this study, the cyclical and interactive nature of checking and confirming was nested between data familiarisation and theme naming. As used in previous studies, such as Ardichvilli et al. (2003) and Chileshe et al (2016), 'member checking', 'participation checks', and 'validation' were carried on the collected qualitative data. The final stage of qualitative TA involved interpretation and discussion of the findings which contained illustrations using extracts from the raw data. A flowchart of the qualitative data analysis is shown in Figure 2.

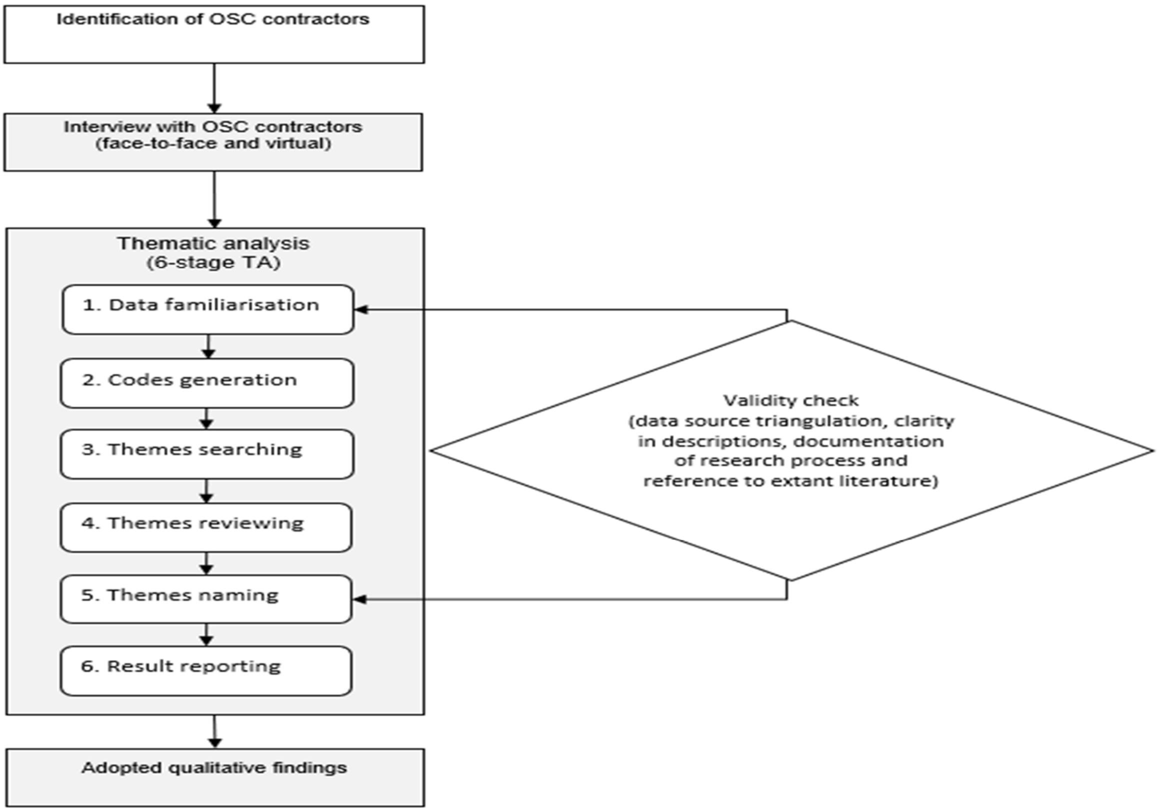


**Fig. 2.** Process flowchart for qualitative data analysis

## 3. Results

As illustrated in the research framework in Figure 1, the fourth step is associated with presenting the research results. The results of the study are presented in three main headings including interviewees' profile, the relevance of the interviews to safety in their organizations, and LPTs applied by contracting organizations.

### 3.1. The Profile of Interviewees

The following sub-sections present results of the individual and organisational characteristics of the interviewees.

#### 3.1.1. Individual characteristics

The profile of the interviewees is given in Table 1. The interviewees included a combination of various professionals holding various key senior management positions. These included company directors, project managers, quantity surveyors, designers/architects, site managers, and safety managers. Regarding their working experience, R2, R3, R5, and R13 have over 15 years of working experience while R1, R4, R8, R10, R11, and R12 have working experience of over ten years. R6 and R7 have working experience of seven and nine years, respectively. Though the level of work experience differs across the interviewees, the banded distribution and mean working experience of twelve years show that their responses can be considered an accurate depiction of their organisations' LPTs.

#### 3.1.2. Organisational characteristics

A total of thirteen professionals were interviewed on behalf of their organisations. A sample of thirteen organisations could be taken as a good response rate, considering that OSC is not mainstream in Malawi. The interviewees contracting organisations were licensed to undertake building and civil engineering works. While two organisations are engaged in building works only, three are involved in civil engineering works. The remaining eight are licenced to undertake both building and civil engineering works. Having eight organisations involved in multiple work categories in the profile of interviewees for this research spreads the responses to the questions across a variety of projects and experiences that would potentially provide credible answers to the research questions. Further, most of the interviewees' organisations are large-sized organisations. Out of thirteen, ten organisations are large-sized firms, while two are medium, and one is a small organisation. The categorisation of organisations into size was based on the number of workers employed in an organization, in which an organisation employing one to fifty employees is classified as small, 51 to 250 is classified as medium, and over 500 is classified as large. The size of a contracting organisation relates to the size and scope of projects the organisation undertakes. By nature, OSC involves extensive offsite and onsite operations that require rigorous planning, extensive use of equipment, and involvement of experts in various trades. Most of the large contractors would have the capacity to handle such projects. Their participation in the study, therefore, provides lived experiences on issues under investigation.

**Table 1.** Profile of interviewees – individual and organisational attributes

| Respondent | Role | Work experience (years) | Type of work the organisation engages in | Number of employees in organisation | Size of organisation |
|---|---|---|---|---|---|
| R1 | Project manager | 12 | X | Over 251 | Large |
| R2 | Managing director | 15 | Z | 51-250 | Medium |
| R3 | Managing director | 20 | Y | Over 251 | Large |
| R4 | Design/Architect | 11 | Z | Over 251 | Large |
| R5 | Site manager/engineer | 16 | Y | Over 251 | Large |
| R6 | Site manager/engineer | 7 | Z | 51-250 | Medium |
| R7 | Quantity surveyor | 9 | Z | 1-50 | Small |
| R8 | Quantity Surveyor | 13 | Z | Over 251 | Large |
| R9 | Quantity surveyor | 6 | X | Over 251 | Large |
| R10 | Quantity surveyor | 12 | Z | Over 251 | Large |
| R11 | Safety manager/officer | 10 | Z | Over 251 | Large |
| R12 | Safety manager/officer | 11 | Y | Over 251 | Large |
| R13 | Designer/Architect | 20 | Z | Over 251 | Large |

Note (X = Building works; Y = Civil engineering works; Z = Building and civil engineering works)

### 3.2. The Relevance of Interviewees to Safety in their Organisations

Two of the interviewees, R11 and R12, are directly involved in safety management in their organisations. As safety managers, R11 and R12 are directly responsible for planning and implementing safety provisions in the manufacturing and construction phases of OSC projects. While the rest of the interviewees were not directly involved in safety management issues in their organisations, they were indirectly involved in promoting safety onsite through inter alia planning site operations, reviewing and selecting work methods, and costing safety requirements. By virtue of their involvement in this regard, the interviewees influence safety management decisions. R7 reported that the primary responsibility for health and safety belongs to the specialised safety managers. As a quantity surveyor, their role is to price safety items, however, "…in case of safety issues such as safety violations as may be observed onsite, I may pinpoint the issue and offer advice. On safety issues, I work hand in hand with the safety officer...". It can be concluded that various senior management personnel contributes to safety management in contracting organisations in different ways. Thus, having a profile of the interviewees made up of senior management personnel involved in organisations' decision-making process enables the collection of appropriate responses that provide relevant answers pertaining to the issue under investigation.

### 3.3. Lean Practice Techniques Applied by Contractors

As illustrated in the research framework in Figure 1, the fourth step is associated with the identification of LPTs implemented by OSC contractors in Malawi. The interviewees were asked to mention the LPTs applied in their organisations. Table 1 presents a summary of the identification frequency of LPTs by the interviewees. The responses are based on the following question: 'What are the LPTs applied in your organisation?'

As can be seen from Table 2, a total of 30 techniques are mentioned by the interviewees. Based on the frequency of citations, the most frequently cited LPTs are as follows: Use of PPE (n = 13, 100%), providing necessary working equipment (n = 13, 100%), shining (n = 13, 100%), use of visual tools (n = 10, 76.92%), use of safeguards (n = 7, 53.85%), and use of visual safety demarcations and borders (n = 6, 46.15%). Thus, out of 30 LPTs, six techniques (20%) reached the 46% cut-off point. These six techniques were significantly implemented by various OSC contractors. Out of the remaining 24 practices (80%), two techniques (15.38%) are mentioned five times, i.e., identifying and eliminating all work constraints (n = 5, 38.46%), orderliness, i.e., arranging materials and working equipment/machinery/tools in a defined manner (n = 5, 38.46%), five techniques (38.46%) are mentioned four times, i.e., selecting safest work methods, orderliness, hazard warning systems, involvement of workers in safety planning, and hazard identification and elimination (n = 4, 30.77%), one technique (3.33%) is mentioned three times, i.e., undertaking pre-task analysis (n = 3, 23.08%), four techniques (30.77%) are mentioned two times, i.e., devising plans for operations and supervision, standardize, equipment failure alert gadgets, and two-way communication (n = 2, 15.38%), and eight techniques (61.5%) are mentioned once, i.e., use of graphical dashboards and digital billboards, organisation, simplification, use of video as files, review of previous work, identification of good and bad practices, and sharing information (n = 1, 7.69%). Considering that LPTs are a sub-set of lean tools (Bashier et al., 2013), most of the lean tools comprise one or more LPTs. LPTs implemented by contracting organisations are discussed under appropriate lean tools.

**Table 2.** Lean practice techniques applied in contracting organisations

| Lean tool | LPT code | Relevant lean practice | Implementing organisation | Frequency | % |
|---|---|---|---|---|---|
| 5S Housekeeping | H1 | Organisation, i.e., separating necessary from unnecessary materials and tools | R5 | 1 | 7.69 |
| | H2 | Orderliness, i.e., arranging materials and working equipment/machinery/tools in a defined manner | R1, R7, R10, R12, R12 | 5 | 38.46 |
| | H3 | Shining, i.e., cleaning the workplace from emplacements | R1, R2, R3, R4, R5, R6, R7, R8, R9 R10, R11, R12, R13 | 13 | 100 |
| | H4 | Standardize, i.e., adopting a standard working procedure to keep the workplace well organized | R1, R3 | 2 | 15.38 |
| | H5 | Simplification of production flow | R6 | 1 | 7.69 |
| Visualization management | VM1 | Signalization devices such as safety signs and labels | R1, R2, R3, R4, R6, R7, R8, R9, R11, R12, R13 | 11 | 84.62 |
| | VM2 | Graphical dashboards | R12 | 1 | 7.69 |
| | VM3 | Digital billboards | R12 | 1 | 7.69 |
| | VM4 | Visual safety demarcations and borders | R1, R2, R5, R8, R10, R13 | 6 | 46.15 |
| Mistake proofing | MP1 | Audible devises | | 0 | 0 |
| | MP2 | MP3Visual tools | R1, R2, R3, R4, R6, R7, R8, R9, R11, R12, R13 | 11 | 84.62 |
| | MP3 | Hazard warning systems | R2, R3, R12, R13 | 4 | 30.77 |
| | MP4 | Equipment failure alert gadgets | R1, R4 | 2 | 15.38 |
| | MP5 | Safe guards | R3, R7, R8, R9, R11, R12, R13 | 7 | 54.85 |
| | MP6 | PPE | R1, R2, R3, R4, R5, R6, R7, R8, R9 R10, R11, R12, R13 | 13 | 100 |
| LPS | LPS1 | Selecting the most appropriate and safest work methods | R2, R3, R10, R12 | 4 | 30.77 |
| | LPS2 | Correlating work methods to workers abilities and skill | R2, R3, R5, R6 | 4 | 30.77 |
| | LPS3 | Providing necessary working equipment | R1, R2, R3, R4, R5, R6, R7, R8, R9 R10, R11, R12, R13 | 13 | 100 |
| | LPS4 | Identifying and eliminating all work constraints | R1, R2, R3, R5, R6 | 5 | 38.46 |
| | LPS5 | Empowering and involving workers in planning operations | R8 | 5 | 38.46 |
| | LPS6 | Undertaking pre-task analysis | R4, R7, R10, | 3 | 23.08 |
| | LPS7 | Devising plans for operations and supervision | R4, R13 | 2 | 15.38 |
| | LPS8 | Coordination and planning of job tasks | R1 | 1 | 7.69 |
| Daily huddle meetings | DHM1 | Review of previous work | R13 | 1 | 7.69 |
| | DHM2 | Identification of good and bad practice | R13 | 1 | 7.69 |
| | DHM3 | Sharing of information | R13 | 1 | 7.69 |

**Table 2.** Lean practice techniques applied in contracting organisations (continued)

| Lean tool | LPT code | Relevant lean practice | Implementing organisation | Frequency | % |
|---|---|---|---|---|---|
| Daily huddle meetings | DHM4 | Involvement of workers in safety planning | R5, R6, R11, R12 | 4 | 30.77 |
| | DHM5 | Hazard identification and elimination | R1, R4, R11, R12 | 4 | 30.77 |
| | DHM6 | Two-way communication | R11, R12 | 2 | 15.38 |
| First run studies | FRS1 | Use of video files, photos and illustrations to show and illustrate, review, analyze and plan work methods | R2 | 1 | 7.69 |

## 4. Discussion

The fifth step in the research framework in Figure 1 deals with discussion of the results. The interviewees individual and organisational characteristics demonstrate their appropriateness in providing credible information to the identification of LPTs applied by OSC contractors in Malawi. The study targeted organisations involved in OSC, and the interviewees were senior management personnel involved in decision making including that of lean practice and safety management.

Frequency citation as recommendation by Kavishe and Chileshe (2020) was used to identify the LPTs applied by organisations. The LPT was considered significant if it was mentioned more than six times, i.e., 46% by the interviewees. On the occasion where the technique was mentioned by less than six times, it was considered less significant. This approach was also used by Kavishe and Chileshe (2020) in the identification of critical capacity building challenges in public private partnerships in Tanzania. As recommended by Namey et al. (2008), the number of times (i.e., a particular technique was mentioned) was based on the frequency of citation determined on the basis of the number of the individual interviewees who mentioned a particular LPT.

The results have shown that only 20% of the LPTs identified in this study are significantly implemented by contracting organisations. Conversely, 80% of LPTs are not significantly implemented by contracting organisations in Malawi, including none in DHM and FRS lean tools. The pseudo-lean implementation strategy of LPTs evident in this study may explain the poor safety performance in the construction industry in Malawi and similar developing countries in SSA and beyond. In fact, earlier studies on OHS have found low implementation of safety measures, including management practices, among construction companies in Malawi. The challenges were attributed to the inverse relationship between national competitiveness (i.e., as measured by the World Economic Forum [Schwab, 2018]) and the rate of occupational fatal accidents. National competitiveness refers to the set of institutions, policies, and factors that determine the level of productivity (Schwab, 2018). This inverse relationship suggests that countries such as Malawi, which have a low competitiveness index, would have higher rates of occupational fatal accidents and, by inference, have weaker systems for managing OHS, including low implementation of LPTs. The lower implementation of LPTs in the construction industry in Malawi and similar developing countries could, therefore, be inferred to the theory of low competitiveness index. Though organisations implementing some of the LPTs would be more likely to experience increased safety performance, the overall desired level of safety performance may not be achieved by implementing LPTs at a lower scale. The LPTs complement one another in practice, and none or selective implementation of the LPTs could cause inefficiencies in safety management on construction sites. Consequently, under appropriate lean tools, the following sections discuss the LPTs implemented by contracting organisations as well as their implication on safety.

### 4.1. 5S Housekeeping

As summarized in Table 1, under 5S housekeeping, five LPTs were mentioned. These include organization, orderliness, shining, standardize, and simplification of production flow. Out of the five LPTs, only H3, i.e., shining, was significantly implemented by OSC contractors (i.e., n = 13, 100%). All other remaining LPTs were not significantly implemented, i.e., H1 (n = 1, 7.69%), H2 (N = 5, 38.46%), H4 (N = 2, 15.38%), and H5 (N = 1, 7.69%). Shining entails keeping the workplace clean to avoid obstructions and unnecessary congestion caused by bulky or unwanted items (Bajjou et al., 2017). However, cleaning or decongesting a construction site is coincidentally done through the implementation of other 5S LPTs, such as organising and orderliness. Orderly arrangement, arranging materials in a defined manner, and organising, separating necessary from unnecessary items of construction assets and materials actually meant cleaning the site. Implementing these LPTs could prevent injuries caused by poor workplace design, poor site awareness, slipping, and tripping. It could also reduce the physical and mental pressure that comes with poor housekeeping. R1 commented that “cleaning the site reduce avoidable accidents such as tripping which may cause critical injuries when one falls from a height. You know, in the unlikely event where the falling person causes the scaffold to collapse, other workers may be injured, and construction tools and materials may also be damaged in the process.” Since the sheer implementation of H3 implies the implementation of other 5S LPTs, such as H1, H2 and H4 in practice, the overall implementation of 5S LPTs in practice may be considered good.

The safety implication of implementing 5S LPTs was shown in earlier studies. Wu et al. (2019) states that 5S LPTs address safety hazards related to unsafe site conditions and onsite equipment. The authors assert that the first 3S for organization, orderliness, and cleanliness are used to keep the workplace and working environment more organized. An organised workplace improves the safety of workers and their satisfaction with working conditions, with a consequential reduction in the number of safety complaints and increased satisfaction with the construction process. Yet, in another study of the connection between lean design/construction and construction worker safety, Gambatese and Pestana (2014) concluded that the implementation of 5S LPTs can prevent injuries and most of the near misses recorded onsite. The authors posit that the 5S process can reduce confusion, extra steps and motions, on-the-spot decisions, and decrease trips and falling hazards. Overall, the 5S housekeeping was said to motivate and increase the morale of workers with consequential positive safety performance. Further, by standardizing operations, the author reported that workers were able to take variables out of the work process and know what to do, thereby creating less room for errors. A study by Aisheh et al. (2022) found that a clean workplace and organized and orderly placement of materials around the workplace limit the likelihood of accidents, especially those related to site congestion. Thus, LPTs under 5S prevent accidents caused by excessive stress, human error, organizational pressure, poorly organized workplaces (Carvajal-Arango, 2021), site congestion, slips and trips, condensation of materials/equipment in the inventory, emplacements of materials/equipment on construction jobsite, and poor ergonomics (Bashir et al., 2011; Bajjou et al., 2017).

### 4.2. Visualisation Management

As far as VM, Table 1 shows that four LPTS were mentioned. OSC contractors significantly implemented the use of safety signs and labels (VM1) and visual safety demarcations and borders (VM4), i.e., n = 11, 84.62% and n = 6, 46.15%, respectively. VM two and VM3 were least implemente, i.e., n = 1, 7.68% each. The importance of VM as a lean tool and associated techniques in relation to safety improvement in OSC cannot be overemphasised. Safety labels, signs, demarcations, and borders improve visualization of onsite safety situations (environment system), provide safety warnings against dangerous usage of equipment or unauthorized entry to dangerous areas (equipment system), and help workers fulfil their safety responsibilities and improve their intuitive understanding of safety issues on site (management system) (Wu et al., 2019). Bashir (2017) posited that displaying standard operating procedures allows workers to acquire real-time information regarding the execution of operations to minimize human errors, which are a source of many safety hazards in the construction sector. Aisheh et al. (2022) observed that VM techniques minimize accidents caused by human errors, unsafe worker behaviour, poor communication, and unplanned sites by guiding workers to avoid dangerous areas. Bajjou et al. (2017) and Le and Nguyen (2023) found that causes of accidents, including excessive stress, human error, organizational pressure, and poor working conditions could be reduced by the use of VM techniques. Thus, the implementation of H1 and H4 could be considered critical in reducing the occurrence of accidents on construction sites. However, the reason for the lower implementation of H1 and H2 was attributed to the cost and technology associated with the procurement and operationalization of the graphical and digital billboards. R5 attributed the short-terminism and temporal nature of construction projects as the reason for not implementing H1 and H2. Furthermore, R13 pointed out that “safety provisions in contracts do not provide for such techniques as graphical dashboards or digital billboards other than perimeter fences, red tapes and other safety signs inscribed on timber boards or steel plates”. This study asserts that the advantage of digital boards is flexibility in terms of displaying information such as safety targets in real time. The rigidity and time lapse associated with other physical forms of displaying information, such as painting signs or inscribing writings on timber boards or steel plates, may prove costly in safety management. Safety information and targets must be displayed in real-time to ensure an immediate response from workers and all parties concerned. In order to improve safety performance in construction, clients, consultants, and contractors need to rethink the importance of digital boards in safety management, especially in displaying important safety information in real time. This could be a large improvement, especially on larger construction sites involving a higher concentration of people and equipment working in the vicinity of each other.

### 4.3. Mistake Proofing

6 LPTs under mistake proofing were cited by interviewees (See Table 1). Out of six mistake proofing techniques, the use of PPE was the most frequently implemented technique (n = 13), followed by the use of visual tools (n = 11) and safeguards (n = 7). PPEs and safeguards are poka-yokes within the mitigation mistake-proofing principle which seeks to minimize the consequential impacts of errors. The prevalence of ‘use of PPE’ among organisations was not surprising considering that it is a basic practice applied by organisations to fulfil contractual obligations. According to R13 “…PPE is required on any project, minor or major…it is basic requirement that shows compliance to OHS that the project stakeholders would be looking at when they inspect the site”. R6 added that “…provision of PPE is provided for in contract…and non-compliance can have huge consequences on the contractor”.

PPEs are a form of body insulation consisting of hard hats, overall or work suits, gloves, boots or gumboots, goggles, as well as masks. PPEs protect the workers from a wide variety of hazards, including burns from sparks generated from hot-work, i.e., welding activities, laceration potential from impaling and striking objects, pinch-point potential from objects struck against objects, struck-by moving equipment or flying objects, contact with power lines or energized cables as well as exposure to hot surfaces, trip and slip hazards, falling hazards, fires and explosions, exposure to chemicals, gasses and carcinogens, harmful fumes and vapors, inhalation of dust, silica, saw dust, and similar harmful substances (Zhang et al., 2020). They are also useful for identification purposes and posting of safety slogans (Saurin et al., 2006; Albert et al., 2020). Safeguards are ideal in protecting workers from fatal falling accidents caused by working from an elevated work platform (EWP), including slips and trips. EWPs present scaffolding hazards which could be better mitigated with the use of safeguards. Such hazards include improper erection and dismantling of the scaffolding system, fixating scaffolding system on unstable ground, performing work on uncomplete, unsecured, uninspected, defective and fragile scaffolding system, non-availability of warning notices and fail-safe systems, lack of adequate safe escape gateways, and use of fragile planks (Akal et al., 2020). Safeguards could also protect workers from safety hazards caused by unguarded edges at higher elevation, unsafe guardrails, unavailability of PPEs, slip and trip hazards, fall through floor openings, fall from ladders and staging, lack of standards and diversion from rules, lack of cognitive skills, training and experience, and bad weather hazards. Thus, PPEs and safeguards are critical in mitigating against a variety of accidents directly or indirectly.

Hazard warning and equipment alert systems as well as audible devices, though not significantly implemented, are used on construction for predicting workers and equipment real-time movements and exact positions on construction site (Zhu et al., 2016) for avoidance of equipment collision accidents (Soltanmohammadlou, et al. 2019). Such tools are used to detect motions and send signals to alert those affected by the threat or request a response from a designated person. They intend to intercept deviation from standard rules and notify the safety officer of the abnormality before the occurrence of the accident. The systems launch an alarm in the form of audible and luminous means when they detect a breach in safety procedures. Such warning alerts would prove beneficial to workers and equipment safety on the construction site. Generally, construction equipment and machine-related accidents such as crane failure and collapse, use of faulty equipment and tools, collision of machines, and failure to adhere to safe use of machines could be avoided through the use of hazard warning and equipment alert systems. According to R3, the implementation of hazard warning and equipment alert systems varies with the nature of the project. R3 indicated that "such techniques are common in civil engineering projects where extensive use of equipment and mobile machines is common…[but it isunlikely in building projects where the use of machinery is minimal. Of course, in OSC, cranes and similar machines are used and as professionals we need to start looking at that as an opportunity to up our game." Accordingly, the construction industry should start investing in technologically advanced LPTs to improve safety on construction sites effectively.

### 4.4. Last Planner System

Under this tool, the most frequently implemented practice was 'providing necessary working equipment' (n = 13, 100%), which all sampled organisations implemented. Within this tool, the next most implemented practices were 'empowering and involving workers in planning operations', 'identifying and eliminating all work constraints' (n = 5, 38.46%), 'selecting the most appropriate and safest work methods', and 'correlating work methods to workers abilities and skill' (n = 4, 30.77%). LPTs under LPS have features that are considered significant in safety promotion in OSC. Bashir et al. (2013) assert that worker empowerment and involvement in safety issues eliminate onsite accidents caused by time, organisational pressure, and excessive stress. Selecting and correlating workers' abilities and skills with tasks at hand could similarly reduce accidents related to physical and mental disabilities, excessive stress, and exposure to safety hazards (Bashir et al., 2013). Arguably, lean techniques, such as involving and empowering workers in selecting tasks and methods that correlate with their abilities, skills and commitments, pre-task analysis, and plan of supervision, contribute tangibly to positive safety performance. LPS mitigates accidents caused by time, organisational pressure, and excessive stress (Bashir et al., 2011). In addition, LPS minimises accidents caused by poor work methods, poor supervision, poor planning and control, poor coordination of workers, physical and mental inability, and lack of empowerment and involvement of workers in safety planning (Bajjou et al., 2017; Bashir 2013). Lower implementation of these LPTs would impact safety negatively and cause organisations to incur direct and indirect costs of accidents, thereby affecting the company's bottom line.

### 4.5. FRS and DHB

LPTs within FRS and DHB were the least implemented techniques, with all LPTs being implemented by less than four organisations. However, LPTs with FRS and DHB are important to safety management in OSC. The LPTs within FRS and DHM provide some form of training avenues to equip workers with basic safety knowledge and skills. Aziz and Hafez (2013) posit that FRS improves safety and quality performance of construction projects. For example, visual illustration of how construction operations must be performed provides clear working methods with positive safety impact on workers. Lingard et al. (2015) observed that teaching of safety information to workers through a visual format like a video is better suited to communicating safety information than written text. According to Lingard et al. (2015), the benefits of FRS were apparent in crane operations and subsequent construction operations. FRS minimizes accidents caused by poor planning and control, human error, lack of knowledge and motivation, poor site awareness, and non-compliance with procedures (Bashir, 2013).

Regarding DHM, Mitropoulos et al. (2007) state that planning for critical tasks through conducting DHM eliminates human errors and makes construction tasks mistake proof. Aisheh et al. (2022) observed that DHM limits the risk of poor communication and improves safety awareness among workers at the workplace. Aisheh et al. (2022) also showed that clarification of work methods reduces accidents caused by lack of knowledge. DHM allows the workers to plan and gather tools and materials required for a particular work to avoid unnecessary movements and rotations with the potential for causing ergonomic hazards and physical and mental fatigue (Nahmens and Ikuma, 2011). A study by Aisheh et al. (2022) showed that communication between management and employees provides an opportunity to control the work thereby limiting accidents from stressful work and poor organization. Further, the study showed that collective meetings limit poor communication and enhance safety performance. DHM also allows for a thorough review of previous work, identification of safety risks, and their mitigation measures to achieve continuous improvements (Aisheh et al., 2022). DHB promotes two-way communication, empowerment and involvement of workers, sharing of information among project stakeholders, and safety planning (Sarhan et al., 2017; Bashir, 2013). It also gives a forum for workers to suggest safe work for performing tasks, to get educated on hazard identification, and mitigation. Thus, DHB eliminates accidents caused by poor communication, poor coordination, and lack of safety knowledge.

## 5. Conclusions

The present study identified LPTs implemented by OSC contractors in Malawi. Overall, 30 LPTs were found to be implemented by OSC contractors in Malawi. These included five LPTs under 5S, four LPTs under VM, six LPTs under mistake proofing, eight LPTs under LPS, six LPTs under DHM, and one LPT under FRS. However, the most prevalent and significant LPTs implemented by OSC contractors included 'use of PPE', 'provision of necessary working equipment', 'shining', 'use of visual tools', 'use of safeguards', and 'use of visual safety demarcations and borders'. Using the cut-off point of 46.25%, this represented 20% of all LPTs identified in the study. The unsatisfactory implementation of the LPTs as revealed in this study is a pointer to higher records of accidents experienced in the construction industry in developing countries. Usually, piece-meal implementation of measures for improving safety leads into inefficiencies.

The contribution of the study lies in its ability to highlight the LPTs applied by OSC contractors in Malawi and similar developing countries. Increased understanding of the LPTs applied by OSC organisations could lead to identification of lean tools and LPTs that need improvement. Factors limiting the implementation of other LPTs could also be explored to ensure adequate implementation of LPTs for safety improvement in construction. For policy makers and clients, the findings could help in making deliberate policy decisions to encourage and support contracting organisations in lean implementation for improved safety performance. Future studies are recommended to conduct quantitative investigation of lean management practices of construction companies to supplement the findings of this study.

While the study contributes to the safety research domain in developing countries, the study has some limitations. Firstly, despite employing purposive and snowballing sampling techniques in data collection, the sample size did not exceed 13. One plausible explanation for the low sample is the relative infancy of modern construction methods such as OSC in Malawi. However, since the data were obtained from construction professionals with lived experience of OSC, the data was deemed credible for further analysis. Secondly, the qualitative data were obtained from OSC contractors operating in Malawi. As such, their opinions on LPTs are restricted to that context. As such, the results may only be analytically generalised to relevant theories applicable to work in a similar context.

## Author Contributions

Wakisa Simukonda contributes to conceptualization, methodology, validation, analysis, investigation, data collection, draft preparation, and manuscript editing. Fidelis Emuze contributes to manuscript editing, visualization, supervision, and project administration.

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