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STRATEGIES TO IMPLEMENT LEAN MAINTENANCE CONCEPT FOR HIGH-RISE COMMERCIAL BUILDINGS IN SRI LANKA

K.K. Arasakulasooriya[1], P. Sridarran[2] and T. Sivanuja[3]

ABSTRACT

Maintenance management (MM) is an important function in managing high-rise commercial buildings. In comparison to low-rise and mid-rise structures, commercial high-rise buildings have severe maintenance management deficiencies. According to prior studies, implementing lean in maintenance is a well-known and effective strategy to improve maintenance efficiency. Thus, this study aimed to identify strategies to implement the lean maintenance concept for high-rise commercial buildings in Sri Lanka. Due to the lack of literature on building maintenance in the context of Sri Lanka, a pilot survey was carried out to establish the research problem of the study. Consequently, a comprehensive literature synthesis was conducted revealing building maintenance, lean and lean maintenance. Further, the applicability of lean maintenance in the global context of building maintenance had been reviewed. Consequently, under qualitative research methodology, a case study strategy was adopted. The findings of the study identified the experts 'perception of lean principles in building maintenance and challenges in implementing lean maintenance in commercial high-rise buildings in Sri Lanka from the selected cases. Lack of knowledge about lean, ineffective tactics, and the absence of standards, regulations, and policies are some of the major challenges to lean adoption in Sri Lanka. Then, experts who have extensive experience in both lean and maintenance were interviewed to identify strategies to address the identified challenges in commercial high-rise buildings in Sri Lanka.

Keywords: *Commercial High-Rise Buildings; Implementation Challenges; Lean Maintenance; Maintenance Management; Strategies.*

1. INTRODUCTION

Organisations concern maintenance as a crucial necessity to deliver a better-built environment to the end-users by ensuring assets and equipment are in operating condition (Mong et al., 2019). Modern maintenance practices are considered activities that contribute to an organisation's strategic objectives. According to De Silva et al. (2012), several maintenance management (MM) concerns are involved with maintaining high-rise buildings in the Sri Lankan context. To illustrate, the authors have identified, a lack of knowledge of effective maintenance strategies, no proper use of policies, schedules,

[1] Associate Engineer, Eutech Cybernetic, Sri Lanka, kanishkaarsakulasooriya@gmail.com
[2] Senior Lecturer, Department of Facilities Management, University of Moratuwa, Sri Lanka, psridarran@uom.lk
[3] Lecturer, Department of Facilities Management, University of Moratuwa, Sri Lanka, sivanujat@uom.lk

and maintenance documents, budgetary constraints, shortfalls of IT applications, and shortage of professional staff and commitment as the main hinders of MM in local high-rise buildings. Consequently, imperfect MM practices performed in local high-rise buildings significantly impact building operability and operation costs. Lean philosophy has been recognised as one of the most successful philosophies applied across the globe, which increases the efficiency and capability of organisations (Jasiulewicz-Kaczmarek & Saniuk, 2018). It has been established that a lean thinking approach can be utilised to address issues in managing maintenance while aligning maintenance with business objectives, thus maximising profits (Davies & Greenough, 2003; Ghayebloo & Shahanaghi, 2010). According to Jasiulewicz-Kaczmarek and Saniuk (2018), lean maintenance focuses on achieving the optimum level of equipment reliability, while consuming the least amount of resources. Additionally, maintenance performance can be improved via adopting lean maintenance tools (Jasiulewicz-Kaczmarek & Saniuk, 2018; Mostafa, Lee, et al., 2015). The application of the lean maintenance concept for high-rise commercial buildings in Sri Lanka has numerous challenges, which require appropriate strategies to overcome them. This paper starts with a literature review on why lean maintenance is required for high-rise commercial buildings. Section 3 presents the research methodology. The research findings and discussion are presented in Section 4 followed by conclusions and recommendations.

2. LITERATURE REVIEW

2.1 FIVE PRINCIPLES OF LEAN

According to Womack and Jones (1996), lean thinking is the antidote to process waste which involves five basic principles as shown in Figure 1.

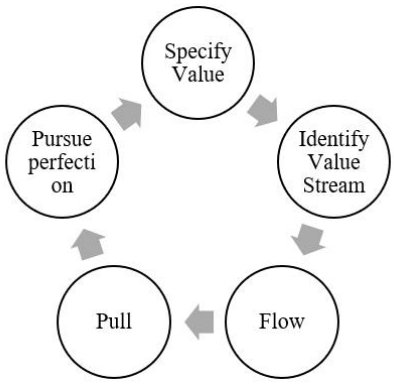

Figure 1: Five Lean Principles

The first lean principle involves defining value according to the customer, then secondly, the value stream should be identified as comprising all the actions needed to bring a product to the customer (Womack & Jones, 2003). Thirdly, value-creating steps will be arranged in a flow and fourthly customers will be let to pull the product and finally measures will be taken to achieve perfection (Womack & Jones, 2003).

2.2 LEAN MAINTENANCE TOOLS

Lean principles have not been only limited to the manufacturing industry but have also increasingly extended to other sectors as well (Bruun & Mefford, 2004; Holweg, 2007). In parallel, Womack and Jones (2003) have hypothesised that lean principles can be

adopted in all organisations. Integration of lean thinking into maintenance activities via applying lean principles and tools is known as lean maintenance (Mostafa, Dumrak, et al. 2015). Non-value-adding activities within maintenance can be reduced substantially by implementing lean tools (Jasiulewicz-Kaczmarek, 2013).

A study performed in 2013 using an integrated list of lean tools in both industrial firms and the service sector shows that Total Quality Management (TQM), Just In Time (JIT), work teams and job re-engineering are the most commonly used lean tools in both sectors: work teams and job reengineering held more important than other tools in the service sector (Krishnan & Parveen, 2013). Abreu et al. (2016) have proposed a model comprising pillars to support the implementation of a lean approach in building maintenance, which is given in Figure 2.

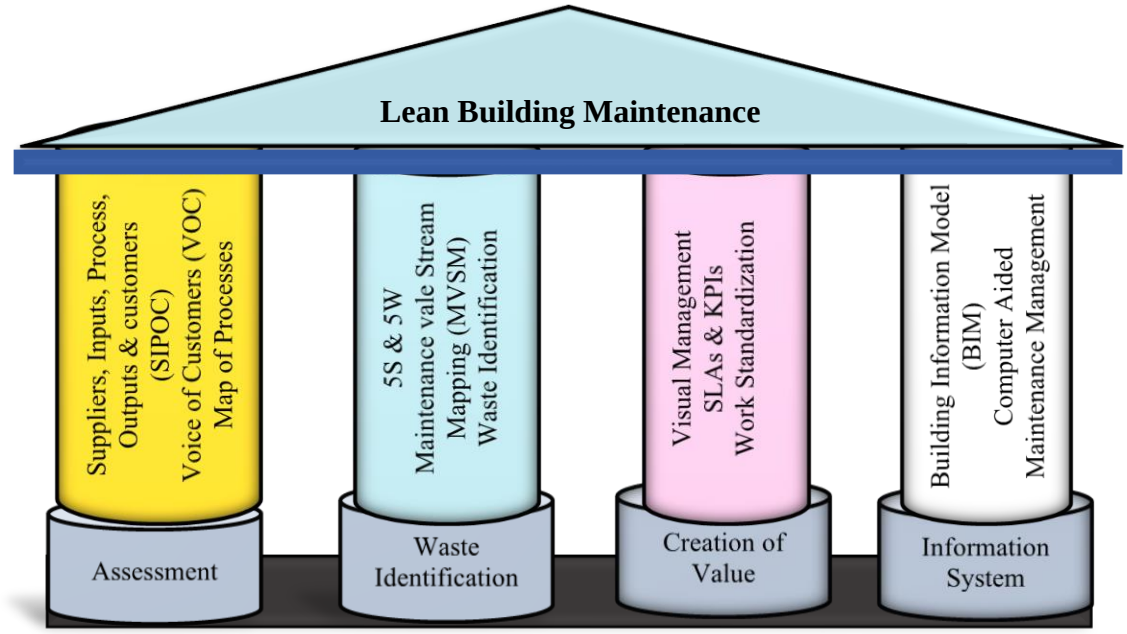

Figure 2: Pillar diagram of lean building maintenance

Source : (Abreu et al., 2016)

The pillar diagram comprises four pillars: assessment, waste identification, creation of value and information system. The first represents the identification of the value of maintenance to the end-users and then via the second pillar, it is expected to identify the available waste in maintenance operations. Subsequently, the third and fourth pillar aims to eradicate waste and enable continuous improvement.

2.3 CHALLENGES IN IMPLEMENTING LEAN MAINTENANCE IN HIGH-RISE BUILDINGS

De Silva et al. (2012) have established eight challenges of lean maintenance out of fifty-one maintainability causes associated with building maintenance in a study conducted using thirty high-rise buildings in the Colombo district as, (1) Architecture and design, (2) Materials and spare parts, (3) Structural and detailing, (4) Maintenance requirements, (5) Services integration, (6) Construction quality, (7) Accessibility, and (8) Maintenance Management. Other than MM, all the other challenges are initiated in the construction and design phase of a building, thus not plausible to address in the operational stage. Similarly, Wood (2005) states that building maintenance lacks the involvement of long-

term and cost-effective strategies such as preventive and conditioned bases methods. Most of these issues hinder the optimal utilisation of resources and thus become challenging in the process of implementing lean. In addition, people resist change since they feel more comfortable and safer being in the immediate environment and fear the consequences of the change (Asnan et al., 2015). According to Almehareb and Graham-Jones (2010), a key challenge in implementing lean philosophy is the resistance from the management and the employees. In conclusion, the implementation of lean maintenance is having scores of challenges given the context of high-rise buildings.

3. RESEARCH METHODOLOGY

Due to the lack of recent research carried out for MM and maintenance practices relating to commercial high-rise buildings in the Sri Lankan context, a pilot survey was carried out by interviewing two professionals who have been engaged in MM and maintenance practices in the targeted context for more than ten years. As proven in the background study and literature synthesis, it is evident that MM in high-rise commercial buildings in Sri Lanka has not been paid enough attention and can be improved by utilising lean maintenance principles and tools. Therefore, MM practices in commercial high-rise buildings in Sri Lanka were selected as the unit of analysis for this study. A comprehensive literature review was conducted to perceive theory-based knowledge regarding the concept of lean maintenance and identify the applications of lean maintenance in building maintenance. The case study technique was used as this study's research problem necessitates a thorough investigation. Excel-based Manual content analysis is used for this study due to the smaller number of respondents and to become more familiar with the respondents' responses. Since this research is focused on the applicability of lean maintenance in commercial high-rise buildings in Sri Lanka, concluding multiple cases was mandated to conduct content analysis. Accordingly, a multiple-case design was selected and the unit of analysis, number of cases and criteria for the selection of cases were defined. Due to the Colombo district's dominance of commercial high-rise buildings relative to other districts, three cases were chosen within it. This study focuses on how lean maintenance and its tools can be applied to improve the efficiency and effectiveness of MM activities in commercial high-rise buildings in Sri Lanka, a qualitative approach would be the best suitable approach for this study. Except for two respondents with more than five years of experience, eight respondents with managerial to executive level expertise who were directly involved in maintenance operations and had more than 10 years of experience been chosen for semi-structured interviews to evaluate the viability of implementing lean maintenance in high-rise commercial buildings in the setting of Sri Lanka. Furthermore, only two specialists with experience in lean maintenance were chosen to provide strategies to overcome identified challenges from Sri Lankan high-rise commercial buildings. A cross-case analysis was used to further analyse the themes found in the manual content analysis. The data gathered from expert interviews are analysed using a qualitative data analysis technique called template analysis.

4. RESEARCH FINDINGS

Table 1 provides a brief description of the selected cases.

Table 1: Profile of the selected cases

Case Name	Description
Case A	A building with 39 floors owned by a property development company which exceeds 150 meters in height.
Case B	A private bank-owned building with 24 floors exceeding 80 meters in height.
Case C	A state bank-owned building with 33 floors exceeding 100 meters in height.

Table 2 presents a summary of the respondents selected from each building.

Table 2: Profile of selected case study respondents

Building	Respondent	Designation	Experience in High-Rise Building Maintenance
A	A1	Head of Facilities Management	10 years
	A2	Electrical supervisor	15 years
	A3	Mechanical Engineer	More than 5 years
B	B1	Assistant Manager- Facilities Management	10 years
	B2	Senior Supervisor Maintenance	More than 10 years
C	C1	Mechanical Engineer	More than 15 years
	C2	Civil Engineer	More than 12 years
	C3	Senior Supervisor - Mechanical	More than 5 years

Table 3 presents a summary of the experts selected.

Table 3: Profile of selected respondents as experts

Expert Respondent	Description
E1	Certified Total Production System & Total Management System Practitioner (Grade IV) by a leading automobile manufacturer in Japan with more than 12 years of industry experience
E2	Systems Consultant (KAIZEN, TQM, Japanese 5'S, TPM Japanese Management Practice) with 25 years of industry experience

4.1 EXPERTS' PERCEPTION OF LEAN PRINCIPLES IN BUILDING MAINTENANCE

Two experts' views on applying lean in high-rise building maintenance are discussed under the following categories. Table 4 presents a summary of the experts' responses on lean principles and respective lean tools in maintenance.

Table 4: Summary of Expert's Responses on Lean Principles Relating to Building Maintenance

Lean Principle	Lean Tools
Specify Value	Activities support achieving Total Productive Maintenance (TPM)'s major goals; Zero breakdowns, zero accidents and zero defects

Lean Principle	Lean Tools
	Voice of the customer (VOC) and Suppliers, Inputs, Process, Outputs and Customers (SIPOC)
Identify Value	Process Mapping
	Value Stream Mapping (VSM)
Flow the Value	Improve availability and eliminate waste
	Eliminate bottlenecks in the process.
Pull the value	Use Kanban and Machinery KPIs
	Centralised system to track progress
Pursuing perfection	KAIZEN
	5S

4.1.1 Specify the Value

E1 explained the first principle, specifying the value involves defining the activities that support achieving the three goals of the TPM: zero breakdowns, zero accidents and zero defects. By specifying the value, the maintenance crew can eliminate intermediate breakdowns (zero breakdowns), minimize defects (zero defects) and eliminate accidents (zero accidents). So, major KPIs from the TPM can be considered to specify the values. Lean maintenance is oriented based on TPM. Contrasting to E1, E2 said "*First, you have to identify the external and internal customers. Then we have to listen to the VOC. We can draw a SIPOC Diagram. We use SIPOC to identify customer requirements. In SIPOC we investigate customer-stated and inclined requirements*". Finally, it can be concluded that to specify value it is required to identify and define the requirements of the customers or the value they expect from doing maintenance. In concluding the experts' assertions, it can be decided that customers' value can be decided based on the SIPOC diagram, VOC and TPM goals.

4.1.2 Identify the Value

Describing the second principle, identifying the value E1 said "*To identify those value-adding activities we perform process mapping.* The maintenance team can easily identify all value-adding and non-value-adding activities by using process mapping, as well as which activities lead to zero breakdowns and zero accidents. Similarly, E2 explained that either VSM or process mapping can be utilised to identify the value. Therefore, according to both experts, VSM or process mapping can be used to identify value-adding activities.

4.1.3 Flow the Value

To flow the value, E1 stated it is required to improve the availability of both maintenance staff and machines. Further, he added *"By eliminating waste as much as possible we can improve the availability of both the staff and machines. We must always try to keep 100% availability.* Further, he highlighted there is no point in holding machinery with 70% of availability. E2 said that to flow the value, it is required to smoothen the flow of processes by eliminating bottlenecks in between processes. Thus, again to eliminate the bottlenecks it will be required to eliminate the waste in between processes. Therefore, it can be concluded that both experts have agreed on eliminating waste to flow the value.

4.1.4 Pull the Value

According to E2 to pull the value it is essential to have a central dashboard notifying the current progress of the maintenance jobs. In the fourth stage, "pull the value", the crew should create a system to pull the smoothened flow. Computerised systems are more likely to be used to show the current progress of the maintenance jobs. These systems can give insight to the maintenance crew about the completed tasks, upcoming tasks and delayed or paused tasks. According to Abreu et al. (2016), CMMS can be utilised to manage building maintenance activities. Thus, CMMS can be used to create a central dashboard and thereon pull the maintenance value-adding activities. E1 suggested to use of Kanban by citing it is utilised by Toyota to control its entire pull system. Further, he highlighted that KPIs for machinery such as OEE and Mean Time Between Failures (MTBF) can also be established to pull the value. In conclusion, it can be affirmed that to pull the value it is essential to have a centralised system for maintenance management as CMMS. Further, it is better if the same system can handle KPIs engaged with maintenance.

4.1.5 Pursuing Perfection

E1 stated that pursuing perfection means continuing improvements. Further, he illustrated the lean tool Kaizen that can be used to maintain continuous improvement. Tools such as equipment Kaizen, workplace revitalization theories, 5S Kaizen, and logistic Kaizen can be used to pursue perfection. 5S Kaizen helps to visualise the workplace how to improve effectiveness and to know how your machine is visualised, and how you can abnormalities of the machine. Logistic Kaizen helps to organise the inventory. Equipment Kaizen focuses on the internal modifications of machines. In parallel, E2 stated that 5S and Kaizen are the main tools that can be used for continuous improvement. In conclusion, Kaizen and 5S are the main lean tools that can be used to ensure continuous improvement.

4.2 IDENTIFICATION OF CHALLENGES IN IMPLEMENTING LEAN MAINTENANCE IN COMMERCIAL HIGH-RISE BUILDINGS IN SRI LANKA

Challenges identified in the literature (Refer to Section 2.4) that will be faced while implementing lean maintenance in the high-rise buildings were discussed with the interviewees to verify their existence in commercial high-rise buildings in Sri Lanka. Subsequently, the presented challenges were modified based on the interview findings and arrived at the list of challenges shown in Table 5.

Table 5: Responses on challenges in implementing lean maintenance

Theme	Category	Case A			Case B		Case C			Total
		A1	A2	A3	B1	B2	C1	C2	C3	
Identification of Challenges in implementing lean maintenance in Commercial	Ineffective Strategies	✓	✓	✓	✓	✓	✓	✓	✓	8/8
	Lack of standards and regulations	✓	✓	✓	✓	✓	✓	✓	✓	8/8
	Lack of policies	✓	✓	✓	✓	✓	✓	✓	✓	8/8
	Lack of lean knowledge	✓	✓	✓		✓	✓	✓	✓	7/8
	Poor involvement of top management	✓	✓		✓	✓	✓	✓		6/8

high-rise buildings in Sri Lanka.	Infirm feedback-collecting mechanisms	✓		✓	✓	✓	✓		✓	6/8
	Lack of technology usage	✓	✓		✓	✓	✓	✓		6/8

Above table shows that all the respondents agreed that they confront ineffective strategies, and a lack of standards, regulations, and policies. Furthermore, it was found that out of all eight respondents, only one respondent knows about lean and its applications. In addition, poor involvement of top management, infirm feedback collecting mechanisms and lack of technology usage also prevail in all the selected cases. The following subsections (4.2.1 to 4.2.7) present the derivation of the challenges shown in Table 5.

4.2.1 Poor Involvement of Top Management

Out of the eight respondents, six respondents highlighted that top management's perception of maintenance is one of the major barriers to introducing innovative strategies in maintenance. Respondents A1, A3, B1 and C2 stated that getting approval from the top management is difficult without sufficient data regarding the implementation of new procedures and systems in the maintenance sector. Generally, top management looks to the maintenance staff for financial data while the maintenance staff only keeps records and data connected to maintenance. Moreover, respondents C1 and C2 also highlighted that top management is not interested in bringing new maintenance strategies into the building since most of them are capital-intensive. All respondents affirmed that the top management does not understand the importance of maintenance upgrades and improvement required over time and they are unconfident in returns that can be gained by improving maintenance processes and systems. Thus, it is identified that introducing new strategies is hindered due to the leading decision-makers and the inability of operation managers to prove the return of the implementations.

4.2.2 Ineffective Strategies

All the respondents agreed that they currently performing preventive maintenance as the main maintenance strategy. There it was shown that only Cases A and B have adopted conditioned-based maintenance up to a certain extent whereas Case C only follows preventive maintenance and corrective maintenance. It is revealed that currently none of the cases has fully adopted cost-effective strategies such as condition-based maintenance. It will be challenging to adopt lean with traditional methods of maintenance.

4.2.3 Infirm Feedback Collecting Mechanisms

As per the statements made by respondents, it was disclosed that none of the cases has a proper mechanism to collect and record feedback on the complaints attended. Respondent A3 further explained that collected feedback is not recorded and reviewed later. Respondent A1 declared that to improve the existing feedback system they have decided to implement a help desk software that will bridge the communication between tenants and the maintenance personnel where real-time status of the tenant complaints are monitored. Since the tenants are requested to give feedback in the presence of the technicians, they are reluctant to reveal their true thoughts on the job. Moreover, respondent B2 affirmed that collected feedback is not evaluated later. Therefore, it is evident that in both cases, current feedback-collecting mechanisms are not well established and collected feedback is not reviewed. Converse to both Case A and Case B, respondent C1 stated that currently there is no feedback mechanism for maintenance.

Respondent C3 further said that no attention has been paid to post-evaluation or feedback mechanisms to assess the maintenance jobs because there are no external tenants in the building. Thus, Case C needs to be introduced with a feedback mechanism. To fine-tune, the services provided it is essential to review and evaluate feedback from the end users and customers. Without properly collecting feedback and not reviewing feedback from end-users, it is difficult to assess the customer value and the quality of the services provided. Most facilities nowadays use helpdesk software to collect feedback from customers which is very effective and less time-consuming. Thus, it is recommended to implement such a computerised mechanism to collect and review feedback from end-users.

4.2.4 Lack of Knowledge in Lean

Out of the eight respondents, seven respondents stated that they are not aware of the lean and lean maintenance concept. Respondent B1 is the only interviewee who has some theoretical knowledge of lean. Further respondent B1 stated that though he has prior knowledge of lean, he has not specifically come across lean maintenance before. Thus, it is revealed that the majority of the respondents do not know about lean. Thus, for the successful implementation of lean, it will be required to educate maintenance staff on lean, its principles, and its tools.

4.2.5 Lack of Standards and Regulations

All the respondents confirmed that for the moment, they do not follow any standard or regulation relating to maintenance. Further respondent A1 added that unlike for hotels, there are no statutory imposed regulations for high-rise building maintenance. Respondents A2 and A3 also confirmed that they do not comply with any standard or regulation relating to maintenance. Similarly, respondents C1, C2 and C3 also stated that currently, they do not comply with maintenance-related regulations or standards. Respondent B2 stated that they only adhere to health and safety guidelines in the context of maintenance. Thus, it is certain none of the cases are following or complying with standards or regulations relating to maintenance. Further, as per respondent A1's statement, it was revealed that in the Sri Lankan context, there are no statutory imposed regulations for high-rise building maintenance.

4.2.6 Lack of Policies

It was discovered that none of the cases has an explicit maintenance policy. All the respondents affirmed this. Respondents A1 highlighted that though there is no written policy for maintenance they always aim to reduce maintenance costs and reduce breakdowns as much as possible. In parallel, respondent B1 stated, *"We have no written policy, but we always focus on not having any major breakdowns that close our business".* Respondents from case C also stated that there is no maintenance policy. Therefore, it can be concluded that none of the cases has identified maintenance aims and objectives explicitly in a maintenance policy.

4.2.7 Lack of Technology Usage

According to all the respondents currently, there is no technological advancement used in the context of maintenance. Respondent A2 mentioned that they are currently *using MS Excel, MS Project and BMS.* In parallel respondent, B1 stated, *"No, we do not use advanced software for maintenance. Our management is also not interested in investing in that kind of engineering software for maintenance".* Respondent C1 also affirmed that

currently no advanced software is used to aid maintenance processes. Further elaborating, respondent C2 added, *"No we don't use advance software. As I know some buildings use Enterprise Resource Planning software likewise, but we don't use such things. We use simple software only for maintenance job costing".* Thus, as per the statements made it is clear that none of the cases uses advanced software to improve and support maintenance activities.

4.3 IDENTIFICATION OF STRATEGIES IN IMPLEMENTING LEAN MAINTENANCE IN COMMERCIAL HIGH-RISE BUILDINGS IN SRI LANKA

Identified challenges in implementing lean maintenance in the selected cases were discussed with the two experts to obtain solutions. Both experts stressed that adopting modern technology solutions is essential to overcome most of the challenges to implement lean maintenance. Further, they stated that most organisations lack knowledge about lean and its potential. E1 mentioned that most of the time it is required to conduct awareness programmes for staff on lean and its purpose.

4.3.1 Strategies to Overcome Poor Involvement of Top Management

When pursuing novel proposals or implementations, poor top management involvement is a problem that affects all types of organisations. It is also typical for top management to evaluate new implementations in terms of their financial worth rather than the actual benefits that the maintenance team will experience from them. Both experts suggested conducting awareness programs on lean methods to increase top management's involvement in lean implementations. In addition, experts added that since top management persons are reluctant to involve in capital-intensive maintenance projects it would be better to introduce low-cost or no-cost lean suggestions as pilot projects.

4.3.2 Strategies to Overcome Ineffective Strategies

Organisation would not have any proper strategies for lean implementation as it was new for the organisation. KPIs give you the information you need to assess the performance and overall health of your company and make the necessary changes to your execution to meet your strategic objectives. KPIs are essential to make strategies effective. Experts added that it is better to adopt strategies that have generated positive results in the building maintenance sector. Maintenance teams can accomplish expected results more quickly in lean implementation by selecting the appropriate KPIs and measuring them. Further experts added that conducting brainstorming sessions will help the maintenance crew and top management to fine-tune the existing strategies and practices. It is proven that brainstorming sessions conducted with the people on the work the floor will give effective results as these sessions will enhance workers' experience in every perspective.

4.3.3 Strategies to Overcome Infirm Feedback Collecting Mechanisms

Good performance management of every new implementation requires timely and effective feedback. Infirm feedback-collecting mechanisms will ruin the accomplishment of intended goals. Both the experts unanimously agreed that it is essential to implement computerised feedback software to collect feedback from customers. Streamlined feedback through a computerised feedback system is the best option for lean maintenance implementations where the maintenance crew and top management can continuously improve the implementation accordingly. Further experts added that the maintenance crew can easily trace the maintenance tasks requested, and actions taken and give

feedback on the tasks performed. Thus, it is apparent that implementing a computerised feedback-collecting system is essential.

4.3.4 Strategies to Overcome Lack of Knowledge in Lean

A lack of knowledge and understanding of lean maintenance is also a barrier to the proper implementation of lean maintenance. Both the experts jointly agreed that to increase awareness of lean among maintenance managers and engineers, it is crucial to conduct awareness programmes. Further experts added that practical knowledge on implementing lean can be gained by engaging in lean professional qualifications for instance lean six sigma professional qualification.

4.3.5 Strategies to Overcome the Lack of Standards and Regulations

The lack of standards and regulations will worsen the proper implementation of lean maintenance. Addressing the challenge regarding the lack of standards and regulations, experts suggested following the best industry practices or complying with other available and relevant concepts or standards. Experts suggested developing SOPs, which is a method specific to a given operation or implementation that outlines the steps required to accomplish tasks following rules and regulations for the industry. Experts further validated that to standardise maintenance operations SOPs are necessarily required.

4.3.6 Strategies to Overcome the Lack of Policies

A policy is a collection of principles or guidelines which serve as the foundation for decision-making. So, a lack of policies will impact the proper implementation of lean maintenance. Both experts also highlighted that the implementation of lean maintenance's goals is outlined in policies which will also offer instructions on how to accomplish the objectives. Further, they suggested that proper maintenance policies are required in place and those policies need to be drafted integrating SMART (specific-measurable-achievable-relevant-timely) objectives.

4.3.7 Strategies to Overcome Lack of Technology Usage

Nowadays, organisations are reluctant to switch toward new implementations due to a lack of technical knowledge and usage. Proper awareness should be given to all workers related to the importance of technological utilisation. Commenting on the challenging lack of technology usage E1 suggested adopting Industry 4.0 applications in maintenance since it is the recent face of the technological revolution. Correspondingly, E2 also contended that it is necessary to adopt information technology advancements to improve conventional maintenance practices. However, both experts suggested hiring or training employees with technological knowledge to the organisation.

5. CONCLUSIONS

Lean maintenance focuses on maximising the availability of assets with minimum input. Maintenance management and related activities in the context of high-rise buildings involve a unique set of waste due to the complexity of maintenance and the nature of the structure. Lean maintenance evolved to assist lean manufacturing processes and involves reducing all input resources to the least possible level while achieving the required level of equipment reliability by adopting lean principles in maintenance, repair, and overhaul operations. Experts' perceptions of lean principles in building maintenance were investigated. Key challenges in implementing lean maintenance in Sri Lankan high-rise

commercial buildings are identified as: (1) ineffective strategies, (2) a lack of standards, regulations, and policies, (3) poor involvement of top management, (4) infirm feedback collecting mechanisms, (5) lack of technology usage and knowledge on lean prevail in all the selected cases. Experts proposed strategies such as conduct awareness and brainstorming programmes, implementing computerised system and low-cost or no-cost lean tools, preparing SOPs and applying Industry 4.0 to overcome the challenges in implementing lean maintenance in Sri Lankan high-rise commercial buildings. Maintenance practitioners in high-rise commercial buildings can apply the findings of this study for the proper implementation of lean maintenance.

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