Janjalkar, K. R., Singh, A. R., & Delhi, V. S. K. (2023). Implementing lean methods for facility maintenance management for IGLC31 papers. *Proceedings of the 31st Annual Conference of the International Group for Lean Construction (IGLC31),* 1570–1581. doi.org/10.24928/2023/0225

IMPLEMENTING LEAN METHODS FOR FACILITY MAINTENANCE MANAGEMENT

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ABSTRACT

The breakdown of facilities in a built environment results in inconvenience to the stakeholders due to the downtime (DT) experience. The facility DT can be brought down through proper facility maintenance management (FMM). Within FMM, different processes occur to make the facility work normally. These activities of FMM are sometimes planned and often executed when a facility undergoes breakdown. This study targets to understand the implementation ability of lean methods in situations when a service of a built environment has failed and the FMM system tries to bring it back to normal functioning. An educational institute's FMM process to address DT is mapped using value stream mapping (VSM), and delays associated with the current process are captured. This mapping helped in identifying delay causes like material unavailability and administrative delay. The research utilizes the 5S (Seiri, Seiton, Seiso, Seiketsu, Shitsuke) and Just In Time (JIT) methods of lean to improve the FMM process, and implementation of these methods resulted in achieving resolution time closer to the time expected by the stakeholders utilizing the facility.

KEYWORDS

Facility maintenance management, lean philosophy, 5S, JIT, VSM

INTRODUCTION

The concept of facility management (FM) is defined as an integration of people, process, technology, and place that can ensure the functionality of the built environment (Atkin & Brooks, 2015). Within FM, the facility maintenance management (FMM) shares the most (65% ~ 85%) of the FM cost (Chen et al., 2019). Any built-up facility requires maintenance to perform satisfactorily and makes the buildings habitable and serviceable for the stakeholders. Unlike residential buildings, the built-up facilities of an educational institute are designed to serve different functions to a large population of stakeholders. With an increase in globalization, the facilities available at an educational institution become a criterion for the stakeholders to make decisions (Cubillo et al., 2006; Price et al., 2003). The Institute facilities are essential in attracting researchers by providing a suitable environment for faster knowledge creation (Fleming & Storr, 1999). Good infrastructure for educational institutes creates the chance to attract and sustain global talent.

Maintaining such facilities has a significant cost that could vary from 15% to 70% of the initial investment cost depending upon the type and size of the project (Fraser, 2014). Generally, these maintenance costs are proportional to the downtime (DT) of the system or an asset

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(Mostafa et al., 2015). The DT can be defined as the time interval when the system/equipment is down for maintenance activity until it is back to its normal working condition (Tinga, 2013). The DT is impacted due to the presence of non-value-adding activities (NVA) and wastes in the process of maintenance (Sawhney et al., 2009). Due to increased DT, there is a chance of overloading the existing working facilities, which may further lead to the failure of the existing system. Frequent occurrences of increased DT in facilities management may have a severe impact on the reputation of any organization (Atkin & Brooks, 2015). Hence, efficient FMM is imperative for the smooth functioning of the day-to-day operations of an organization.

The lean philosophy provides waste minimization methods while creating value for the stakeholders (Denzer et al., 2015). Lean philosophy mentions the elimination of waste (Viana et al., 2012) and reducing NVA to improve the process (Mostafa et al., 2015). Previous research studies have focused on lean implementation for construction and supply chain management, but a narrow focus is given to FM (Gao et al., 2020; O'Reilly et al., 2019). With a rising focus on FM as a strategic element for revenue generation, the FMM is recognized as an essential process (Mostafa et al., 2015). The present study attempts to highlight the NVA in the process of addressing the complaints of the stakeholders in an educational institute. The focus remained on investigating the applicability of lean tools for FM, and some lean methods like 5S, Just-in-Time (JIT), and Value Stream Map (VSM) are utilized to bring down the DT. The study considers unplanned DT for facilities and presents a lean approach to handling and improving the process of FMM in an educational institute.

REVIEW OF LEAN-FM SYNERGY

The FMM comprises but is not limited to activities that are scheduled and planned. In the event of a system breakdown, the stakeholders suffer due to unplanned DT. An unplanned DT request for maintenance indicates a 'pull' of value from the system. Similarly, lean works on the principle of creating value for the stakeholders, i.e., the services upstream should be produced when the stakeholders downstream require them (Gao et al., 2020). In an educational setup, the service DT impacts the habitants, and a quick-fix approach is traditionally adopted. It is essential for these services to be functional to deliver value to the stakeholders. The breakdown of any service in an educational institute is an unanticipated event that makes it challenging in comparison to other sectors like construction, and supply chain management, where lean implementation is proven beneficial. This study attempts to utilize some lean tools like 5S, JIT, and VSM to deliver value to the stakeholders just-in-time.

5S AND JIT FOR FM

The philosophy of 5S originated in Japan (Chandrayan et al., 2019). It is an acronym for five different Japanese terms 'seiri (organization of the workplace, sorting, elimination of unwanted inventory), seiton (neatness, set in order, place for everything), seiso (cleaning, shine), seiketsu (standardization, constant place for things, constant rules for organization of things), and shitsuke (sustain, discipline)' (Kobayashi et al., 2008). The Western literature from the UK and USA mentions 5S as a technique or a tool to improve working conditions. The lean studies report the implementation of 5S as an easy and uncomplicated process (Bayo-Moriones et al., 2010). Alongside process improvements, the 5S implementation is also reported to channel other lean tools like JIT (Kobayashi et al., 2008). The JIT concept was framed by Taiichi Ohno in Japan (Kumar & Panneerselvam, 2007). The JIT emphasizes continuous waste reduction and eventually eliminating all forms of waste (Brown & Mitchell, 2017). The JIT concept of lean focuses on providing the required items at the right place and right time. Research studies indicate the JIT implementation in synergies with pull planning systems to generate value (Mumani et al., 2022). In attempts to understand the bottlenecks of push-pull systems, another tool highlighted in lean literature is VSM.

VSM FOR FM

VSM is an essential tool associated with lean methodology and is extensively used to map information and process flow (Sawhney et al., 2009). VSM is an effective tool for identifying and resolving the issue that can be seen in current approaches. This allows for the maximization of performance at the project level (Pothen & Ramalingam, 2018). It helps to map the process and identify the wastes and their sources in the process. Application of VSM is a five-stage process that starts with selecting an activity, developing a current state map, analyzing waste and developing a future state map, proposing an action plan, and its validation. The lean research presents the applicability of VSM to map processes using one key metric of value-adding time. These maps primarily capture the process flow through icons and symbols, following which the value-adding activities, non-value-adding activities & non-value adding but necessary activities time are measured (Mostafa et al., 2015). Although the planned FMM activities might appear as non-value adding to the stakeholders when an unplanned DT strikes, the FMM becomes a value-adding activity.

RESEARCH DESIGN

The DT of services at an educational institute impacts the habitant's academic achievements and brings a bad reputation to the institution (Lok & Baldry, 2015). Therefore, to mitigate the ill effects of service breakdown, an efficient FMM system is needed. This study reviews the existing FMM system at an educational institute and presents opportunities to improve using lean methods. Figure 1 presents the sequential procedure followed in this study to understand the implications of implementing lean methods to FMM. The initial stage of this research starts with collecting data related to the DT encountered by the stakeholders of the built-up facilities in the institute considered for this study.

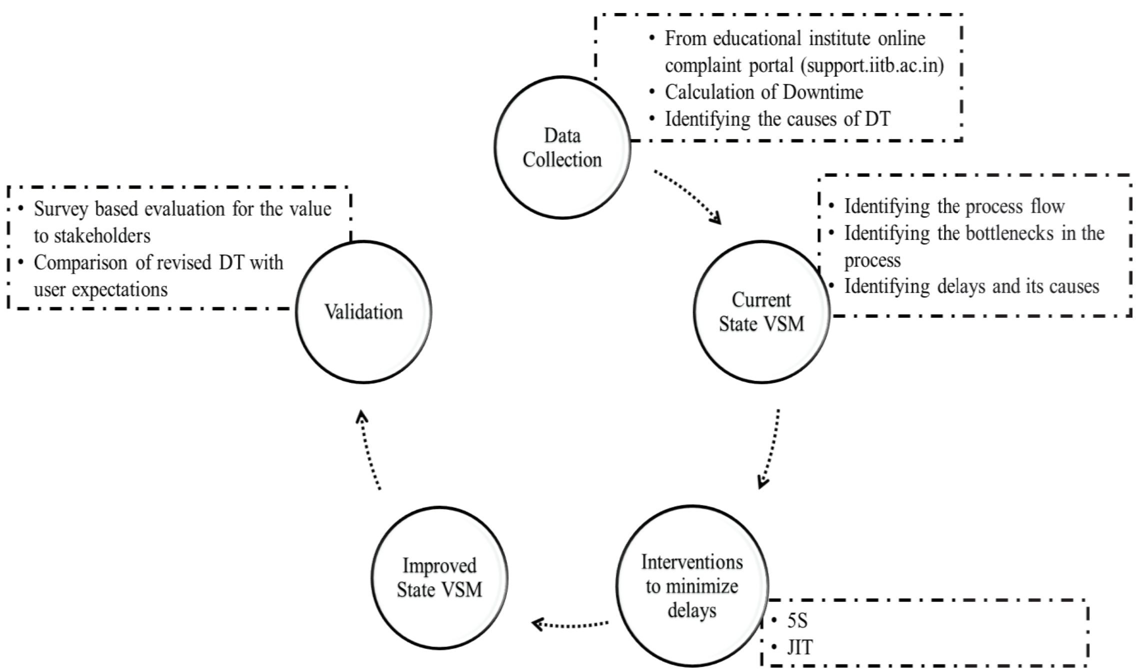


Figure 1: Methodology followed in this Study

Upon data collection, the current state VSM for the existing FMM process is mapped, targeting two different delays, and bottlenecks in the FMM process are identified. Although the current state VSM is followed with future state VSM in lean research, the researchers for this research targeted to implement 5S and JIT methods of lean to address the bottlenecks identified from current state VSM. After the implementation of lean methods, an improved state VSM is developed to understand the improvement achieved. Finally, to verify the observed improvement in the improved state VSM, the resolution time expectations of the stakeholders residing in the institute are compared with the achieved time to resolve complaints.

DATA COLLECTION AND CURRENT STATE MAP

In an attempt to understand the delays in FMM, a web-based DT complaint registering portal is utilized to collect the complaints of the stakeholders. The support portal can be accessed through a web address mentioned in Figure 1. This portal allows the stakeholders to report any maintenance requirements from the 17 student accommodation buildings of the institute. After a complaint is raised, it is transferred to a concerned administrative section, following which a required action is initiated against the complaint. For our context, the Down Time (DT) is the duration between registering a complaint and closing the same. As per internal guidelines, registration can only be done by the users through the portal and closed by the concerned staff after verbal confirmation by the users.

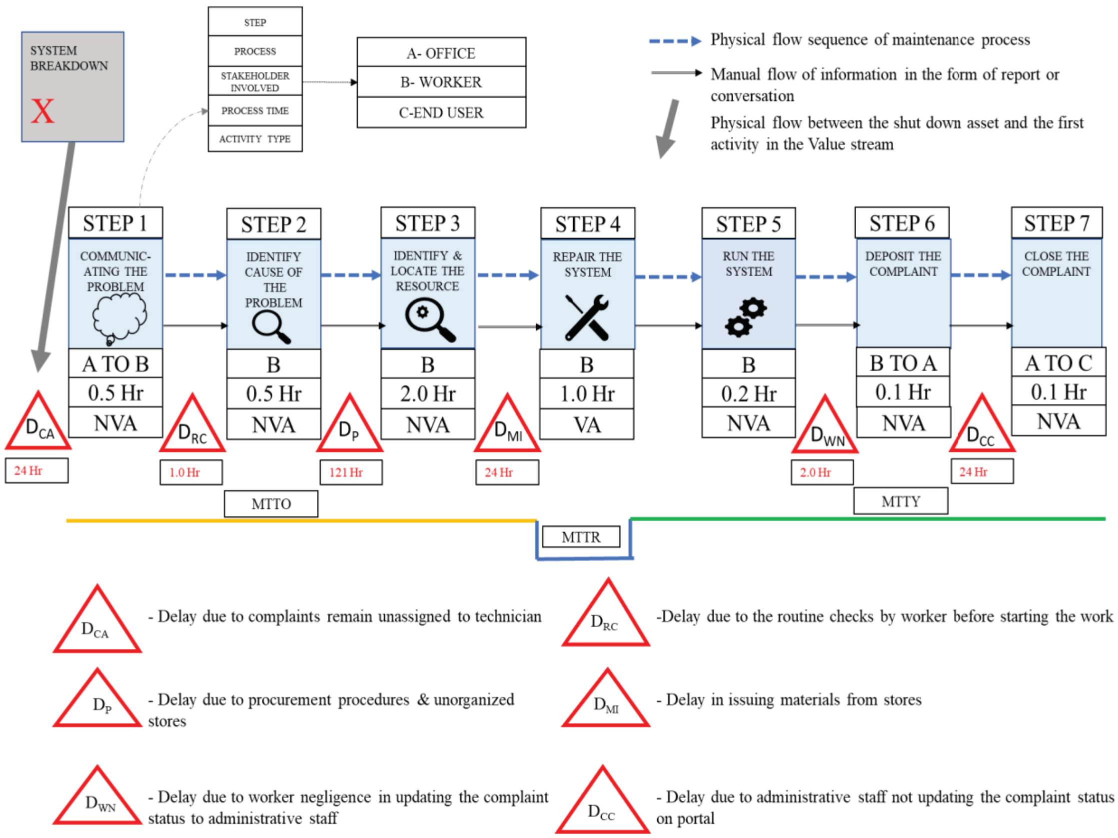
The VSM of the current process is prepared to map the activities, and the associated time with each activity is mapped accordingly to get an understanding of Mean Maintenance Lead Time (MMLT) (Sawhney et al., 2009).

CURRENT STATE VSM

The first step in plotting the current state is determining the steps and processes involved in the existing FMM system of the educational institute. The maintenance process is triggered by detecting and reporting the failure of an asset or system (Marttonen-Arola & Baglee, 2020). Such type of maintenance comes under corrective and unplanned maintenance strategies.

Once a maintenance work request is raised on the support portal of the institute, the concerned administrative person collects the requests and forwards it to the concerned technician of the department only after a bulk of requests are accumulated. Then, the technician performs a manual inspection of the reported problem by making a visit to the respective building from which the end-user has placed the complaint.

Then a request for necessary resource requirements to rectify the defect is raised by the technician. The requested resources will be made available to the technician either from the inventory if the material is available with the institute material store or is procured from retail vendors. Then, the technician will fix the complaint, take confirmation from the user, and deposit the complaint to the office for closure. The office staff will then mark the complaint status as resolved on the complaint management system. Figure 2 presents the current state of the maintenance process, where seven main activities are identified in the process communicating the problem, identifying the problem, identifying, and locating the required resources, repairing the system, running the system, depositing the complaint, and closing the complaint. The process time (PT) associated with each activity in the developed current state VSM is taken from the visual observations and experts’ opinions.

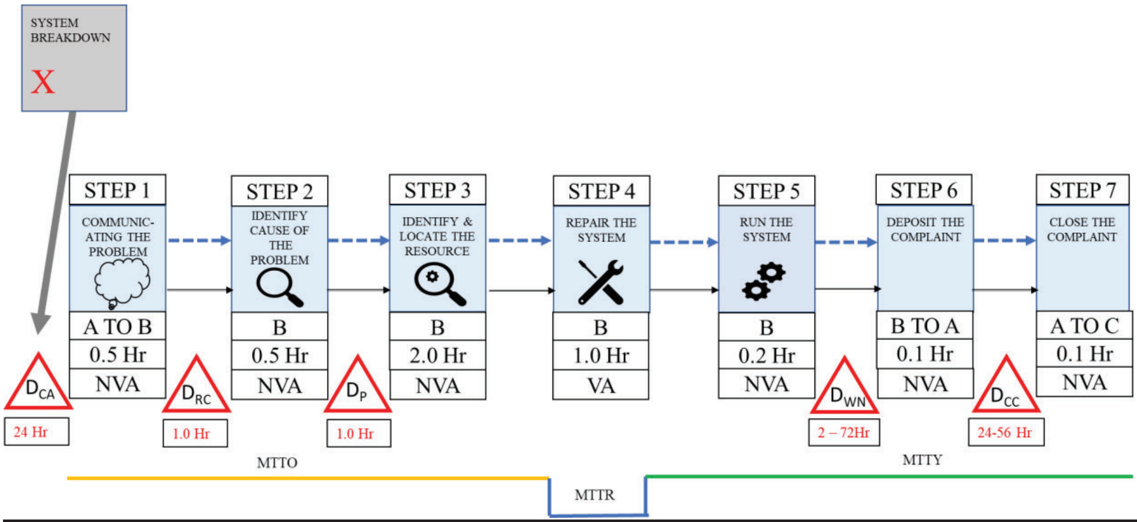


200.4 hrs.	Mean Maintenance Lead Time	MMLT
173.0 hrs.	Mean time to organize	MTTO
1.0 hr.	Mean time to repair	MTTR
26.4 hrs.	Mean time to yield	MMTY
1.0 hr.	Value adding time	VAT

Figure 2: Current State Map for Complaints Delayed Due to Material Unavailability

In the entire process of rectifying the defect, only repairing the system activity is value-adding to the end-user, whereas the rest of the activities remain non-value adding. From the above Figure 2, the Mean Maintenance Lead Time is 200.4 hours, i.e., approximately eight days, and there is a significant delay of 121 hours in locating the resource termed as delay D_P in Figure 2, resulting in a long DT of the services. It is identified that a significant time portion is spent on organizing resources to address the end-user problem. This is due to the time lost in searching for materials in the inventories, and sometimes the material is not available with the store department resulting in procuring the resources from the market; such delay in material search and procuring results in longer DT of the system.

Therefore, to understand the delays in the system where the actual DT of services is lesser than the recorded DT, another VSM is prepared, as shown in Figure 3.



MMLT	MMTO	MMTR	MTTY	VAT
56.4-158.4 hrs.	29.0 hrs.	1.0 hr.	26.4-128.4 hrs.	1.0 hr.

Figure 3: Current state map for complaints delayed due to administrative delay

From Figure 3, the maximum MMLT is 158.4 hours, i.e., approximately six days. The end user is not concerned about delays D_{WN} and D_{CC} because the complaint is resolved in 30.0 hours, and the services are working again. However, such complaints cause overloading of the complaint management system, which overall affects the efficiency of the facilities management system. The delay in updating the status of the complaints on the portal does not provide the current availability of the resources for attending to any other system breakdown, thus resulting in a delay in attending to the complaints that keep on piling up due to administrative negligence. Timely updating of the complaint status will bring down the MTTY and help in identifying resource availability. Consequently, by bringing down the MTTY, the other DT associated with other system breakdowns can be brought down by the timely resolution of the complaints. Hence, it is essential to reduce waste associated with material procurement and delays in updating complaint status.

RESULTS

The data for this study is collected on the complaints raised between August and September 2022. A total of 349 complaints were received, among which the carpentry and plumbing works are found to be the major complaints. Other complaints include masonry, fabrication, and cleaning-related works. A breakdown of complaints is presented in Table 1.

Table 1: Complaint data of 17 buildings

Month	Plumbing	Carpentry	Other	Total
August 2022	88	106	20	214
September 2022	62	61	12	135

Upon receiving the data of complaints registered in the period mentioned in Table 1, the complaints are studied with the help of the concerned technicians to extract the possible reasons for the delays. From the obtained complaints data, ten causes of delays are identified, as shown in Figure 4, namely workmen (technician) unavailability, material unavailability, duplicate complaints, multiple departments involved, major modification work required, works require outsourcing, unique material requirements, delays due to external sources, end-user unavailability, and administrative delay.

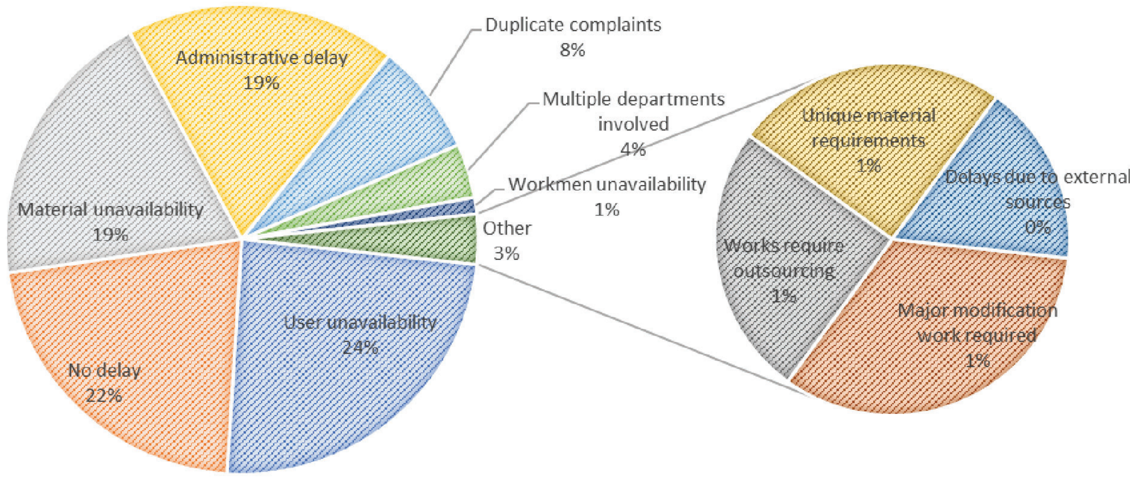


Figure 4: Distribution pattern for no delay and reasons for delay

It is observed that a significant share (24%) of the DT is due to the unavailability of the user when the maintenance team comes to address the problem raised by the stakeholder. This share of facility DT is hard to address as the end user for whom the value generation is targeted by addressing the raised concern is unavailable. Thus, such complaints and the DT are not addressed in this study. Following user unavailability, 22% of the raised complaints are addressed as quickly as possible, and the services are restored with no delay. Since the FMM comprises but is not limited to the involvement of administrative, technical, and end-user stakeholders, the other 38% share in the delay of addressing complaints is shared equally by the administrative and the material unavailability to address the problem. 19% of complaints indicated DT associated with material unavailability. It is primarily due to the initial time lost in searching for the appropriate material for replacement or sometimes due to the unavailability of the material in the inventory. It is observed that the unavailability of the material is identified upon a significant amount of time lost in searching the inventory maintained by the maintenance department, consequently increasing the DT.

Another share of complaints (19%) results in delay because of system inefficiency in closing the complaints and marking them resolved. It means that the raised complaints are attended timely, but they are not closed immediately upon successful resolution on the portal by the administrative staff and thus are categorized under administrative delay. This category of the complaint will be considered under as waste category, as the delayed closing of the complaint will not have any impact on the DT of the facilities.

Two categories of complaints - material availability and administrative delay, are selected for the application of appropriate lean methods.

Interventions to Minimise Delays

From the current state of VSM, it is clear that there are wastes involved in the process flows. The MTTO is approximately 173 hrs. which equates to more than a week's time to organize the resources to carry out the actual repair. There are multiple delays associated with the delayed resolution of complaints due to material unavailability, as shown in Figure 2. Among these delays, the D_{CA} of almost a day indicates the delayed assignment of the task to the technician. A provision of immediate allotment after receiving a complaint is introduced to address this delay. After allotment of the task to the technicians, delay D_{RC} is observed where the technicians have to manually inspect the nature of the registered complaint, and such visits result in loss of time due to travel to the location of service under DT. In an attempt to minimize the travel time only for inspection, an option of uploading the photographs of the service requiring maintenance is asked from the user in an online complaint portal of the educational institute.

This approach of collecting information related to the service requiring maintenance is developed so that upon receiving the complaint along with photographs, the material procurement step of the process can be initiated as soon as possible. Within MTTO, a significant delay is noticed between the process of 'Identifying the cause of the problem' and 'Identifying and locating the resource.' Although the process of identifying and locating resources takes two hrs., the initial search process for the resources consumes the delay time and results in longer DT. The authors observed that the delay in resource search also results in vain if the appropriate material is not found in the institute's inventory.

Upon noticing the material unavailability, the material procurement step from external sources starts. Therefore, the search time spent locating an unavailable material in the inventory results in unnecessary longer DT of the system. Thus, to minimize the search time for unavailable material, the inventory unit is redesigned by implementing the 5S concept of workplace design, as shown in Figure 5. As the cluttered place of storing materials became organized, the situation of the available inventory became more precise, and such organization is also implemented in record keeping of the inventory.

Figure 5: 5S Implementation in the Inventory Room

Upon identifying material unavailability, the procurement of materials is initiated, for which a separate contract is created that results in a time delay. Some lean literature presented that this type of waste can be eliminated by adopting the Just in Time (JIT) lean concept. The JIT highlights no requirement for inventory, and the material is directly procured from the suppliers. Therefore, to implement JIT, an annual maintenance and supply contract is proposed for materials used in the buildings for which complaints are received. So, the vendor can be asked to carry out the maintenance work when required. In this way, the delay due to material procurement is reduced to an extent, and DT is shortened.

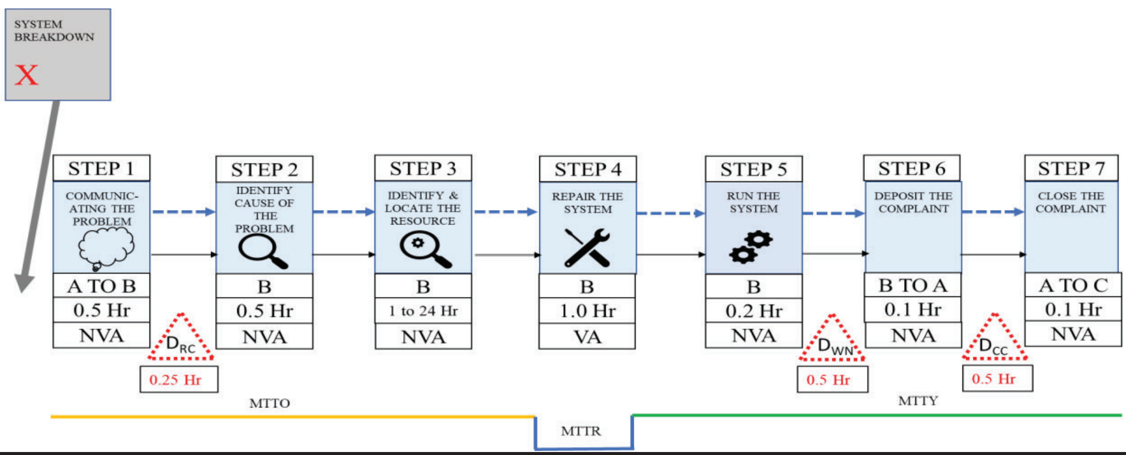
Thus, how the wastes related to the process before the repair work starts and the material unavailability are attempted to be minimized by applying lean philosophy.

Other delays D_{WN} and D_{cc} is related to the closure of the registered complaint that results in MTTY. These delays do not create value for the end user, but it overloads the complaint management system and impacts the efficiency of the FMM system. This waste can be easily eliminated by transferring the information as soon as the complaint is attended to and the services return to normal functioning. It is proposed that the status of the complaint upon successful resolution should be reported JIT to the administrative staff for closing up the complaint and releasing the resources from the task. This JIT reporting will not only bring down the recorded DT on the portal but will also affect the other services under DT, as the resources are now available to address those complaints.

DISCUSSION

The implementation of web-based direct allotment of complaints and allowing users to report issues with photographs of the service under DT are implementations of computer-based (Smith & Hawkins, 2004). This approach of reporting the issue improved the information flow between the stakeholders and indicates the essentiality of information flow for improved flow in the process (Dave et al., 2014). Also, lean concepts like 5S and JIT are now incorporated into the current FMM process flow, and the process mapping is done to assess the impact. 5S is implemented in the institute’s stores, where the material is kept and collected by technicians for attending to the complaints.

JIT is implemented where an annual maintenance contract (AMC) is prepared for the supply of various materials and services as and when required. This will reduce the material waiting time in the process. These lean methods for process improvement are incorporated into the existing process to bring down the MTTO. Figure 6 shows the proposed improved VSM.



MMLT	MMTO	MMTR	MTTY	VAT
4.65-27.65 hrs.	2.25-25.25 hrs.	1.0 hr.	1.4 hrs.	1.0 hr.

Figure 6: Improved State VSM for FMM in an Educational Institute

It is evident from the VSM that the delays contributing to MTTO are now reduced. It might be argued that the PT of identifying and locating resources has increased, and this increased time is not commonly observed but only extends when the AMC contractor does not have the required material. Although the end-user is not delivered any value in this time period, the delay in the FMM system is now transferred to the AMC provider process flow. Outsourcing non-core activity is suggested as a lean practice that enables collaborations (Cudney et al., 2020), and improved services can be availed (Lok & Baldry, 2015). Another delay time in MTTY is handled by making the information flow follow the JIT concept of lean philosophy.

USERS’ EXPECTATIONS ON DT VS ACHIEVED RESOLUTION TIME

The study results are limited to an educational institute where students worldwide come and study. These students reside in 17 student accommodation buildings located within the institute's premises, and thus the service DT for the facilities is considered for improvement;

those are reported as complaints on the institute portal. To understand the improvements obtained from implementing lean in the FMM process of the institute, a survey is drafted for the authorities in these 17 buildings. The drafted survey asked questions related to the expectations of the end-users in terms of the expected time to procure materials to address the DT and the expected resolution time for a complaint raised on the portal. The authorities in charge of maintaining the facilities at each student accommodation building participated in the survey. A total of 23 responses are collected, and it is indicated by the authorities, as presented in Table 2, that they expect a time duration varying from 1 hour to 3 days to be spent in the procurement of materials in instances when the material is not available in the institute's inventory.

Table 2: Distribution of Expected Time Indicated by Stakeholders

Duration	1.0 to 3.0 hrs.	4.0 to 10.0 hrs.	11.0 to 20.0 hrs.	21hrs. to 1.5 days	1.5 to 3.0 days
Material procurement	13%	22%	17%	26%	22%
Resolution of complaint ticket	65%	17%	0%	9%	9%

The respondents also indicated that the resolution time for a complaint registered with the FMM of the institute should not exceed 3 hours when the required material is available, as shown in Table 2. This duration remains less than the achieved MMLT after incorporating lean methods into the FMM process.

Although the achieved MMLT remains higher than the stakeholders' expectations, the lean method implementation has achieved a resolution time closer to a minimum of 5 hours. This resolution time indicates lesser DT; thus, lean implementation in the FMM process of an education institute has created value for the stakeholders.

CONCLUSION

The study presented a lean approach to improving the FMM process of an educational institute. Lean methods like 5S, JIT, and VSM are employed in this research, where VSM proved helpful in mapping the FMM process and highlighting delays in the existing process. The 5S and JIT implementation indicated improvements by reducing the DT observed due to delays in the process of the FMM. The primary delays identified in this study are related to material unavailability and administrative delays. The reduced delays indicate the process followed in the educational institute considered in this research. However, the results are not typical but indicate process improvement through implementing lean methods in the FMM. The study presents an implementation of lean in a reactive scenario when a service experiences DT whereas the essence of FMM is to prevent DT; therefore, the study will be continued to identify the advantages of lean in a proactive FMM scenario.

REFERENCES

Atkin, B., & Brooks, A. (2015). Total Facility Management (Vol. 4). Wiley Blackwell.

Bayo-Moriones, A., Bello-Pintado, A., & de Cerio, J. M. D. (2010). 5S use in manufacturing plants: Contextual factors and impact on operating performance. International Journal of Quality and Reliability Management, 27: pp.217–230. https://doi.org/10.1108/02656711011014320.

Brown, A. K., & Mitchell, R. T. (2017). A Comparison of Just-in-Time and Batch Manufacturing: The Role of Performance Obstacles. Academy of Management, 34:

pp.906–917. https://doi.org/10.5465/256395
Chandrayan, B., Solanki, A. K., & Sharma, R. (2019). Study of 5S lean technique: A review paper. International Journal of Productivity and Quality Management, 26: pp.469–491. https://doi.org/10.1504/IJPQM.2019.099625
Chen, K., Chen, W., & Cheng, J. C. P. (2019). A BIM-based location aware AR collaborative framework for facility maintenance management. Journal of Information Technology in Construction, 24: pp.360–380. https://www.itcon.org/2019/19
Cubillo, J. M., Sánchez, J., & Cervio, J. (2006). International students' decision-making process. International Journal of Educational Management, 20: pp.101–115. https://doi.org/10.1108/09513540610646091
Cudney, E. A., Venuthurumilli, S. S. J., Materla, T., & Antony, J. (2020). Systematic review of Lean and Six Sigma approaches in higher education. Total Quality Management and Business Excellence, 31: pp.231–244. https://doi.org/10.1080/14783363.2017.1422977
Dave, B., Kubler, S., Främling, K., & Koskela, L. (2014). Addressing information flow in lean production management and control in construction. 22nd Annual Conference of the International Group for Lean Construction: Understanding and Improving Project Based Production, IGLC 2014, pp.581–592. http://eprints.hud.ac.uk/id/eprint/26202/
Denzer, M., Muenzl, N., Sonnabend, F. A., & Haghsheno, S. (2015). Analysis of definitions and quantification of waste in construction. 23rd Annual Conference of the International Group for Lean Construction, IGLC 2015, pp.723–732.
Fleming, david, & Storr, J. (1999). Lecture theatre design. Facilities, Volume 17, 231–236.
Fraser, K. (2014). Facilities management: the strategic selection of a maintenance system. Journal of Facilities Management, 12: pp.18–37. https://doi.org/10.1108/JFM-02-2013-0010
Gao, S., Sui Pheng, L., & Tay, W. (2020). Lean facilities management: preliminary findings from Singapore's international schools. Facilities, 38: pp.539–558. https://doi.org/10.1108/F-07-2019-0076
Kobayashi, K., Fisher, R., & Gapp, R. (2008). Business improvement strategy or useful tool? Analysis of the application of the 5S concept in Japan, the UK and the US. Total Quality Management and Business Excellence, 19: pp.245–262. https://doi.org/10.1080/14783360701600704
Kumar, C. S., & Panneerselvam, R. (2007). Literature review of JIT-KANBAN system. International Journal of Advanced Manufacturing Technology, 32: pp.393–408. https://doi.org/10.1007/s00170-005-0340-2
Lok, K. L., & Baldry, D. (2015). Facilities management outsourcing relationships in the higher education institutes. Facilities, 33: pp.819–848. https://doi.org/10.1108/F-05-2014-0043
Marttonen-Arola, S., & Baglee, D. (2020). Assessing the information waste in maintenance management processes. Journal of Quality in Maintenance Engineering, 26: pp.383–398. https://doi.org/10.1108/JQME-11-2018-0100
Mostafa, S., Dumrak, J., & Soltan, H. (2015). Lean Maintenance Roadmap. Procedia Manufacturing, 2: pp.434–444. https://doi.org/10.1016/j.promfg.2015.07.076
Mumani, A. A., Magableh, G. M., & Mistarihi, M. Z. (2022). Decision making process in lean assessment and implementation: a review. Management Review Quarterly, 72: pp.1089–1128. https://doi.org/10.1007/s11301-021-00222-z
O'Reilly, S. J., Healy, J., Murphy, T., & Ó'Dubhghaill, R. (2019). Lean Six Sigma in higher education institutes: an Irish case study. International Journal of Lean Six Sigma, 10: pp.948–974. https://doi.org/10.1108/IJLSS-08-2018-0088
Pothen, L. S., & Ramalingam, S. (2018). Applicability of Value Stream Mapping and Work Sampling in an industrial project in India. IGLC 2018 - Proceedings of the 26th Annual

Conference of the International Group for Lean Construction: Evolving Lean Construction Towards Mature Production Management Across Cultures and Frontiers, 1, pp.516–526. https://doi.org/10.24928/2018/0263
Price, I., Matzdorf, F., Smith, L., & Agahi, H. (2003). The impact of facilities on student choice of university. Facilities, 21: pp.212–222. https://doi.org/10.1108/02632770310493580
Sawhney, R., Kannan, S., & Li, X. (2009). Developing a value stream map to evaluate breakdown maintenance operations. International Journal of Industrial and Systems Engineering, 4: pp.229–240. https://doi.org/10.1504/IJISE.2009.023539
Smith, R., & Hawkins, B. (2004). Lean maintenance: reduce costs, improve quality, and increase market share. Elsevier Butterworth-Heinemann.
Tinga, T. (2013). Maintenance concepts. In Springer Series in Reliability Engineering (Vol. 69). Springer London.
Viana, D. D., Formoso, C. T., & Kalsaas, B. T. (2012). Waste in construction: A systematic literature review on empirical studies. 20th Conference of the International Group for Lean Construction, September 2015: pp.1–10.