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Lean Management Concept in Energy Efficiency Improvement for Non-domestic

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Abstract

Lean management is a proven tool that can improve efficiency in manufacturing industry, building construction, healthcare and maintenance sectors. In this paper, lean management concept was adopted to improve energy efficiency in non-domestic buildings at a reduced cost without neglecting the occupant's satisfaction. This paper proposed the implementation of lean management concept towards achieving the energy efficiency in non-domestic building. The Lean activities that related to energy efficiency measures were classified into Just-In Time (JIT), Pull system, Design for Occupant Needs, Total Quality Management, Continuous Improvement (CI) and also Total Preventive Maintenance (TPM) categories. The definitions of lean activities and the current energy efficiency measures were analysed based on an extensive literature survey. Through this classification framework, it could enable a more structured evaluation of the effectiveness of each activity. Future work is on the determination of weightage for each category, by distributing questionnaire to relevance respondents.

Keywords: Energy efficiency measures; lean activities; non-domestic buildings

INTRODUCTION

Lean indicates the reverse of bloated whereby going lean shows the way of cutting out the fat—taking direct intention at operational waste in all its forms and thus reducing business operational cost [1]. Recently, Lean is recognised as the most reliable approach in organising and operating any enterprise [2]. The Japanese industry had a very low rate of production after the World War II ended due to a huge shortage of resources which then caused them to stop adopting a mass production model [3]. Toyota had developed their own model to ensure continuous waste elimination that known as Toyota Production System (Lean Manufacturing/Lean Production) [4]. Halling [5] further described that the Toyota Way includes dual aim which to ensure Continuous Improvement (CI) and Respect for People (RfP).

Sayer and Williams [2] accentuated that Lean acts as a business strategy that enables an organisation to produce higher quality products and services at optimum level of development cycles and lower costs in addition to make use of resources more efficiently. In other words, lean is a holistic approach to create an organisation or process to be more effective and efficient which has different dimensions of cultural change as well as mindset change by embedding the lean toolkit into the approach [6]. Weigel [7] stated that there are five lean thinking principles namely value identification, value stream mapping, flow creation and pull establishment along with perfection. Lochan [6] emphasised that lean focuses on identification and minimisation or removal of activities also classified as wastes which not add value to the customers.

The philosophy of lean thinking has rapidly adopted across a broad range of industries which mostly applied in automotive, aerospace, construction, energy, healthcare, banking and public sector as well as trading [2] [8]. Although through this extension to these new areas, but still the key practice of lean thinking is not broadly adopted in other areas [2]. Lean can be applied to any area that has wastes and opportunities for enhancement which indirectly defines Lean could be found in every area of industries without being noticed actually Lean has already applied in their daily work processes. As per that Lean is not limited to any particular part of the industrial areas, organisation or enterprise function. Sayer and Williams [2] highlighted again that even though the formal Lean practices was began in manufacturing sector but it could be adopted across a variety of areas.

The current literatures have not yet reached an agreement concerning the advantages of adopting lean concept towards achieving energy efficiency improvement in non-domestic buildings. Numerous articles have focused predominantly on the energy efficient technologies diffusion in closing the gap between optimum and real performance implementation. However, there are other approaches than efficient technologies. Backlund et al. [9] claimed that the possible energy savings and improved in energy efficiency is greater than if only technology is included. The authors suggested that a cost-effective way of improving energy efficiency is by combining investments on energy-efficient technologies with continuous practices of energy management. This has been mentioned as the extended energy efficiency potential. In bridging the communication gap that commonly to be the barrier during the decision making and operation stage as to ensure an optimal energy efficiency technologies implementation. Jia, Srinivasan & Raheem [10] verified that the occupants presence and their behaviour gives weighty influences on building energy consumption and indoor environment. Shifting of their attitudes and behaviour to support the energy efficiency culture are more simple to achieve approximately 20% energy savings compared to other improvement measures which is more costly and complicated [11][12]. Therefore, it is necessary to also include social science in technological studies [13][14][15][16][17].

This paper proposed to adopt the lean management concept into energy efficiency improvement for non-domestic buildings.

OBJECTIVE

The paper main objective is to make classifications of energy efficiency measures into certain lean activities which shared the same ideology of ways for reducing wastes, cost, while maintaining end users satisfaction in addition to efficiency improvement. The recognised activities are Just-In Time (JIT), Pull system, Total Preventive Maintenance (TPM), Quality Management, Continuous Improvement (CI) and also Design for Occupant Needs. Particular energy efficiency measures were analysed based on an extensive literature survey to find the links between the measures and lean practices that are moving to the same direction of improvements before being classified into the listed classifications. Based on these classifications framework, the effectiveness evaluation of each energy efficiency measures could be more structured which then to be used for further studies in finding the causal relationships with the influencing factors and its implementation contributions to building energy performance.

METHOD

This study was a literature-based survey of particular articles that related to the current implementations of energy efficiency measures as the approaches in reducing energy consumption, demand, waste and cost other than to improve efficiency. In the first stage of this study, definitions of each lean activity were studied as to find similarities with the key purposes of energy efficiency measures that already being considered in building operation management before classifying the measures into lean groups. In collecting data, preference was given to the most recent studies on the subject matters which those published between 2010 and 2017were retrieved since the objective of this study is need to be based on the update knowledge on energy efficiency. This survey has mostly considered journals with high impact factors such as:

i. Renewable and Sustainable Energy Reviews
ii. Energy Conversion and Management
iii. Energy Policy
iv. International Journal of Sustainable Built Environment
v. Energy and Buildings
vi. Applied Energy
vii. Energy
viii. Journal of Cleaner Production
ix. Sustainable Cities and Society

Based on the study objectives, the information obtained from the articles was classified into the six lean activities with the intention of introducing lean in building energy efficiency improvement approaches.

RESULT

The result of this paper is the classifications of energy efficiency measure into the lean activities namely Just-In Time (JIT), Pull system, Design for Occupant Needs, Total Quality Management (TQM), Continuous Improvement (CI) and Total Preventive Maintenance (TPM) which also supported by facts from the literatures.

Just-In time

Lean Manufacturing System (LMS) implementation will primarily include Just-in time (JIT) that acts as an activities to control the production of products or services within the customer demands [18]. Kootanaee, Babu & Talari [19] further described JIT adopts from the Japanese management philosophy which focuses in producing the desired products or services with the right quantity and quality at the exact place and time. JIT has driven to improve the quality, efficiency and productivity on top of decreasing wastes and cost in manufacturing sector.

In terms of energy consumption in buildings, just-in time (JIT) is referred as the control practice in ensuring the balance of energy supply-demand that use to reduce energy waste and cost other than to ensure the smooth building operation. The functions of JIT in building operation and manufacturing sector shared the same similarities in giving only what is demanded by the end users without supplying more than what is needed that will only contribute to supply wastages. As for non-domestic buildings like offices that imposed by JIT makes the buildings to be less-price elasticity to respond to Real-time pricing (RTP) tariffs. RTP tariffs are expected to influence the peak demand reduction and also demand variations as well as to meet obligations over the increased in end users communication pertaining to demand responsiveness (DR) [20]. Barooah, Bušić, & Meyn [21] suggested that an intelligent and automation demand response controls are needed to consider as to perform proper implementation of JIT in buildings. Besides, an effective scheduling of the building appliances operation that strictly based on the real-time consumption can also be one of the demand respond control strategies [22][23].

Pull system

Under JIT concept, pull system is a part of the concept that also known as Kanban production system which a system emphasises on a minimum inventory level in addition to the tools used are to manage and control the materials flow in manufacturing plant [19][24][25]. Naufal et al. [26] concluded that Kanban system is critical in determining the success of Just In Time activities in meeting customer demands as well as minimising inventory and optimising storage area. Therefore, the elimination of waste will be more effective by integrating both of these activities simultaneously.

In achieving proper implementation of JIT for buildings, the previous sub-section stated that demand response controls are required to make the buildings to be price elasticity to respond to RTP tariffs. Under demand-side management (DSM), one of the initiatives to respond to RTP tariffs is load shifting which will include several approaches such as financial incentives and change in behavioral through education [27]. Bhatia [28] and Aduda [29] agreed to that extent that building services should be designed to deliver full flexibility for load shifting and energy controls with the intention of achieving the most economical operation. Most non-domestic customers are charged not only for the total of energy they use, but also for the on-peak demand charges. Therefore, the installation of thermal energy storage (TES) can be used to produce cooling and stored by chill storage mediums such as water, ice or phase-change material during the off-peak energy period when the tariff rate is much cheaper than the on-peak period [30]. This approach may seems lead to higher capital cost than the direct cooling system but a significant reduction on the building operation cost and on-peak demand charges will be the driven factors that can be considered. However, an appropriate design and selection of storage system which either full storage or partial storage is crucial to be based on the amount of cooling load shifted from on-peak to off-peak[30]. This is when pull system kicks into consideration where a proper evaluation of TES need to be at a reasonable cost-benefit level as to optimise the system functions other than to meet the real demand without oversizing the system that will only be non-value-added to the customers.

Other than TES, pull system may have already being implemented without we realised in spare parts and materials management as limited or even no storage in office buildings were identified by Au-Yong et al. [30]. De Groote [31] incorporated spare parts and materials management with spare parts efficient reordering, storage, stocks level and revision of spare part needs. A study by Au-Yong et al. [32] listed the criteria that need to be evaluated under each significant predictors identified through literature namely skill and knowledge of manager; skill and knowledge of employees; quality of spare parts and material; response towards failure and downtime. However, it is often turned out to be unclear record of all the criteria especially on stock-outs in the real implementation which will end up with over buying of things and creating excess inventory [2]. There are two Lean methods in Kanban system commonly being use to reorder items based on real consumption at the point of use that will simultaneously increase on-time delivery performance, stock-out reduction besides reducing costly last minute changes. First, “two-bin” method that may requires an operator to have two bins of inventory. Second, the kanban-card method that involves the use of a kanban-card containing information of an individual work item to travel together with the inventory.

The current maintenance implementation with limited or no storage in buildings, there are specific alternatives that can be considered to ensure that no delay in maintenance processes such as the management team may require to have a number of spare parts and material suppliers that could make the delivery within the shortest time at reasonable costs [32]. The concept of reducing and elimination storage that being suggested is the same concept as pull system where the system aims for a minimum inventory plus to manage and control the flow of materials in manufacturing plant [26]. Therefore, the current building maintenance practices can be significantly improved by adopting the two Lean methods stated previously.

Design for specific customer needs

A comprehensive understanding on the exact customer’s needs is important as to achieve their high satisfaction other than to upkeep JIT practice in an organisational or manufacturing cycle [33]. Sayer and Williams [2] justified that this is because LMS majorly considers the perceptions of seeing value through the eyes of the customer. In building operation insight, the customers are the building owner who will decide and make investment on the enhancements that to be taken and also the building occupants who mostly will be using the whole function of building throughout its life span. Moreover, the building occupants may vastly take seriously the aspect of proper building management as the main consideration to decide whether the building has become obsolescent or still capable of sustaining their business operation. This is said to be significant to consider both the investor and occupants’ values when designing building functions that will based on specific customers need. Therefore, the value-added and non-value-added in each activity in every building function to customers are needed to be identified and evaluated.

Energy management is the gist of an approach in reducing energy consumption but it tends to be a very intricate organisational issue for non-domestic buildings due to the heterogeneity of occupants’ activities [34][35]. Bhavani & Mohan [36] accentuated that building systems are intended to have the roles of fulfilling the dual aim of minimising energy use as well as maximising occupant satisfaction. The dual aim could be achieved by an effective energy management implementation that use to optimise energy consumption which strictly based on the real demand of occupants besides maintaining comfort levels [37]. Thermal comfort and visual comfort are two different aspects of comfort that essential in designing and providing building services at the highest satisfaction level of occupants on top of optimising energy consumption in buildings. There are certain standards referred in calculating these aspects as for thermal comfort is ANSI/ASHRAE Standard 55 and CIBSE Standard Service Illuminance Levels for visual comfort. Bhavani & Mohan [36] deliberated a great improvement in visual comfort will lead to higher satisfaction and increases in the individuals' productivity and wellbeing. In a Danish study by Govén et al. [38] determined that occupants will be more satisfied when they able to control over lighting systems to satisfy specific needs based on their activities. Abdulaal & Asfour [22] further suggested that demand shifting with incorporating of thermal storage according to the hourly electricity price rates and occupants' comfort tolerance level will not only maintain the desired comfort level but also reduce energy consumption and similarly to reduce operation cost and improve the exergy efficiency. Furthermore, through the integration of HVAC and/or lighting in an energy efficient building automation and the interaction of systems may aids occupants to monitor, control and compare real time consumptions from different time frames as to ensure their usage is at its optimal level [22].

Some of these approaches may already be applied altogether or separately and some may be still under consideration when deciding for the best enhancements without jeopardise occupants satisfaction. This reflects that the current energy efficiency measures portray the same objectives of LMS in taking the customer values into their optimal operation strategies.

Continuous improvement

Buildings should be flexible enough to adapt to the changes of weather, electrical loads, cooling and heating load besides to fulfil occupant needs and staff turnovers which make the available systems turn out to be inefficient and absolute frequently. Therefore, continuous improvements of building systems are important to be assured as to ensure that the building operates at the highest satisfaction level. In ensuring that high customer satisfaction is achievable at effective ways of utilising resources and time, coupling lean and six sigma that also known as Lean Six Sigma would not only help to reduce waste but various reduction in business processes [39]. The very basic of this approach begins with Kaizen which defines as "taking apart and making better" and the most common project management techniques used is the principles of 5S (Sort, Sweep, Straight, Schedule, Sustain).

The continuous improvements in building energy performance optimisation are undertaken by the Facilities Management (FM) team through low and/or even no cost maintenance strategies, commissioning and retrofits by means of proactive operational control and maintenance (O&M) [40][41][42]. Cao et al. [43] added that an integrated facilities management strategy with mainly focus on proactive O&M that targeted at continuous improvement by on-going commission and retrofits that found to be more effective and cost efficient as the baseline of energy performance could be optimised and more useful data could be obtained and recorded.

Marinakis et al. [44] further suggested that the building energy management systems (BEMS) could also significantly contribute to continuous energy management for achieving the potential energy and cost savings. One of the energy management cycle elements is verification, monitoring and reporting and by systematic monitoring of building system operation and regular review of the operational data, the systems could continually operate in an efficient function in addition to identify energy costs and usage control measures to be implemented [45][46]. In building performance assessment, it is imperative to consider energy audits to recognise energy saving potentials along with to provide key information that to be used in the assessment. According to Podgornik et al. [47], the information on energy consumption could also be obtained through feedback or survey. Sarrica et al. [48] added in energy transition, feedback may not only help the user to determine the performance of new technology installation in matching their needs but also to provide such information from the occupancy stage that could be used by the manufacturers, installers and design team to identify any fault and not to repeat the same mistakes. Baborska-Narozny et al. [14] evidenced that the energy use feedbacks would be more effective in promoting the energy saving practices implementation if to be also included more peers sharing energy use information in the feedback system that gives the short term savings approximately within the range 5% - 25%.

Gulbinas, Jain & Taylor [49] specified commercial buildings may need to be applied particular modular eco-feedback systems that allow the building owners to realise energy could be saved without massive physical interventions and equipment advancements that will only end up with high capital costs. In this approach, it is essential to understand on how energy feedback systems affects occupants' behaviour and interactions with the systems in the organisational presence as well as social forces where the individuals have no direct financial accountability for their energy usage that are frequently not relevance to residential settings [49]. The authors concluded that eco-feedback affects the building occupant energy conservation differently in both commercial and residential buildings. Jain et al. [50] further indicated that the integration of eco-feedbacks with computerised systems such as web-based interfaces aids occupants to stay connected with their usage data and its implications in reaching certain organisational energy goals whether to perform cost savings, energy conservation, emissions reduction or/and increase competition. Jain et al. [50] proved significant relation with the findings for the rewards and penalisation component in encouraging conservation behaviour and discouraging wasteful behaviour that may leads to further or even maximum energy use reductions.

The continuous improvement initiatives in building sectors are in some other points focused on the same basic issues and similar results which to ensure rapid performance improvements during operation stage without neglecting the investors and users satisfactions within a reasonable cost-benefits ratio.

Total Quality Management

The principles of Total Quality Management (TQM) to ensure a product or service are able to function as intended over the time [51]. Sayer and Williams [2] defined TQM as the driving force covers all principles of an organisation operation from leadership, planning and design to improvement determinations. TQM will not only include quality design as its component but also taking other measures simultaneously such as quality assurance, quality control and quality improvement. Moreover, TQM underlines similar concerns with other lean activities specifically a customer orientation, top management commitments, fact-based decision making, fast action, continuous improvement and human interaction [2].

The shared principles of TQM implied for any sector as for buildings, Christen et al. (2016) classified the important measures that need to be considered to ensure a building continues to perform at its desired level of functionality into three types such as maintenance measures (MMs), refurbishment measures (RMs) and enhancement measures (EMs) include energy efficiency measures (EEMs) of which be further categorised into two types namely energy conservation measures (ECMs) and energy production measures (EPMs). These measures are closely interrelated but often planned and conducted separately. Lower cost of building performance improvements could be achieved if simultaneous synergies are executed by not includes twofold counting of costs. According to Pikas [52], the practicability investigation of executing RMs simultaneously with EEMs is significantly evaluated by proper understanding of RMs execution costs with or without include EEMs that also respectively referred as “anyway costs” and “additional costs”. EMPs could be combined with ECMs execution when modifying a building within its portfolio. Therefore, the cost performance indicator (CPI) should help the decision making in correctly measuring the cost-benefits ratios in evaluating the optimal cost reduction measures that possible to be applied [53]. There are numbers of studies that bring to the same conclusion that more EEMs planning and executions are considered when there is an upsurge in understanding on the cost and benefits of EEMs which then changes the actions of owners [54][55].

These strategies answer the aim of quality assurance that is to gather all the necessary activities to maintain a system back to its best performance promptly at a reasonable cost without any waste of resource and efforts.

Total productive maintenance

Maintenance is one of the main aspects in keeping the machines and facilities to function as intended at their maximum profitable capability without any interruption by remedying any problematic system. Sayer and Williams [2] considered that lean and its continuous process of improvement initiatives will include total productive maintenance (TPM) other than total quality management, Six Sigma and business process management. The big idea of TPM is to achieve perfect production with fewer breakdowns, emergency and unscheduled maintenance by shifting to planned maintenance activities [56]. TPM developed from TQM and it is recognised as an operative introductory approach within a Lean framework [2]. TPM is an holistic approach of maintenance that emphasing on proactive and preventive maintenance in order to maximise the operational efficiency of equipment and encouraging greater involvement of maintenance team workers that will not only lead to an increase in uptime but also to an decrease of cycle times and defects/wastes in operation stage[56].

In building sector, the implementation of energy saving initiative and enhancement of energy efficiency can be done through improved Operational and Maintenance (O&M) practices. Building operation and maintenance (O&M) programmes can enhance the building operating efficiency by implementing proper maintenance works [57]. Au-Yong et al. [32] stated that the maintenance of centralised HVAC is the most critical maintenance programme in buildings by reason of if any failure occurs it may affects the entire building operation. Wu et al. [58] categorised the HVAC maintenance programme four types which comprises of test and inspection, scheduled maintenance, condition-based maintenance as well as corrective maintenance. Au-Yong et al. [32] further suggested that the corrective maintenance should be replaced with proper preventive maintenance strategies as to minimise the downtime of HVAC system and to prevent sudden failures. Cao et al. [59] argued that an extensive downtime creates delay in performing maintenance works may affect occupant comfort level, productivity besides the image of an organisation owing to poor working environment. These same maintenance programmes are applied and implicated to other energy-using systems associated in buildings such as lighting and hot water.

Au-Yong et al. [32] further ascertained that there is a significant correlation finding between the frequency of monitoring and inspection with the occupants’ satisfaction. This statement is in line with the explanations by Lo & Choi [60] and Jardine et al. [61] as regular intervals of inspections may ensure optimum monitoring of building systems allowing the technicians to detect and rectify any abnormality in system operations promptly and efficiently without causing further damage of the defective parts that will risk and hazard the occupants safety on top of ensuring the system operates smoothly with interruptions from the damage.

These methods of building maintenance programmes are actually shared the focal concerns in lean application that not only limiting to the technical aspect of improvements but also in people and cultural elements.

DISCUSSION

This study conducted an extensive literature survey of the literature on energy efficiency measures that are moving to the same improvement directions of lean activities. The current literatures have not yet reached an agreement to include lean concept into energy efficiency improvement for buildings. Throughout the survey, there are a number of energy efficiency measures identified that reflect the same ideology of lean activities that engage the utilisation of sources effectively at minimal level of waste and cost in addition to improve operation efficiency. The classification of energy efficiency measures into certain lean activities such as Just-In Time (JIT), Pull system, Design for Customer Needs, Continuous Improvement (CI), Total Quality Management (TQM) and also Total Preventive Maintenance (TPM) as tabulated in Table 1.

Table 1: Classifications of energy efficiency measures into lean activities.

Lean activities	Energy efficiency measures
a. Just-In Time (JIT) Produce the right products or services of the right quantity and quality at the right place and time.	• The effective Demand Responsiveness (DR) and the Real Time Pricing (RTP) tariffs are applied by some policymakers to control the supply-demand scheduling process.
b. Pull system The system underlines a minimum level of inventory other than to manage and control the flow of materials in manufacturing plant.	• The installation of Thermal Energy Storage (TES) can be used to produce cooling and stored during the off-peak energy period when the tariff rate is much cheaper than the on-peak period as this will be able to support JIT activities but proper evaluations on the system sizing and cost-benefits are crucial as any non-value added to the customers. • The needs to have a number of spare parts and material suppliers to delivery within the shortest time at reasonable costs when to consider a minimal or no storage for maintenance parts.
c. Design for specific customer needs Lean product development (LPD) is an integration of emotional customer value into the traditional model which concerns on minimising operating costs and reducing time-to-market.	• The dual aim of optimising building energy consumption need to be based on the real demand of occupants and maintaining comfort levels. • There are certain standards referred in calculating these aspects as for thermal comfort is ANSI/ASHRAE Standard 55 and CIBSE Standard Service Illuminance Levels for visual comfort.
d. Continuous Improvement (CI) An continuous improvement of products, services or processes over time with the goal of waste reduction in improving workplace functionality, product performance or customer service.	• Under Building energy management systems (BEMS), Facilities Management team is responsible to ensure continuous improvements for achieving the potential energy and cost savings. • Feedback is used to gather the occupants' suggestions on any improvement of the building services and management.
e. Total Quality Management (TQM) The key use to ensure the end goal of a system is met through desired level in terms of cost, quality and time as to be competitive in business.	• The cost performance indicator (CPI) should help the decision makes in combining the activities of refurbishment measures (RMs), maintenance measures (MMs), and enhancement measures (EMs) include energy efficiency measures (EEMs) to ensure building continues to perform at its desired level of functionality.
f. Total Productive Maintenance (TPM) This approach is targeted to improve the consistency, reliability and capacity of machines by proper maintenance management practices.	• Corrective maintenance should be replaced with proper preventive maintenance practices as to minimise the downtime and to prevent sudden failures of any building system.

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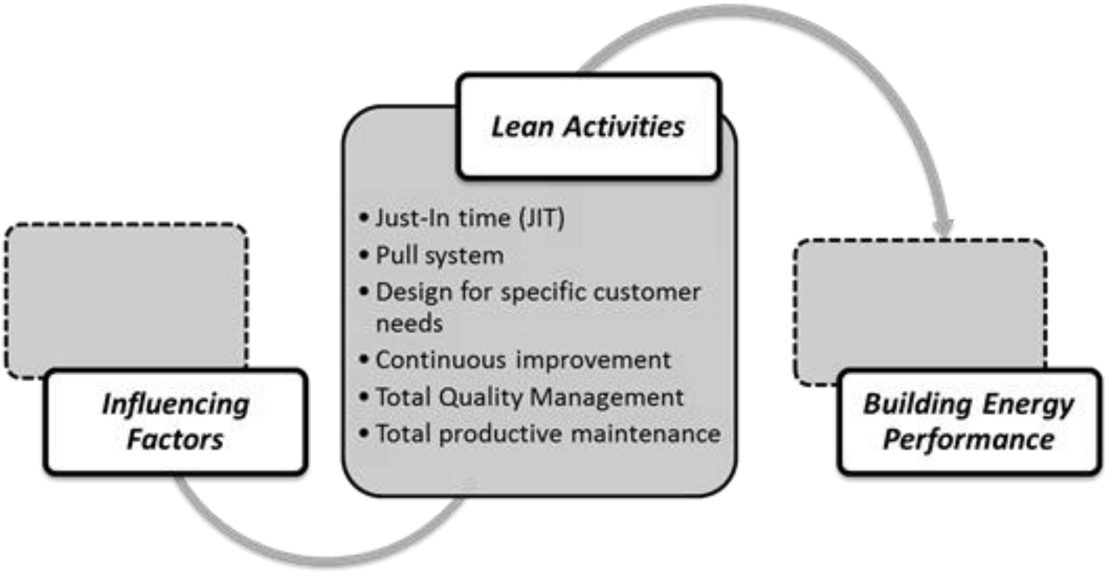

Figure 1: Framework of lean management concept adoptation towards achieving energy efficiency improvement

CONCLUSION AND FUTURE WORK

Lean may be already implemented in the current energy efficiency improvement initiatives but it was not formally recognise as the approaches of lean management concept. Therefore, this study acts as the inception of taking lean concept into building energy efficiency improvement in non-domestic buildings. Through the classification of energy efficiency measures into lean activities, an effective and comprehensive evaluation of each measure could be more structured in the future which to be the first step of adopting lean into the building energy efficiency improvement. However, further studies in finding the causal relationships with the influencing factors and its implementation contributions to building energy performance are necessary as illustrated in Figure 1. Next, an in-depth understanding on the weightage and interrelations between each influencing factor in supporting the lean activities which then will contribute to certain improvements in building energy performance are need to be explored in the future works in order to form a better framework for energy efficiency measures evaluation.

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