A New Methodology of Preventive Maintenance for Sustainable Building

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Abstract— **The complication of Sustainable Building Maintenance (SBM) environment enforces the management to use a standardized maintenance quality management system, which can be applied in all maintenance departments. This study presented a new methodology of a hybrid Knowledge-Based Lean Six Sigma (L6σ) Building Maintenance System. This methodology aimed at applying the Lean Six Sigma philosophy to develop implementation of sustainable building maintenance system. This model included GAP and AHP approaches with aiming to support benchmarking and decision making.**

Key Words— **Preventive maintenance, Knowledge based system, Analytical hierarchy process, Lean 6 Sigma.**

I. INTRODUCTION

As part of facility management processes, building maintenance plays an important role since it deals with uncertain factors affecting the performance of the organization. Practically, maintenance oriented organizations are spending substantial amount of their annual budgets in auditing and measuring their quality performance through hiring experts which in many cases are difficult to find [1]. According to Dhillon [2], maintenance cost may reach up to 75% of life cycle costs. Therefore, this creates a challenge to maintenance managements in validating asset performance and allocating the required funds. One of the main reasons behind weaknesses in maintenance management systems is the lack of experience which results in imprecise information obtained for the decision making and hence, losing the control of priorities. This gives a reason to develop a Knowledge-Based management system that can integrate Lean Six Sigma ((L6σ)) as an advance quality philosophy for sustainable building maintenance based on international best practice. The system will be embedded with GAP and AHP techniques to support benchmarking and decision making process.

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A. Maintenance

Maintenance is regarded as a necessary evil over the years, from work permit of low priority to high priority even become an important factor impacting quality, safety, availability and profitability of an organization [3]. Maintenance is seen today as a concept of value added, because it is carried out efficiently to attain strategic targets of the company. This can be achieved more efficiently by relying on the implementation of maintenance policy to provide all the relevant information about the life of the item. According to BS Institution [4], the maintenance is a set of technical and administrative activities that contribute in the retaining or restoring an item to the proper operation conditions.

B. Lean Six Sigma (L6σ)

L6σ is a quality philosophy that utilizes Lean management technique to speed up the process while applying Six Sigma (6σ). This is performed by eliminating the non-adding value elements from the process. In fact, the whole process will be leaned to the minimum requirement of Six Sigma (SS) tools and techniques. Therefore, Lean and SS are complementary to each other. L6σ is recognized as “a business strategy and methodology that increases process performance resulting in enhanced customer satisfaction and improved bottom line results” [5]. Officially, L6σ is using belts in certification as in SS, these are Champion, Master Black Belts, Black Belts, and Green Belts.

C. GAP and AHP

Gauge Absence Prerequisite (GAP) is a benchmarking tool that will be used in Knowledge Base Lean6-SBM. It will assess the existing company situation with the desired situation (i.e.; the Benchmark) in order to find out the gap between them. In addition to GAP, Analytic Hierarchy Process (AHP) will be applied to prioritize the improvements needed to achieve the benchmark. Wong and Li [6] have described some advantages of AHP. They elaborate the importance of applying AHP in construction projects to solve complex “decision making” problems. They have emphasized that AHP is a powerful Multi Criteria Decision Making (MCDM) tool that can measure the consistency in judgments. The following sections are designed to give a brief research background, followed by defining the main attributes of the proposed Knowledge Base Lean6-SBM new methodology.

II. Research Background

The evidence in the literature [3] that the implementation of current maintenance management systems has not achieved the expected level of success (e.g.; maintenance schedules are not implemented on time and priorities are difficult to identify). This is due to lack of maintenance management skills and execution experience which lead to poor impact and crucial negative effects on facility performance.

The main objectives of the maintenance function in any organization is to maximize asset performance and optimize maintenance resources. These objectives cannot be achieved without strengthening the missing link between maintenance and quality. In fact, failure to perform maintenance strategies results in dramatic waste of resources and resulting in poor quality. Elwerfalli et al. [7] have described this waste in maintenance area by saying that unnecessary repair or inspection will definitely lead to increase in maintenance budget commitments and drop in quality performance. These give indication that maintenance processes have non-value adding steps which need continuous improvement. Therefore, there is a need to examine the integration of Lean with SS in such environments from the fact that SS will tackle process control and customer focus with relevant tools, and Lean will accelerate the process by reducing the lead times through eliminating waste [8].

In parallel to this, the complexity of sustainable building maintenance environment requires managers to define and implement appropriate standardized quality management system suitable for this function. Currently, and as part of performance auditing, maintenance quality management approaches vary from one organization to another. The researcher experience has noted that building maintenance practitioners are varied in measuring the quality performance in maintenance management, from regular building inspections to advance monitoring of equipment [9] through Key Performance Indicators (KPI) using software applications like Computerized Maintenance Management System (CMMS) and Enterprise Resource Planning (ERP).

A key aspect of current thinking in all matter of resource utilization is the concept of sustainability and 'greenness'. This is also applicable to building design, construction, operation, and maintenance. Constructing green building means shifting towards sustainability since it aims to minimize the total environmental impacts. This might justify the frequent mentioning of word green in the context of sustainable buildings. Despite the move towards sustainable buildings, there must be comprehensive environmental building assessment method. This shall assess the building performance based on environmental pillars (social, environmental, and economics) and will reflect the sustainability concept in the context of building maintenance.

In order to achieve the main objectives of this research, the Sustainable Building Maintenance (SBM) management will be integrated with L6σ, an advance quality philosophy which will be refined to suite the targeted environment. However, there will be a need to focus the process due to the complexity of many variables in Sustainable Building Maintenance.

The impact of the alternatives in a multi-criteria problem cannot be quantified accurately, and therefore it will affect the decision making [10]. Therefore, a strong multi-criteria decision making tool will be used to deal with such complexity. For this purpose, AHP will be selected to be integrated with the new system. AHP has been used for many quality related applications: It has been used in setting priorities of fire safety attributes in building facility management system [10]. In manufacturing, Nawawi et al. [11] have applied AHP as a prioritization tool into a Lean Manufacturing Management system. Mohamed and Khan [12] have utilized the same for the sake of Low Volume Automotive Manufacturing system. Last but not least, Elwerfalli et al. [7] have presented a new methodology to improve maintenance strategy.

The significant of this research is to advance the use of a hybrid KB/GAP/AHP system to develop a Lean6-SBM. This approach is very new and will assist in identifying quality perspectives while implementing different maintenance strategies in sustainable building context. It will go further to suggest optimum and semi-optimum solutions based on experts' opinions and functional priorities. Thus, the research will deliver an affective decision support system that will assist top management, quality/maintenance managers and practitioners in sustainable building maintenance sector to prioritize and monitor their performance and hence, increase the productivity. In addition, the system will integrate L6σ and a readiness evaluation framework to facilitate the implementation of this system.

III. A New Methodology

This Methodology focuses on proposing Knowledge Base Lean6-SBM that can examine the implementation of L6σ in sustainable building maintenance with the support of KB capabilities exists. The following subsections will detail the proposed methodology that has been derived based on extensive literature review and field experience. A new methodology is divided into four stages as shown in Fig.1:

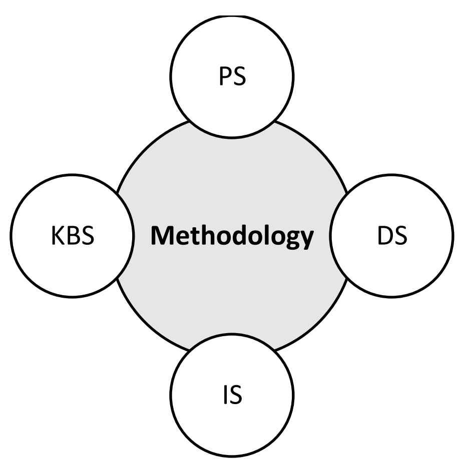

Fig.1. A New Methodology Development Steps

A. Planning Stage (PS)

The Planning Stage includes the strategic level, which contain the organization business, environment, and resources perspectives, in addition to the change management readiness assessment framework. In this stage, general information of the organization will be requested in order to assess its strategic capabilities and readiness to change into the new L6σ (green) environment. Due to its criticality, this stage can be described as a filtration chamber, in which it can ascertain whether the organization can proceed further with L6σ implementation or it will be in need of major changes.

1) Organization Environment

The organization environment explores the current situation of the building maintenance organization, general information about numbers of customers, suppliers, competitors, age of the organization, and number of employees, which can be used to detect the size of the firm [11]. According to Khan et al. [13], different environments require different performance standards and therefore, different strategies of improvement. For this reason, the identification stage is very essential to ensure the validation of performance diagnosis.

2) Business Perspectives

In order to achieve a comprehensive assessment for a building maintenance environment, there must be an investigation to the organization objectives, market share, and financial analysis. The organization statement represents the gate of the initial identification. It specifies vision, mission, and business objectives that describe the bold guidelines of the business operation. Vision and mission are practically very effective to inspire managers and employees. On the other hand, it is obvious that market place highlights the area where the maintenance service is applied, whether it is restricted area, local or global. This might influence the service lead-time. Therefore, it is necessary to analyze the market performance and evaluate how well the organization in attracting the customers through its services. In parallel with market share, the Financial Analysis has a critical importance in deriving the actual organization financial statement, impacting on how well it will be able to deliver its kay performance indicators.

3) Resources Perspectives

Mohamed and Khan [12] have tested the organization resources capabilities in manufacturing sector. However, this research has listed similar resources which can be applied to building maintenance organization. These can be categorized into three resources: first, the human resource which will trigger employees' development, the associated culture, and benefits (e.g.; rewards, and salaries). Secondly, the technology resource which deals with managing technologies (e.g.; maintenance systems like Enterprise Resource Planning or CMMS). Finally, the financial resource will take place in regard to annual budget allocated for employees, technical aspects and technology development in the field of sustainable building maintenance.

4) L6σ McKinsey Concept

The literature indicates that in more than 90% of surveys about Lean, 6σ, and L6σ projects there is a degree of resistance to change, and lack of management commitment. These are the main impediments against successful project implementation [14]. Despite having built-in change management awareness process in DMAIC model, there is a need to enhance this approach with a comprehensive plan that should analyze and assess the organization readiness to tackle such obstacles. For that reason, a readiness evaluation framework is necessary to be integrated into the system. This will be based on the McKinsey 7S framework, which is widely used in the field of Information Technology. The organization readiness has to be tested prior to L6σ implementation in order to highlight the degree of HR gap points. Hanafizadeh and Ravasan [15] indicate that McKinsey's 7S framework can be categorized into soft S's and hard S's. Soft S's are difficult to implement and contain Staff, Skills, Style, and Share values, whereas hard S's are easy to identify and contain Systems, Structure, and Strategy.

B. Designing Stage (DS)

This Designing Stage is identified as the second stage. It will study the core business of the organization by assessing the capability of integrating L6σ to support relevant know how of sustainable building maintenance based on the applied taxonomy structure. In this stage, the Lean6-SBM model will proceed with benchmarking and prioritization through integrating GAP and AHP techniques as shown in Fig. 2. The outcome of the stage will reflect how far the organization or the maintenance department is from the desired best practice (benchmark).

1) Lean Six Sigma (L6σ)

Due to the nature and complexity of this philosophy, there is a need to narrow down the selective tools and techniques, which are going to be included in the KB system in later stage. Setijono et al. [14] stated in their findings of the survey done in 101 manufacturing and service companies some critical success factors which might affect the L6σ implementation. The majority of respondents highlighted the importance of "leadership styles", "organizational culture", "management commitment", and "linking L6σ to business strategy". This study has been enhanced by Albliwi et al. [8], where they show that around 34 factors affect L6σ implementation. The top factors are related to lack of top management attitude, lack of training, poor project selection, and lack of resources. According to Al-Aomar and Setijono [16], there are seven types of wastes in production and construction environment: these are delays, defects, excessive people movement, excessive transport, over inventory, over production, and delivery of equipment and materials. They have developed a framework using L6σ to reduce the above wastes in construction projects. Karthi et al. [17] have integrated L6σ with QMS standard ISO 9001:2008 under the SS DMAIC phases. They argue that organizations need to adopt this type of integration in order to achieve their future competitive advantages based on continuous improvement approach. This paper will propose the use of eight different L6σ tools and techniques which have been selected based on literature review. These are Total Productive Maintenance (TPM), Kaizen, 5S, Value Stream Mapping (VSM), Statistical Process Control (SPC), Design of Experiment (DOE), Failure Mode and Effect Analysis (FMEA), and Quality Function Deployment (QFD). However, the list will be screened in accordance to the validation process which will take place in later stages.

2) Sustainable Building Maintenance Taxonomy

From the researcher's experience, and close investigation in maintenance practices of sustainable buildings, it is found that sustainable maintenance taxonomy and strategies are not independent of the traditional maintenance processes and practices. Motawa and Almarshad [18] have mentioned some general building taxonomy schemes in construction and building maintenance projects which aim to facilitate the knowledge sharing across the organization. In construction, these schemes are: Construction Index, RIBA Uniclass (Unified Classification for the Construction Industry), and the Construction Specifications Institute (CSI). For Building Maintenance taxonomy, (ibid.) [18] have designed their Building Maintenance (BM) taxonomy based on existing BM contracts of public sector. This scheme has been verified by professionals to suit with the specified work environment. The research will extend the use of this taxonomy with a provision of verification and refinement in later stage. It will be presented as the main sustainable building maintenance taxonomy structure that will be integrated into the Knowledge Base Lean6-SBM system. The taxonomy can be broken down into three categories: Administrative, technical, and legal.

3) Gauge Absence Prerequisite (GAP)

It has been proven from literature review that the Gauge Absence Prerequisite (GAP) is a powerful benchmarking technique. For examples, it has been integrated with hybrid Knowledge Base Systems (KBSs) as a benchmarking tool in some areas, like performance measurement system [13], lean manufacturing [11], low volume automotive [12] and Maintenance Strategy and Operation. Therefore, this research will extend the use of GAP to the area of sustainable building maintenance in order to measure the differences between exiting practices and the desired (benchmark) ones.

Fig. 2. Designing stage of Conceptual model

4) Analytic Hierarchy Process (AHP)

AHP approach has been used widely as a multi-criteria decision making tool. AHP as a measurement technique can deal with tangible and intangible factors. Therefore, it allows quantitative and qualitative attributes to be evaluated. They insist that overall priorities of criteria (i.e.; main criteria and sub-criteria) are combined to establish alternative decision. This can be justified through the intensive use of AHP in various applications [11], [12], [13]. In this research, and due to the complexity of the conceptual integration between Lean and 6S, it appears to be the best technique.

C) Implementation Stage (IS)

SS is widely implemented through DMAIC process, which consisted of Define, Measure, Analyze, Improve, and Control cycle as given in Fig 3. According to Hokoma et al. [9], this method is developed in practice from engineering industries, and that DMAIC is suitable to solve complex problems, but if and only if it is required to expose all problem components (i.e.; define, diagnose, design, and test).

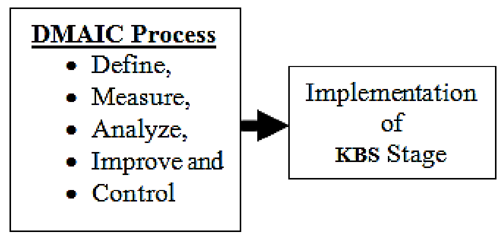

Fig. 3. Implementation stage of a new methodology

Further, they declare that it is not suitable for unstructured or subjective problems. The process shown in Fig. 3 represents the DMAIC methodology for the proposed KB system. It can be explained as: Define the sustainable building maintenance values, and results along with customer needs for a particular area, department, or a project. Measure and validate data which helps in setting priorities and criteria, Analyze to find out root causes and well understanding of the process and problem, Improve by developing solutions and refining goal statements, and finally Control and monitor the changes by developing a tracking process.

D) *Knowledge-Based System (KBS)*

An Expert System (ES) or a Knowledge Based System (KBS) is one of the Artificial Intelligence concepts and methodologies. The terms ES and KBS are having the same meaning and therefore, most of the scholars use them synonymously. In fact, when ESs were developed, they contained considerable knowledge regardless if it was not matching with the performance of human experts, and therefore they were called KBS. This Knowledge Base contains rules, facts, and the acquired knowledge from human experts [11]. Currently, there is an increase in applying KBSs as a tool to reduce the high expenditures of hiring experts, ease of knowledge transfer within the organization, and to improve the productivity of organization.

IV. CONCLUSION

The purpose of the study was to present a new methodology of a KB system to support the application of L6σ principles in building maintenance with a focus on sustainability. The maintenance function can have a strong impact on organizational performance. This is also relevant in the context of sustainable building maintenance. The L6σ philosophy seeks to achieve continuous improvement of the maintenance function. The novelty of this approach consists of the integration of GAP analysis for benchmarking and AHP for prioritization in order to support decision making within a hybrid KB system.

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