A Conceptual Model for a Hybrid Knowledge-based Lean Six Sigma Maintenance System for Sustainable Buildings

Jasim Aldairi, M K Khan, and J E Munive-Hernandez

Abstract **- The complexity of sustainable building maintenance environment enforces top managements to develop a standardized maintenance quality management system that can be applied in all concerned departments. This paper presents a novel conceptual model of a hybrid Knowledge-Based Lean Six Sigma Sustainable Building Maintenance System (Lean6-SBM). This model seeks to apply the Lean Six Sigma philosophy to support implementation of an ideal building maintenance system. The conceptual model integrates GAP and AHP techniques to support benchmarking and decision making. The proposed conceptual model is presented to show the fundamental components of the Lean6-SBM.**

Index Terms **- Sustainable Building Maintenance, Knowledge Based System (KBS), Lean Six Sigma (LSS), Analytic Hierarchy Process (AHP), Benchmarking**

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 organisations 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 is costing 60% to 75% of the large system's or product's life cycle costs. This automatically 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 (LSS) 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.

Manuscript received March 23, 2015; revised April 03, 2015. The research is fully sponsored by the Ministry of Defense Engineering Services (MoDES)-Oman. Jasim Aldairi, PhD research student (j.s.s.aldairi@student.bradford.ac.uk); M K Khan, Professor of Manufacturing Systems Engineering (m.k.khan@bradford.ac.uk); and J E Munive-Hernandez, Lecturer in Advanced Manufacturing Engineering (j.e.munive@bradford.ac.uk).

A. *Maintenance*

Maintenance is defined by *CIBSE Guide M* [3] as "*the combination of all technical and associated administrative actions intended to retain an item in, or restore it to, a state in which it can perform its required function*".

Zawawi et al. [4] insist that the performance in maintenance operations management have to be analysed and reviewed continuously in order to achieve high service quality. However, the traditional approach to achieving a high consistent performance leads to over exhaustion of resources. Thus there is a need for a newer approach to these problems.

B. *Lean Six Sigma (LSS)*

LSS is a quality philosophy that utilizes Lean management technique to speed up the process while applying Six Sigma (SS). 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 SS tools and techniques. Therefore, Lean and SS are complementary to each other. LSS is recognized as *"a business strategy and methodology that increases process performance resulting in enhanced customer satisfaction and improved bottom line results"* [5]. Officially, LSS 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

ISBN: 978-988-14047-0-1
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

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 conceptual model.

II. Research Background

There is evidence in the literature [4] 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. Milana 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 LSS, 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, Milana et al. [7] have applied AHP to improve maintenance strategy and operation.

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 LSS and a readiness evaluation framework to facilitate the implementation of this system.

III. The Conceptual Model

This paper focuses on proposing a novel generic model for Knowledge Base Lean6-SBM as currently no existing model that can examine the implementation of LSS in Sustainable Building Maintenance with the support of KB capabilities exists. The following subsections will detail the proposed conceptual model that has been derived based on extensive literature review and field experience. The conceptual model is divided into three main stages: Planning, Designing, and Implementation. The Planning and Designing Stages formulate the strategic level, while the operational level is represented by the Implementation Stage. Therefore, the Planning Stage is the starting point, which defines the organization profile, status, general financial and market statements. In addition, it investigates organization resources capabilities and readiness to change.

ISBN: 978-988-14047-0-1
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

The readiness evaluation framework is based on the concept of the McKinesy 7S framework. The information will be used in design stage to find out the combination of sustainable building maintenance functions and the quality aspects required to run this business. The conceptual design will consider the most suitable quality elements with respect to sustainable building maintenance, in order to generate KB rules. Next, the Knowledge Base Lean6-SBM will be supported by a decision making process to finalize the model conceptual design. The Lean6-SBM conceptual model will need to be verified, validated, and refined prior to conversion into an applicable model.

A. *Planning Stage (Identification)*

As it can be seen in Fig. 1, 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 LSS (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 LSS 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 KPIs.

3) *Resources Perspectives*

Nawawi et al. [11] and 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.

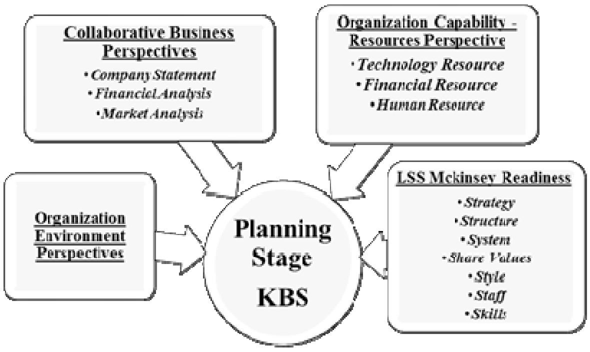

Fig. 1 Conceptual model (Planning)

4) *LSS McKinsey Concept*

The literature indicates that in more than 90% of surveys about Lean, SS, and LSS projects there is a degree of resistance to change, and lack of management commitment. These are the main impediments against successful project implementation [8], [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 LSS 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*

This Designing Stage is identified as the second stage. It will study the core business of the organization by assessing the capability of integrating LSS to support relevant know-

ISBN: 978-988-14047-0-1
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

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 (see 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 (LSS)

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 LSS implementation. The majority of respondents highlighted the importance of "leadership styles”, "organizational culture", "management commitment", and "linking LSS to business strategy". This study has been enhanced by Albliwi et al. [8], where they show that around 34 factors affect LSS 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 LSS to reduce the above wastes in construction projects. Karthi et al. [17] have integrated LSS 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 LSS 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 cited 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, Motawa and Almarshad [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 is consisted of three categories:

- Administrative, which contains maintenance processes and staff index.
- Technical, which refers to the technical work package.
- Legal, which serves contract conditions, bidding law, health and safety.

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 [7]. 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.

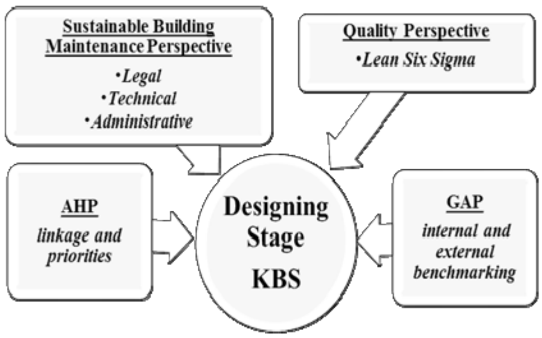

Fig. 2 Conceptual model (Designing)

4) Analytic Hierarchy Process (AHP)

AHP approach has been used widely as a multi-criteria decision making tool. Chan et al. [19] state that 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 [7], [11], [12], [13]. In this research, and due to the complexity of the conceptual integration between Lean and SS, it appears to be the best technique.

ISBN: 978-988-14047-0-1
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

C. Implementation Stage

SS is widely implemented through DMAIC (Define, Measure, Analyse, Improve, and Control) cycle. According to Abdullah Hokoma et al. [9], De Mast and Lokkerbol [20], this method is developed in practice from engineering industries, and that DMAIC is suitable for solving complex problem tasks if and only if it is required to expose all problem components (i.e.; define, diagnose, and design of solutions).

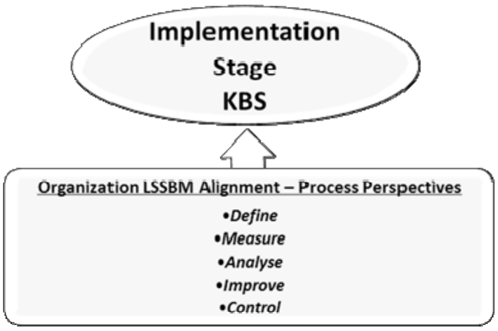

Fig. 3 Conceptual model (Implementation)

On the other hand, 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, *Analyse* 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 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]. The following example illustrates one of the production rules which relates to detecting the size of an organization based on environment perspectives [12]:

IF *the company annual sales turnover is more than £5 million*
OR *the number of full time employees is more than 150*
THEN *the company is classified as a large size company*
OR *the company annual sales turnover is between £2 and £5 million*
AND *the number of full time employees is 150 or less*
THEN *the company is classified as a medium size company*
OR *the company annual sales turnover is between £50,000 and £2 million*
AND *the number of full time employees is at least 5*
THEN *the company is classified as a small size company*
OR *the company is classified as a micro size company*

Currently, there is a dramatic increase in using KBSs in various disciplines. The reason is basically to reduce the high expenditures of hiring experts and to get ease of knowledge transfer within the organization, and consequently improving the productivity.

IV. Conclusion

This paper has presented the conceptual model of a KB system to support the application of LSS principles in building maintenance with a focus on sustainability. The maintenance function can have a strong impact on organisational performance. This is also relevant in the context of sustainable building maintenance. The LSS 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 prioritisation in order to support decision making within a hybrid KB system. The Mckinsey 7S framework is applied to assess organisations for readiness.

Future research will consider further development of the conceptual model into a practical knowledge-based system.

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ISBN: 978-988-14047-0-1
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)