# New Methodology for Improving Quality Management in Healthcare Environment using a Hybrid Knowledge-Based System

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***Abstract* - The complexity of Healthcare Environment directs decision makers to develop a standardized Quality Management System that can be applied in all healthcare areas. This paper will present an original and novel approach (KB/ES coupled with AHP and GAP analysis) for designing and implementing L6σ in QMHE. The KB system embeds GAP for benchmarking (evaluating the existing practices with the benchmarked ones), and AHP for prioritization of implementation.**
**The proposed KB system will benchmark the current position of QMHE with the ideal benchmark one (resulting from extensive evaluation by the KB/GAP/AHP system of international quality concepts in healthcare organizations).**

***Index Terms* – Quality Management in Healthcare Environment (QMHE), Knowledge Based System (KBS), Lean Six Sigma (L6σ), Analytic Hierarchy Process (AHP), Benchmarking.**

## I. INTRODUCTION

According to the UK's Department of Health, almost £400 million is being paid in clinical negligence claims and adverse incidents, causing nearly £2 billion per year of losses [1]. As a result, the National Health Service (NHS) has implemented a number of quality improvement concepts, most recently 6σ and Lean [2]. In the USA, the National Committee of Quality Assurance estimates that $3.6 billion had been paid as a result of preventable hospitalization, which could have been avoided had the total health care system operated at benchmark levels [3].

In Oman, the Oman's Health Vision 2050 Report [4] highlighted a number of challenges for enhancing and developing health research which will impact on the Quality Management of Healthcare such as: insufficient funds, lack of research prioritization with the national plans, poor coordination between Ministry of Health (MoH) and other healthcare organizations within Oman, poor communication of research results, limited research topics' implementation, insufficient follow up of the outcomes and immature research culture among health care providers.

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As a results of these challenges, this paper presents a Knowledge Based System (KBS) to assist healthcare managers and practitioners during decision making in the context of achieving excellent benchmark Quality Management. This KBS will be developed through integrating Analytical Hierarchy Process (AHP) and Gauging Absence of Pre-requisite (GAP) methods as a decision making tool.

### *A. Lean Six Sigma (L6σ)*

Six Sigma (6σ) as a term refers to a statistical measure of defect rate in a system. Sigma (σ, also called a Standard Deviation) is a measure that is used to calculate the amount of variation of a set of data values from a mean of the samples (following a Normal Distribution). As a quality concept, 6σ was coined by the reliability engineer Bill Smith working at Motorola Company in 1987 [5].

Lean thinking emerged within Japanese automobile industries after world war II by Taiichi Ohno and associates [6]. There is no agreement on a definition of Lean production between the researchers [7]. According to Lummus, et al. [8] Lean manufacturing concentrates on waste elimination to reach competitiveness. Anvari et al. [9] listed the main elements helping to the elimination of this waste activities as: excess production, excess processing, delays, transport, inventory, defects and movement.

The integration of Lean and 6σ aims to target each and every opportunity for improvement in particular organization and attempts to provide empowerment even at the higher-level process analysis stages [6].

According to Sharma [10] 6σ methodologies should be used to aid and support the implementation of Lean in the organization. When an organization plans to construct a new framework for L6σ, this framework should be strategic and process focused, balanced between the two philosophies, balanced between complexity and sustainability and structured around the type of problem experienced [6].

### *B. Quality Management in Healthcare Environment (QMHE)*

There is no agreement among reserachers to define Quality Management in Healthcare Environment. Harteloh [11] in his paper *'The Meaning of Quality in Health Care: A Conceptual Analysis'* discussed how difficult it was to

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standadrize a definition for quality in healthcare. The patient's satisfaction has been used widely to measure the quality of services provided in healthcare facilities.

Sloan, et al. [12] found seven important categories of readiness factors of a successful launch of Lean in healthcare which are: strong leadership support, finding Lean with the strategic program, understanding what value and customer groups be present in healthcare. Furthermore, undertaking the end-to-end process view, staff training and participation in Lean principles and methods, measurement and reward systems aligned to Lean objectives, and equivalent demand and capacity levels to increase flow.

### C. KBS, GAP and AHP

The goal of Artificial Intelligence (AI) as a science is to make machines think things that would need intelligence if done by humans [13]. According to [14], there is no standard definition of AI. He defined AI as '*the study of making computers do things that the human needs intelligence to do*'. AI has several techniques and methods used for implantation.

One of the widely used techniques of AI is the Knowledge Based (or Expert) Systems (KBS). Quinn [15] defined an Expert System as '*an interactive computer program that asks the same questions a human expert would ask, and from the information given to it by the user, provides the same answer the expert would provide'*. The use of KBS will be covered later in this paper.

In any type of application, an audit should be conducted to assess the gap between what actually exists in a specific environment and the essential or desirable prerequisites for effective implementation [16]. The information needed to apply GAP could also be collected from the users through the designed questionnaire embedded in the KB. After the GAP analysis audit or questionnaire, the Problem Categories (PCs) should be recorded into two reports: all positive elements and procedures (Good Points – GPs) already existing in one report and all negative elements (Bad Points – BPs) representing non-existence of data, poor systems in the other report [17].

Saaty [18] defined AHP as a systematic analysis method established for multi-criteria decision. Wang, et al. [19] summarized the steps of AHP as: determining and structuring of all elements influencing the decision-making process, developing judgment matrices, computing of local priorities and deriving alternatives' ranking. The AHP technique processes the complex decisions to a series of pair-wise comparisons until it computes the prioritised decision by giving a clear rationale for the judgements being concluded [20].

## II. Research Background

The report of an Expert Group on Learning from Adverse Events in the NHS [1], The National Committee of Quality Assurance [3], and The Report of Quality and Patient Safety in Oman [21] show that the application of existing Quality management Systems in Healthcare Environment have not achieved the expected level of success.

Consequently, this paper aims to present the development of a Knowledge Based System (KBS) to assist healthcare managers and practitioners during decision making in the context of achieving excellent benchmark Quality Management.

The paper proposes a conceptual framework for QMHE which will be the model for designing a hybrid KBS by integrating Analytical Hierarchy Process (AHP) and Gauging Absence of Pre-requisite (GAP) methods. The two methodologies are essentially required to optimize the solutions obtained for the decision making.

The KBL6σ-QMHE system will then be arranged in a decision level hierarchy in which the Key Performance Indicators (KPIs) are considered. This process will be done in order to produce KB production rules which are the corner stone of the proposed system.

## III. The New Methodology of KB Lean Six Sigma in QMHE

This paper focuses on suggesting a new methodology of KBL6σ in QMHE because there is no current methodology that covers this issue of implementing L6σ to assess QMHE. Furthermore, the process of implementing the suggested methodology will be explained by transforming it into a structured model based on hierarchal decision making levels. Such a step will aid in generating the necessary modules that will be useful to produce the KBS rules which will evaluate the L6σ elements of QMHE with the support of KB competencies.

### A. Planning Stage

As it can be seen in Fig.1, to accomplish L6σ-QMHE model the first step, as part of strategic level, formulates the planning stage. This stage consists of healthcare organization's statement and healthcare quality dimensions. Healthcare quality dimensions have been discussed and illustrated in World Health Organization, Accreditation Canada International, Joint Commission International and NHS as part of several healthcare dimensions. ACI [22] introduced eight quality dimensions in healthcare, as follows: *population focus, accessibility, safety, work life, client-centered services, continuity of services, effectiveness and efficiency.* Comparing with ACI, the WHO report [23] added *equitability* and excluded *population focus and work life.* The selection of L6σ-QMHE model dimensions (*patient- centered, accessibility and effectiveness*) has been taken after a process of comparison between literatures and discussion with healthcare quality experts.

The clarity of goals, objectives and readiness assessment are very essential in development of the planning stage to look for the different aspects that affect the main target. Poister and Streib [24] found that the most frequently reported elements were the development of goals

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and objectives and the development of a vision for a future followed by review of the organizational mission.

George and George [25] summarized approaches to conducting a readiness assessment as: select the L6σ Champion, establish a baseline of the organization, interview top management, engage key influencers and assess the impact of what is found. As mentioned above, the researcher is going to consider two main factors in the planning stage: an organization's statement and the assessment of quality dimensions.

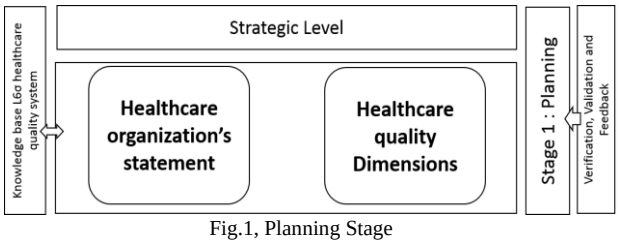


Fig.1, Planning Stage

### B. Designing Stage

Moving to the designing stage, the first factor that needs to be considered is healthcare Quality Management standards. JCI has divided its standards into two sections: patient-centered standards and healthcare organization management standards. The first section focuses on clinical quality and the second section focuses on administrative part that includes Quality Management, leadership and governance.

There is an entity (for example, a Ministry of Health), an owner(s), or a group of identified individuals (for example, a Board or Governing Body) responsible for overseeing the organization's operation and accountable for providing quality health care services to its community or to the population that seeks care. This entity's responsibilities and accountabilities are described in a document that identifies how they are to be carried out [26].

Leadership standards address the growing international request for clarity regarding the roles and responsibilities of health care organizations and their leaders to deliver the supports and infrastructure needed to drive excellence and quality improvement in health service delivery. According to ACI [27], the leadership standards are grouped into five sections that each address a key leadership responsibility that organizations must have in place as part of their pursuit of quality and safety.

Governance standard and leadership standard must be integrated with L6σ performance measures. As Fig. 2 shows, this stage will consider the most suitable L6σ elements with respect to governance standard and leadership standard in order to generate L6σ of QMHE. Thus, this new product of integration has to be maintained by a decision making process to conclude the application conceptual design. This requires having a controlling methodology that can activate two deliverables in KBL6σ, governance standard and leadership standard and the benchmarks between the current practice and the desired ones. The wide and positive use of GAP analysis for benchmarking and AHP for prioritization has directed the research to integrate both methods into the KBL6σ of QMHE model.

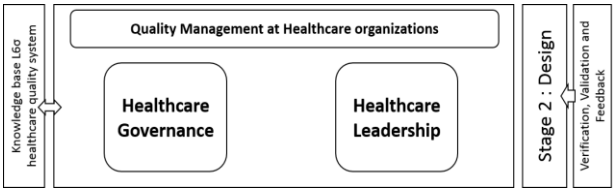


Fig. 2, Designing Stage

### C. Implementation Stage

The third stage is the implementation which arises under the operational level. In this stage, both allocating resources and implementation of L6σ are used to accomplish the selected projects after passing the initial assessments. In this stage, the KBS will assess how the financial resources are allocated to cover human resources, capital and consumable expenditures. WHO considers human resources as one of three principal health system inputs, with the other two main inputs existence physical capital and consumables [28].

It can be seen from the model diagram in Fig. 3, feedback acquired from discussion of research supervisors, healthcare quality managers, presenting conference paper (and receiving feedback) and using the knowledge of L6σ black belt and master black belt holders is input to refine the model and accordingly the related development steps, as part of the verification and validation process. This will speed up the system development process and improve the capability of implementing the KBL6σ of Quality Management in real hospitals.

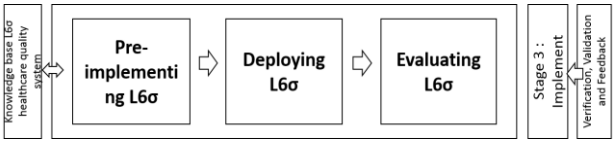


Fig. 3, Implementation Stage

### D. Knowledge Based System (KBS)

The KBS is the source of the rules, facts, and knowledge acquired from the human expert. The knowledge in this base is typically represented in the form of **IF**…**THEN** type KB rules, facts and assumptions about particular problem the system is developed to solve [29]. The knowledge base is not static; as new knowledge becomes available the knowledge base needs to be updated [30]. The knowledge in the KB is combined with the system via a process called knowledge representation[31] . There are two general types of rules in KB: a definitional rule and a heuristic rule. In a *definitional rule*, the inference engine establishes a relationship between terms.

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The following brief example shows the KB rules of *healthcare quality dimensions sub-module:*

**IF** *the healthcare organization is delivering healthcare that is adherent to an evidence base results* (**Yes**: GP; **No**: BP-**PC-1**)

**AND** *the healthcare organization is delivering health care that is timely* (**Yes**: GP; **No**: BP-**PC-2**)

**AND** *the healthcare organization is delivering health care that is geographically realistic* (**Yes**: GP; **No**: BP-**PC-3**)

**THEN** *the healthcare organization has a well-defined healthcare quality dimensions*

**OR** *the organization statues is poor in respect to healthcare quality dimensions.*

The above KB rules are example of *Healthcare Leadership* sub-module, where BP is Bad Point, GP is Good Point and PC is Problem Category, as discussed earlier. Such knowledge rules will be developed for all modules and sub-modules in the three stages (Planning, Designing and Implementing). It is expected that the final KBS will contain around 2000 rules.

## IV. Conclusion

This paper has presented new methodology of KBL6σ in QMHE which is used to develop the KPI elements and process flowcharts that act as a roadmap to generate the desired KB rules. Consequently, this will lead to a comprehensive hybrid KBS that will be supported by benchmarking (GAP) and prioritization (AHP) improvement techniques. The phase is extended to include the designing stage, which includes the main area of this research that deals with the core assessment components of the KBL6σ-QMHE system (i.e., governance perspectives). The final implementation phase considers the operational side. Future research will consider further development of this model into a practical KBS in Healthcare Environment.

## References

[1] D. o. H. UK, "Report of an Expert Group on Learning from Adverse Events in the NHS," 11/1/2017 2001.
[2] N. Proudlove, C. Moxham, and R. Boaden, "Lessons for Lean in healthcare from using Six Sigma in the NHS," *Public Money and Management*, vol. 28, pp. 27-34, 2008.
[3] Q. Feng and C. M. Manuel, "Under the knife: a national survey of six sigma programs in US healthcare organizations," *International Journal of Health Care Quality Assurance*, vol. 21, pp. 535-547, 2008.
[4] M. o. Health, "Oman's Health Vision 2050," Ministry of Health, Muscat08/03/2016 2014.
[5] E. Lindsay, "An Introduction to Six Sigma & Process Improvement Pengantar Six Sigma," *Jakarta: Salemba Empat*, 2005.
[6] M. P. J. Pepper and T. A. Spedding, "The evolution of lean Six Sigma," *International Journal of Quality & Reliability Management*, vol. 27, pp. 138-155, 2010.
[7] J. Pettersen, "Defining lean production: some conceptual and practical issues," *The TQM Journal*, vol. 21, pp. 127-142, 2009.
[8] R. R. Lummus, R. J. Vokurka, and B. Rodeghiero, "Improving quality through value stream mapping: A case study of a physician's clinic," *Total Quality Management*, vol. 17, pp. 1063-1075, 2006.
[9] A. Anvari, Y. Ismail, and S. M. H. Hojjati, "A study on total quality management and lean manufacturing: through lean thinking approach," *World applied sciences journal*, vol. 12, pp. 1585-1596, 2011.
[10] U. Sharma, "Implementing lean principles with the Six Sigma advantage: how a battery company realized significant improvements," *Journal of Organizational Excellence*, vol. 22, pp. 43-52, 2003.
[11] P. P. Harteloh, "The meaning of quality in health care: a conceptual analysis," *Health Care Analysis*, vol. 11, pp. 259-267, 2003.
[12] A. F. Sloan, Kathryn J. Hayes, Zoe Radnor, Suzanne Robinson, T. Amrik Sohal, S. Al-Balushi, A. Sohal, P. Singh, A. Al Hajri, *et al.*, "Readiness factors for lean implementation in healthcare settings–a literature review," *Journal of health organization and management*, vol. 28, pp. 135-153, 2014.
[13] M. A. M. A. Boden, *Artificial intelligence and natural man*, 1977.
[14] T. Munakata, *Fundamentals of the new artificial intelligence: neural, evolutionary, fuzzy and more* vol. 2ndition. New York;London;: Springer, 2008.
[15] K. Quinn, "Expert system shells: what to look for," *Reference Services Review*, vol. 18, pp. 83-86, 1990.
[16] A. Kochhar, A. Suri, and R. Hather, "Design and implementation of a general purpose knowledge-based gap analysis system with particular reference to the implementation of effective material requirements planning systems," *C429/051 ImechE*, pp. 129-133, 1991.
[17] M. K. Khan, "Development of an expert system for implementation of ISO 9000 quality systems," *Total Quality Management*, vol. 10, pp. 47-59, 1999.
[18] T. L. Saaty, "The analytic hierarchy process: planning, priority setting, resources allocation," *New York: McGraw*, 1980.
[19] L. Wang, J. Chu, and J. Wu, "Selection of optimum maintenance strategies based on a fuzzy analytic hierarchy process," *International Journal of Production Economics*, vol. 107, pp. 151-163, 2007.
[20] A. A. Aguilar-Lasserre, M. A. B. Bautista, A. Ponsich, and M. A. G. Huerta, "An AHP-based decision-making tool for the solution of multiproduct batch plant design problem under imprecise demand," *Computers & Operations Research*, vol. 36, pp. 711-736, 2009.
[21] O. Ministry of Health, "Quality and Patient Safety:Health Vision 2050," 2016.
[22] A. C. International. (2016, 03/03/2016). *Accreditation Canada International*. Available: https://accreditation.ca/about-us
[23] W. H. Organization, "Quality of care: a process for making strategic choices in health systems," 2006.
[24] T. H. Poister and G. Streib, "Elements of strategic planning and management in municipal government: Status after two decades," *Public administration review*, vol. 65, pp. 45-56, 2005.
[25] M. L. George and M. George, *Lean six sigma for service*: McGraw-Hill New York, NY, 2003.
[26] JCI, "ACCREDITATION STANDARDS FOR HOSPITALS," ed. U.S.A.: JOINT COMMISSION INTERNATIONAL 2010.

ISBN: 978-988-14048-3-1
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

[27] Q. International, "Leadership standards," vol. version 3, ed. Canada: ACI, 2016.
[28] WHO, "The World Health Report 2000," ISBN 92 4 156198 X, 2000.
[29] E. M. Awad and D. Huntington, *Building expert systems: principles, procedures, and applications*: West Publishing Co., 1996.
[30] S. Maqsood, M. K. Khan, and A. Wood, "Novel Heuristic for Low-Batch Manufacturing Process Scheduling Optimisation with Reference to Process Engineering," *Chemical Product and Process Modeling,* vol. 6, 2011.
[31] M. Milana, M. K. Khan, and J. E. Munive, "A Framework of Knowledge Based System for Integrated Maintenance Strategy and Operation," in *Applied Mechanics and Materials*, 2014, pp. 619-624.

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