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Abstract:

The current healthcare systems have numerous gaps that need to be filled to reach the best practice. Healthcare organizations have used different Quality Management (QM) tools to monitor and control its services.

This paper presents a novel approach to design and validate a hybrid Knowledge-Based System (KBS) to evaluate QM of healthcare Environment (QMHE) using a hybrid system that has not been used before. The proposed system will be combined with Gauge Absence Perquisite (GAP) method to sustain a successful operation of the large number of Key Performance Indicators (KPIs) that involved in QMHE and to detect the gap between each KPI and the anticipated point. Employment of KB system offers the chance to deal with users in an appropriate way and to support in the decision-making process. Moreover, by including instructive features, the KB system can be used as a learning device for quality managers in healthcare organizations. It firstly focuses on the KB components, followed by the GAP methodology and then the application of the KB-QMHE at a tertiary hospital in Oman. Finally, a summary of the complete KB-QMHE outcomes of its application there is shown.

The system will support the healthcare governance to enhance the patient safety culture and QM efficiency. Out of 354 KB rules answered, the system has categorised 225 as GPs and the remaining 128 as BPs. The 128 bad points are categorised into different problem categories (20 PC-1, 34 PC-2, 34 PC-3, 40 PC-4, and 0 PC-5) where they represent the actions that need to be enhanced to reach the desired level of quality management.

***Keywords**:* Knowledge-Based System (KBS), Quality Management in Healthcare Environment (QMHE), Gauging Absence Pre-requisites (GAP), and Oman

Introduction

Quality Management (QM) in Healthcare has used different tools to monitor and control its services. As per several authors, all the new QM tools are initiated by business and manufacturing sectors and then will be used by healthcare organizations (Black and Revere, 2006, Langabeer et al., 2009, Vest and Gamm, 2009 and Al Khamisi et al., 2017b). For example, a method called Lean thinking emerged within Japanese automobile industries after world war II by Taiichi Ohno and associates (Pepper and Spedding, 2010). According to Lummus et al. (2006), Lean manufacturing concentrates on waste elimination to reach competitiveness.

After that, Deming (1986), In his book *Out of the crisis,* has introduced Fourteen points of management. He emphasized that the goal should be to improve overall productivity, and key of this is to understand the nature of variation and having operational definitions. Thereafter, Juran discussed new concepts of quality in his book *Juran on leadership for quality* such as: quality improvement, quality planning, quality control (Juran, 2003).

Furthermore, Ishikawa brought new concept called *fish bone diagram* which was widely used as a quality tool to organize causes of variation in the outcome of the work (Best and Neuhauser, 2008). Then, Feigenbaum devised the concept of Total Quality Control, which later became known as Total Quality Management (TQM).

In 1987, the reliability engineer Bill Smith who was working for Motorola Company introduced another a quality concept called Six Sigma (6σ) method (Lindsay, 2005). It aims to reduce defect rate to 3.4 defects for every million opportunities. 1990s was the real start of 6σ when Jack Welch, CEO of General Electric Company, implemented the concept in the company (Welch and Byrne, 2003).

Thereafter, a new concept has raised combining both Lean thinking and 6σ process called Lean Six Sigma (L6σ). This concept had started to appear pointedly since the new millennium particularly after the 2004-2007 or 2008 period (Muraliraj et al., 2017). The separate concepts of Lean and 6σ are greatly researched compared to the integrated concept. In fact, L6σ aims to delight the organization's customers by delivering higher quality service in less time. Hence, to achieve the aim of L6σ, it is important for an organization to improve its process by eliminating defects and focus on how the work flowed through the process.

Despite all these quality improvement initiatives, The report of *To Err is Human* recognized healthcare error as a major public health subject leading to the death of at least 44,000 and perhaps as many as 98,000 Americans each year in US hospitals (Brown and Patterson, 2001). The National Health Service (NHS) in the UK distributed a report in 2000 detecting the important effect of adverse events in the NHS (Baker and Norton, 2002) and (Vincent et al., 2001). These adverse events are costing NHS almost £2 billion per year (UK, 2001). Suter et al. (2009) recommended that the current knowledge on health systems needed to be integrated to advance effective service delivery with evidence-informed decision-making as an expectation in healthcare management and policy.

Subsequently, this paper presents a novel approach to design and validate a hybrid Knowledge Based-System (KBS) to evaluate QMHE using a hybrid system that has not been used before. The proposed system will be combined with GAP method to sustain a successful operation of the large number of Key Performance Indicators (KPIs) that involved in QMHE and to detect the gap between each KPI and the anticipated point. Employment of KBS offers the chance to deal with users in an appropriate way and to support in the decision-making process.

Moreover, by including instructive features, the KBS can be used as a learning device for quality managers in healthcare organizations.

The paper firstly focuses on the KBS components, followed by the GAP methodology and then the application of the KB-QMHE at a tertiary hospital in Oman. Finally, a summary of the complete KB-QMHE outcomes are shown. The system will support the healthcare governance to enhance the patient safety culture and QM efficiency. It will help, also, in minimizing risk and cost needed to operate (Gillies et al., 2006)

Knowledge-Based System (KBS)

The goal of Artificial Intelligence (AI) as a science is to make machines think things that would need intelligence if done by humans (Boden, 1977). It is the study of making computers do things that the human needs intelligence to do (Munakata, 2008). In fact, Hundreds of AI applications in healthcare can be seen in literatures. For example, it was used in Patient-focused and continues performance improvement in healthcare (Büyüközkan et al., 2011), Evaluating health-care waste disposal alternatives (Dursun et al., 2011), Measuring relationship between healthcare professionals and knowledge management (Chen et al., 2011) and Exploration of healthcare quality indicator (Chae et al., 2003).

KBS, as a branch from AI, is an information technology system or software that can generate knowledge or use a knowledge base to support decision making to solve real-world problems.

Knowledge acquisition

Knowledge acquisition usually starts by reviewing documents and reading books, papers and manuals related to the problem domain. After that, capturing of more knowledge can achieved by different ways such as:

- Interviewing

Since knowledge is not available systematically, researcher has to conduct several sessions of interviews with an expert till the system is built to the satisfaction of the domain expert and the end user. The interview as a tool is used mainly in early stages of the acquisition. Validity and reliability of questions during interviews must be considered. The interview has different advantages such as: flexibility, evaluating the validity, eliciting information and many people enjoy being interviewed. It could be structured or unstructured interview. However, there are disadvantages with interviews: communication difficulties between parties, response bias, hostile attitude or standardized questions.

- On-site observation

It is a process of observing, interpreting, and recording an expert's problem solving behavior while it takes place (Awad and Huntington, 1996). This methodology enables the knowledge engineer to request knowledge within the working world of the expert. The challenges of on-site (*in situ*) observation technique is that a knowledge engineer may spend a long time waiting for the problem to happen and, if does happen, it might not be completed at that time.

- Brainstorming

It is unstructured approach of gathering ideas about a particular problem. In this technique, knowledge engineer is inviting two or more experts into a session and presenting them a problem where they will generate ideas. Brainstorming tool could be conducted electronically between multiple experts.

- The Delphi method (Awad and Huntington, 1996)

It is a survey of experts concentrating in a given problem domain. It is designed by a series of questionnaires to capture expert's opinion in solving a particular problem. Each expert's contribution will be shared with other experts to build the next questionnaire. The Delphi method has anonymous response and controlled feedback. Tsai et al. (2010) implemented this method to assess a hospital performance in quality.

Knowledge representation

This step is the most critical phase in building KBS because of representational framework is the basis for learning how information was obtained, interrupted. Actually, there are several ways of representing knowledge in the KBS such as; Semantic network, frames or rules. In this paper, authors have selected to represent the knowledge acquired in rules format. Actually, Rules are made in IF….THEN way where IF is the premise and THEN is the action (Awad and Huntington, 1996). These rules are re-formatted into structured questions for easy interaction with the user as the following example shows:

IF *The organization's leaders know why they are implementing strategies built on Lean Six Sigma philosophies (Yes: GP; No: BP-PC-2)*
Q*. Do the organization's leaders know why they are implementing strategies built on Lean Six Sigma philosophies? (Yes or No)*

Selection of *Yes* means a Good Point (GP) and selection of *No* means Bad Point (BP). This BP is ranged from Problem category (PC) 1 which indicate a very serious problem to Problem category (PC) 5 which indicates a minor problem as it will be discussed in GAP section and as Table 1 shows.

Sunnapwar and Kodali (2006) emphasized that KBS should be implemented carefully because it is expensive and relative investments are not reversible. Failures of KBS range from selecting the wrong problem domain, chasing the wrong talent to develop the KBS, poor verification and validation of the system, a lack of understanding of the expert's knowledge, and other causes. Currently, KBS is widely applied in business organizations to facilitate the decision making process (Udin, 2004, Nawawi, 2009, Milana et al., 2014, Aldairi, 2015, Al Khamisi et al., 2018a and Al Khamisi et al., 2018d) because it is a time-saving and accurate decision-making tool. It makes uncommon expertise more commonly available and provides beginners trusted information.

Gauging Absence of Pre-requisite (GAP)

GAP analysis is a method to measure the gap between current services level compared to the standard level or a desired point (Mohamed, 2013). Authors have measured the gap between what actually occurs in healthcare quality management environment and the desired requirements for effective application (Kochhar et al., 1991).

The information needed to use GAP can be gathered from the users through a designed questionnaire implanted in the KBS. In this paper, 354 IF….THEN rules have been created from the knowledge acquisition process to assess the QMHE implementation in healthcare. As discussed in knowledge representation, the answer of each rule will be either *Yes* which will be

GP or *No* which will BP and will be given PCs. These PCs should be measured based on the range shown in Table 1.

Table 1 Problem categories and its descriptions, adopted from (Nawawi, 2009)

Category	Description
PC1	This indicates a very serious problem, which should and can be resolved in the short term and the result of the problem is quite likely to provide a real short-term benefits.
PC2	This indicates a major problem, which is likely to have pre-requisites to the system and is better dealt with as part of an appropriate and logical improvement and implementation plan.
PC3	This indicates a problem and can be dealt with now. If resolved, it is likely to produce short-term benefits.
PC4	This is not a serious problem. Although it could be dealt with now, it is unlikely to produce short-term benefits. Therefore, it should only be dealt with if it is a prerequisite for other things.
PC5	This is not really a good or bad point itself. The questions associated with this category are primarily asked to identify certain situations in the environment, which upon subsequent probing by succeeding questions may well reveal problems.

The following KB rules set demonstrates a general example of a typical rule-based structure in this system:

IF *the healthcare organization has enough number of healthcare providers* (**Yes**: GP; **No**: BP-**PC-1**)

AND *the healthcare organization has enough financial resource to maintain a required training for its employees according to plan* (**Yes**: GP; **No**: BP-**PC-1**)

AND *the healthcare organization is monitoring the increase of services introduced compared to the current human resources* (**Yes**: GP; **No**: BP-**PC-1**)

AND *the healthcare organization is measuring its human resource satisfaction periodically* (**Yes**: GP; **No**: BP-**PC-1**)

THEN *the healthcare organization status is good in respect to human resource management implementation*

OR *the organization level is poor in respect to healthcare human resource management implementation.*

Validation of KBS via a real implementation at a tertiary hospital in Oman:

In this part, the paper presents the detailed implementation processes of the KB-QMHE model. The aim is to confirm the model reliability of acquiring and translating the know-how of experts in industry and academia into an explicit form within the model (Al Khamisi et al., 2018f and Al Khamisi et al., 2018g). Moreover, the validation of the model also studies the competence of detecting and recommending the parts that need progresses in priority order.

The KB-QMHE system contains four decision-making Levels as Figure 1 shows. Within each module are criteria and sub-criteria that contain KPIs, which are developed in order to assess the organization through KB rules. In Level 1, Organization's statement perspective. This level is linked to the sub-criteria in Level 2; governance perspective. This level has 3 sub-criteria: effective governing body, supporting and sustainable results. Again, the upper level influences the next sub-criteria, which belong to leadership perspective in Level 3. In fact, they will shake the criteria of Organization's resource perspectives. These are human resources, physical capital resources, and consumable resources, which comes next in Level 4. The entire model of KB-QMHE has been tested, verified and validated in to published papers Al Khamisi et al. (2017a) and Al Khamisi et al. (2017b).

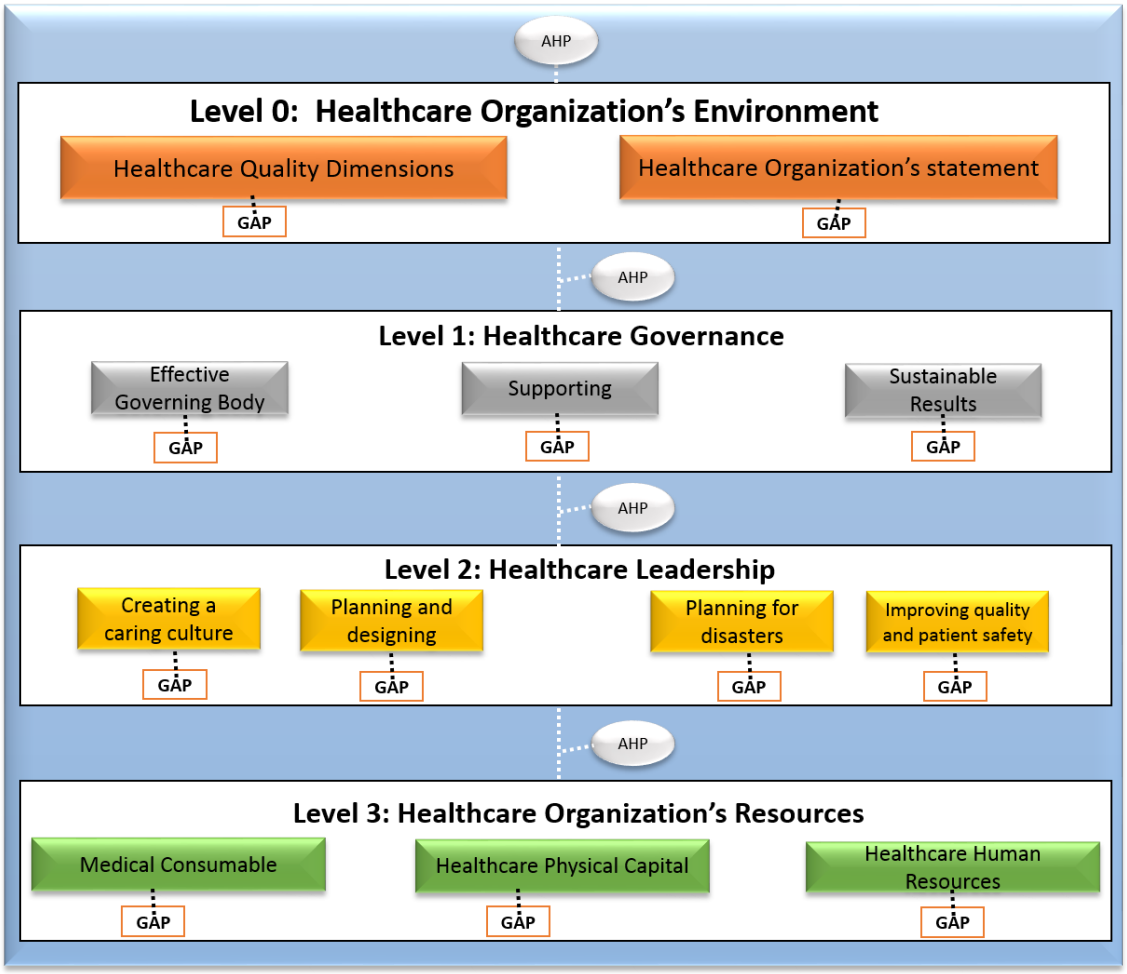

Figure 1 Structure of KB-QMHE Model

Level 0: Healthcare Organization's Environment

This section shows how the *Organization Environment* Level (Figure 2) will help in capturing data about the quality dimensions and organizational statement of the hospital. It shows also how the rules set in the module will launch relationships, transforming that data into information. The *Level 0: Organization Environment* of the KB-QMHE model contains two sub-modules: quality dimensions and organizational statement as shown in Figure 2. In KB-QMHE *Organization Environment*, the KB System calculates the competence of these two sub-modules.

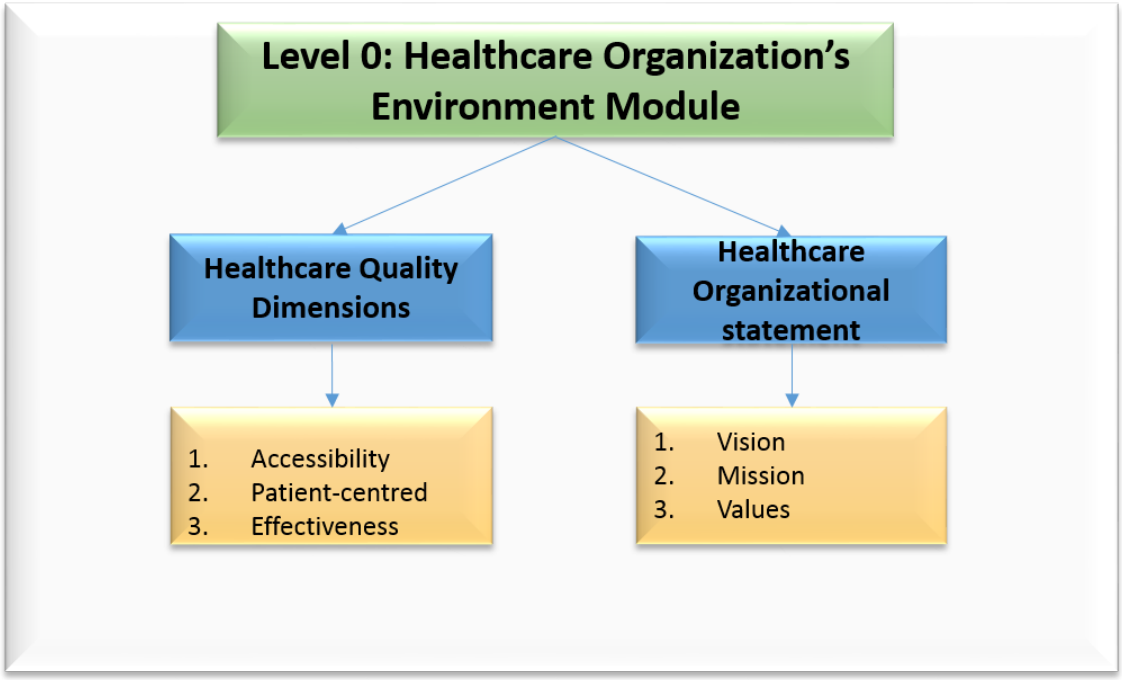

Figure 2 Level 0, Module of organization's environment

Level 0 of the KB-QMHE model needs the user to provide some basic information as shown in Table 2. The *Healthcare Quality Dimensions* and *Healthcare Organizational Statement* sub-modules contain three dimensions under each to be evaluated. The *Healthcare Quality Dimensions* is assessed based on three dimensions; Accessibility, patient-centered and effectiveness. The *Healthcare Organizational Statement* is assessed based on three dimensions as well; vision, mission and values. This module contains a total of 67 KB rules that have been developed for the KB. Based on the answers from the user of the hospital, the GAP analysis results of the *Level 0: Organization Environment* can be summarized as organized in Table 2.

Table 2 GAP analysis results of hospital's Environment

Level 0: Healthcare Organization's Environment									
Sub-module	**Dimensions**	**No. of KB rules**	**Good Points (GP)**	**Bad Points (BP)**	**Bad Points Problem Category (PC)**				
					1	**2**	**3**	**4**	**5**
Healthcare Organizational statement	Vision	**11**	**3**	**8**	**4**	**3**	**1**	**0**	**0**
	Mission	**9**	**5**	**4**	**2**	**0**	**2**	**0**	**0**
	Values	**9**	**7**	**2**	**0**	**1**	**1**	**0**	**0**
	Sub-total	**29**	**15**	**14**	**6**	**4**	**4**	**0**	**0**
Healthcare Quality Dimensions	Accessibility	**6**	**0**	**6**	**0**	**3**	**3**	**0**	**0**
	Patient-centred	**19**	**1**	**18**	**0**	**5**	**4**	**9**	**0**
	Effectiveness	**13**	**0**	**13**	**0**	**5**	**3**	**5**	**0**
	Sub-total	**38**	**1**	**37**	**0**	**13**	**10**	**14**	**0**
Total		**67**	**16**	**51**	**6**	**17**	**14**	**14**	**0**

These results reflect the difference between the present practice and the benchmarked practice. A total of 67 KB rules generated in this module which include the number of good points (GPs), and the number of bad points (BPs) rated as problem categories (PCs) from PC-1 to PC-5. The GAP analysis in this research suggests that only the BPs are categorised as PC in order to find out the necessary pre-requisites for further improvements. Out of 67 KB rules answered, the system has categorised 16 as GPs and the remaining 51 as BPs. The 51 bad points are categorised into different problem categories (6 PC-1, 17 PC-2, 14 PC-3, 14 PC-4, and 0 PC-5) where they represent the actions that need to be enhanced to reach the desired level of quality management.

In the *Healthcare Quality Dimensions* sub-module, a total of 38 KB rules were asked of which 1 was GPs. However, there were 37 KB rules, which were not met (BPs), representing a gap in pre-requisites for accomplishing benchmark. A more analysis of these BPs shows that major key BPs were in the dimensions of *Patient-centered* and *Effectiveness*. A key aspect from this analysis is that in the *Patient-centered* dimension (18 BPs, of which 0 PC-1 and 5 PC-2)

which, for quality management, is a really significant factor that will reflect negatively on maintaining a patient satisfaction. It is remarkable that this hospital is not using patient-reported measures to assess the level of emotional support that reduce psychological distress and their patients are not feeling able to express views.

The second major key BPs are noticed in *Effectiveness* dimension (13 BPs, of which 0 PC-1 and 5 PC-2). It is remarkable from user's answers that this hospital is not maintaining a good system of learning from adverse and is not maintaining a good system of patient education. Consequently, this hospital has to focus on correcting the problems from category 13 PC-2 before fixing the other 24 PCs (10 PC-3, and 14 PC-4).

Level 1: Healthcare Governance

This section shows how the *Healthcare Governance* Level (Figure 3) will help in capturing data about the effectiveness of governing body, its support and the sustainable measures of the hospital. It shows also how the rules set in the module will launch relationships, transforming that data into information (Al Khamisi et al., 2018c). The *Level 1: Healthcare Governance* of the KB-QMHE model contains three sub-modules: Effective Governing Body, Supporting and Sustainable Results as shown in Figure 3. In KB-QMHE *Healthcare Governance*, the KB System calculates the competence of these three sub-modules.

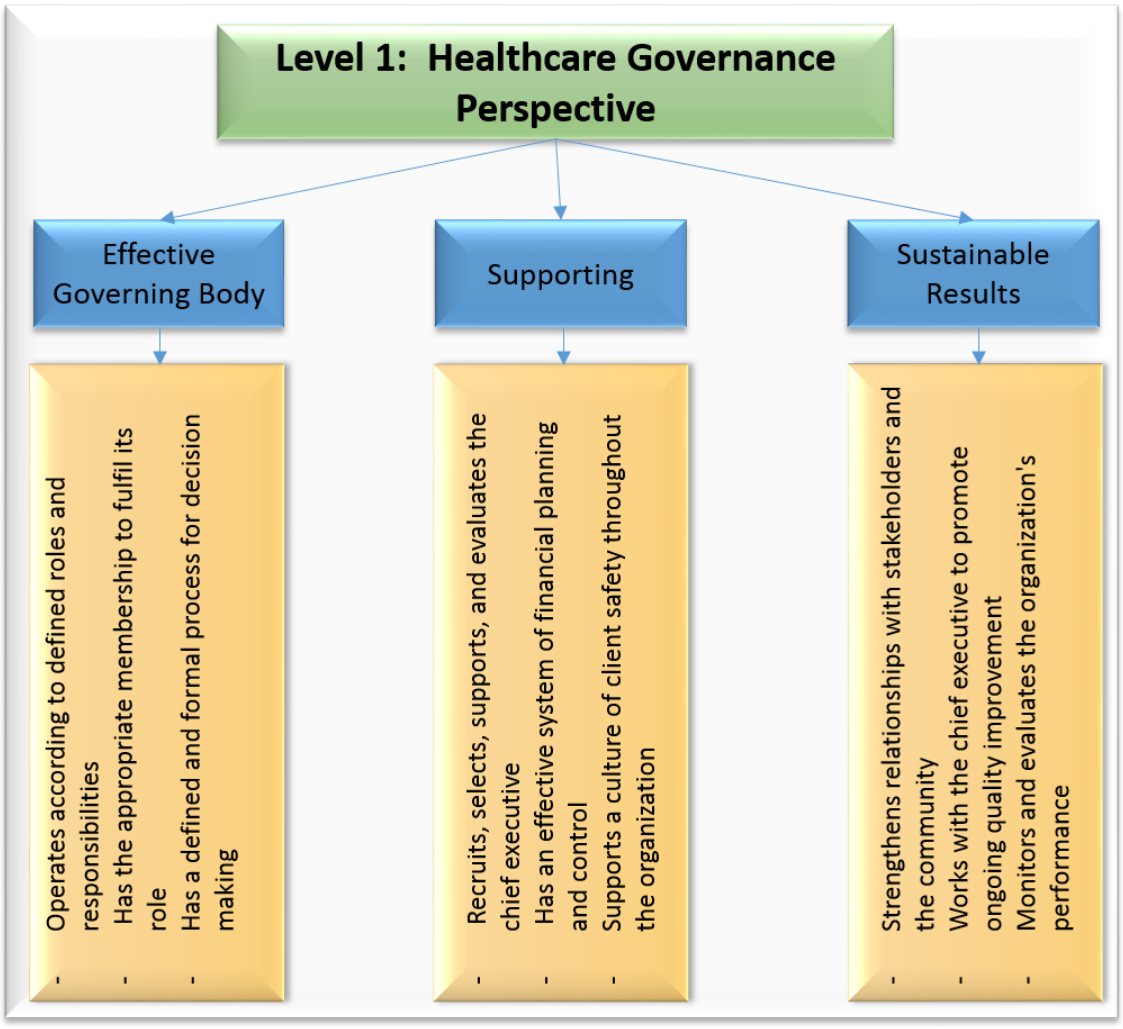

Figure 3 Level 1, Module of Healthcare Governance

Level 1 of the KB-QMHE model needs the user to provide some basic information as shown in Table 3. The *Effective Governing Body, Supporting and Sustainable Results* sub-modules contain three dimensions under each to be evaluated. The *Effective Governing Body* is assessed based on three dimensions; Roles and responsibilities, Membership and Decision making. The *Supporting* is assessed based on three dimensions as well; evaluating the CEO, Financial planning and supporting patient safety culture. *Sustainable Results* sub-module is assessed based on; Relations with community, promoting quality improvement and monitoring performance. This module contains a total of 98 KB rules that have been developed for the KB.

Based on the answers from the user of this hospital, the GAP analysis results of the *Level 1: Healthcare Governance* can be summarized as organized in Table 3.

Table 3 GAP analysis results of hospital's Governance

Level 1: Healthcare Governance									
Sub-module	**Dimensions**	**No. of KB rules**	**Good Points (GP)**	**Bad Points (BP)**	**Bad Points Problem Category (PC)**				
					1	**2**	**3**	**4**	**5**
Effective Governing Body	Roles and responsibilities	**13**	**8**	**5**	**5**	**0**	**0**	**0**	**0**
	Membership	**22**	**20**	**2**	**0**	**2**	**0**	**0**	**0**
	Decision making	**5**	**5**	**0**	**0**	**0**	**0**	**0**	**0**
	Sub-total	**40**	**33**	**7**	**5**	**2**	**0**	**0**	**0**
Supporting	Evaluating the CEO	**10**	**10**	**0**	**0**	**0**	**0**	**0**	**0**
	Financial planning	**10**	**10**	**0**	**0**	**0**	**0**	**0**	**0**
	Supporting patient safety culture	**5**	**1**	**4**	**4**	**0**	**0**	**0**	**0**
	Sub-total	**25**	**21**	**4**	**4**	**0**	**0**	**0**	**0**
Sustainable Results	Relations with community	**10**	**9**	**1**	**0**	**0**	**1**	**0**	**0**
	Promoting quality improvement	**6**	**1**	**5**	**0**	**5**	**0**	**0**	**0**
	Monitoring performance	**18**	**5**	**13**	**7**	**4**	**2**	**0**	**0**
	Sub-total	**34**	**15**	**19**	**7**	**9**	**3**	**0**	**0**
Total		**98**	**69**	**29**	**14**	**11**	**4**	**0**	**0**

These results reflect the difference between the present practice and the benchmarked practice. A total of 98 KB rules generated in this module which include the number of good points (GPs), and the number of bad points (BPs) rated as problem categories (PCs) from PC-1 to PC-5. The GAP analysis in this research suggests that only the BPs are categorised as PC in order to find out the necessary pre-requisites for further improvements. Out of 98 KB rules answered, the system has categorised 69 as GPs and the remaining 30 as BPs. The 29 bad points

are categorised into different problem categories (14 PC-1, 11 PC-2, 4 PC-3, 0 PC-4, and 0 PC-5) where they represent the actions that need to be enhanced to reach the desired level of quality management.

In the *Effective Governing Body* sub-module, a total of 40 KB rules were asked of which 33 was GPs. However, there were 7 KB rules, which were not met (BPs), representing a gap in pre-requisites for accomplishing benchmark. A more analysis of these BPs shows that major key BPs were in the dimensions of *Roles and responsibilities* and *Membership*. A key aspect from this analysis is that in the *Roles and responsibilities* dimension 5 BPs in PC-1 which, for quality management, is a really significant factor that will reflect negatively on maintaining an effective healthcare governance. It is remarkable that the hospital has no processes in place to oversee the functions of quality and the governing body is not reviewing regularly its roles, responsibilities and accountabilities. Consequently, the hospital has to focus on correcting the problems from category 5 PC-1 before fixing the other 2 PC-2.

In the *Supporting* sub-module, a total of 25 KB rules were asked of which 21 was GPs. However, there were 4 KB rules, which were not met (BPs), representing a gap in pre-requisites for accomplishing benchmark. A more analysis of these BPs shows that all key BPs were in the dimensions of *supporting patient safety culture*. A key aspect from this analysis is that in the in this dimension 4 BPs in PC-1 which, for quality management, is a really significant factor that will reflect negatively on supporting patient safety culture. It is remarkable that hospital's governing body is not regularly using the information of adverse events and near misses to understand client safety issues in the organization. Consequently, the hospital has to focus on correcting the problems from category 4 PC-1.

In the *Sustainable Results* sub-module, a total of 34 KB rules were asked of which 15 was GPs. However, there were 19 KB rules, which were not met (BPs), representing a gap in pre-requisites for accomplishing benchmark. A more analysis of these BPs shows that major key BPs were in the dimension of *monitoring performance*. A key aspect from this analysis is that in this dimension 13 BPs (7 PC-1, 4 PC-2 and 2 PC-3) which, for quality management, is a really significant factor that will reflect negatively on monitoring performance. It is remarkable that hospital's governing body is not monitoring data to assess the organization's performance and not identifying opportunities for improvement in how it functions. Consequently, the hospital has to focus on correcting the problems from category 7 PC-1 before fixing the other 4 PC-2 and 2 PC-3.

Level 2: Healthcare Leadership

This section shows how the *Healthcare Leadership Leve* 2 (Figure 4) will help in capturing data about healthcare leadership is planning for disaster, improving quality and creating caring culture at the hospital. It shows also how the rules set in the module will launch relationships, transforming that data into information (Al Khamisi et al., 2018b). The *Level 2: Healthcare Leadership* of the KB-QMHE model contains four sub-modules: *Creating a caring culture, Planning and designing, planning for disasters and improving quality* as shown in Figure 4. In KB-QMHE *Healthcare Leadership*, the KB System calculates the competence of these four sub-modules.

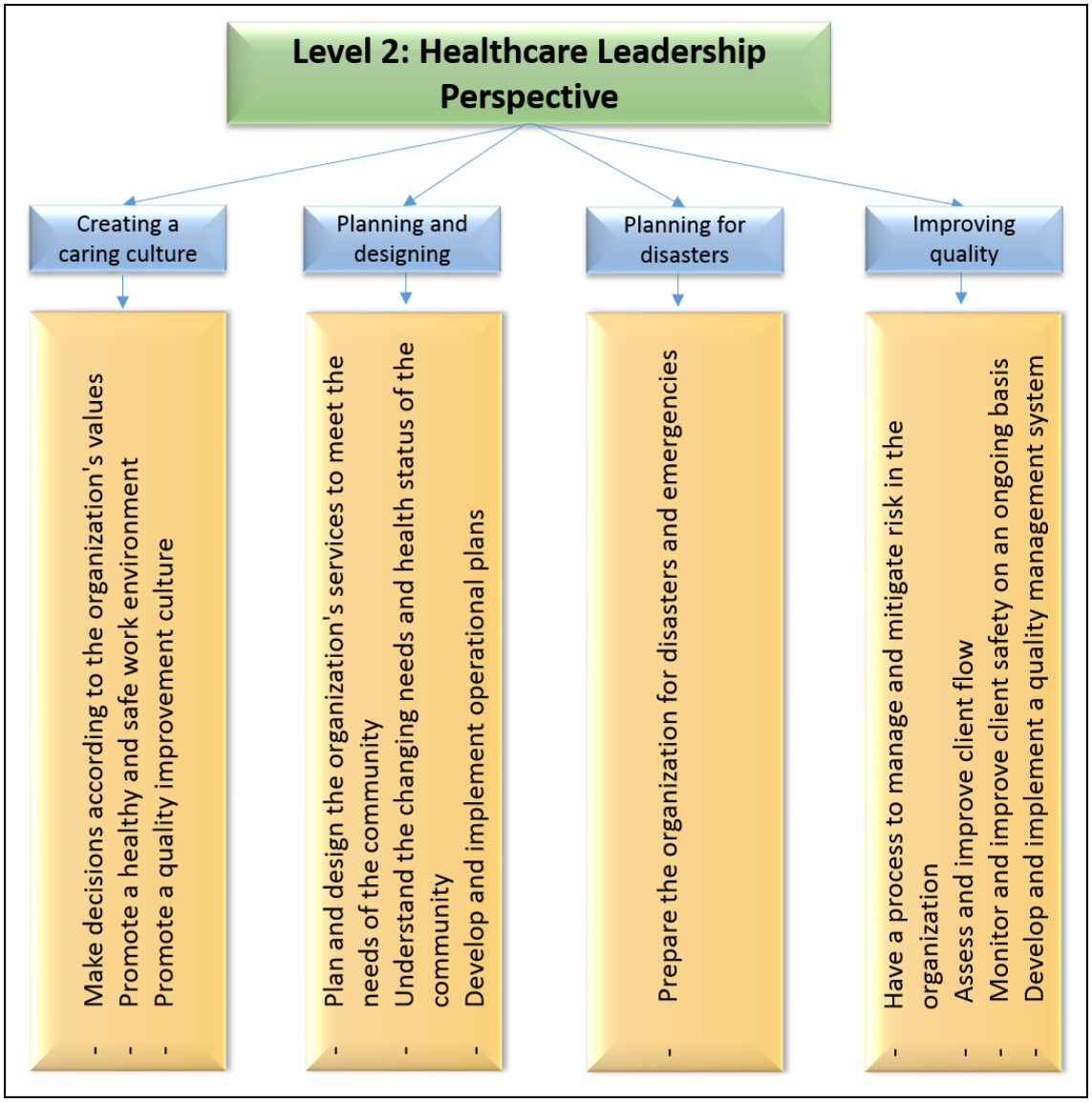

Figure 4 Level 2, Module of Healthcare Leadership

Level 2 of the KB-QMHE model needs the user to provide some basic information as shown in Table 4. The *Creating a caring culture, Planning and designing, and improving quality* sub-modules contain three dimensions under each to be evaluated. *Planning for disasters* sub-modules contain one dimension to be evaluated. The *Creating a caring culture* is assessed based on three dimensions; Decisions according values, promoting a safe work environment and promoting a quality culture. The *Planning and designing* is assessed based on three dimensions as well; planning for community needs, Understanding community health status change and

Developing an operational plans. The *Improving quality* sub-module is assessed based on; Managing Risk, Improving client flow and improving client safety. The *Planning for disasters* sub-module is assessed based on Preparing for disasters and emergencies. This module contains a total of 126 KB rules that have been developed for the KB. Based on the answers from the user of the hospital, the GAP analysis results of the *Level 1: Healthcare Leadership* can be summarized as organized in Table 4.

Table 4 GAP analysis results of hospital's Leadership

Level 2: Healthcare Leadership									
Sub-module	**Dimensions**	**No. of KB rules**	**Good Points (GP)**	**Bad Points (BP)**	**Bad Points Problem Category (PC)**				
					1	**2**	**3**	**4**	**5**
Creating a caring culture	Decisions according values	**24**	**24**	**0**	**0**	**0**	**0**	**0**	**0**
	Promoting a safe work environment	**16**	**16**	**0**	**0**	**0**	**0**	**0**	**0**
	Promoting a quality culture	**17**	**2**	**15**	**0**	**1**	**4**	**10**	**0**
	Sub-total	**57**	**42**	**15**	**0**	**1**	**4**	**10**	**0**
Planning and designing	Planning for community needs	**13**	**11**	**2**	**0**	**0**	**2**	**0**	**0**
	Understanding community health status change	**9**	**5**	**4**	**0**	**1**	**2**	**1**	**0**
	Developing an operational plans	**7**	**6**	**1**	**0**	**0**	**0**	**1**	**0**
	Sub-total	**29**	**22**	**7**	**0**	**1**	**4**	**2**	**0**
Planning for disasters	Preparing for disasters and emergencies	**11**	**11**	**0**	**0**	**0**	**0**	**0**	**0**
	Sub-total	**11**	**11**	**0**	**0**	**0**	**0**	**0**	**0**
Improving quality	Managing Risk	**8**	**8**	**0**	**0**	**0**	**0**	**0**	**0**
	Improving client flow	**5**	**4**	**1**	**0**	**1**	**0**	**0**	**0**
	Improving client safety	**10**	**10**	**0**	**0**	**0**	**0**	**0**	**0**
	Implementing a quality management system	**6**	**1**	**5**	**0**	**1**	**2**	**2**	**0**
	Sub-total	**29**	**23**	**6**	**0**	**2**	**2**	**2**	**0**
Total		**126**	**98**	**28**	**0**	**4**	**10**	**14**	**0**

These results reflect the difference between the present practice and the benchmarked practice. A total of 126 KB rules generated in this module which include the number of good

points (GPs), and the number of bad points (BPs) rated as problem categories (PCs) from PC-1 to PC-5. The GAP analysis in this research suggests that only the BPs are categorised as PC in order to find out the necessary pre-requisites for further improvements. Out of 126 KB rules answered, the system has categorised 98 as GPs and the remaining 28 as BPs. The 28 bad points are categorised into different problem categories (0 PC-1, 4 PC-2, 10 PC-3, 14 PC-4, and 0 PC-5) where they represent the actions that need to be enhanced to reach the desired level of quality management.

In the *Creating a caring culture* sub-module, a total of 57 KB rules were asked of which 42 was GPs. However, there were 15 KB rules, which were not met (BPs), representing a gap in pre-requisites for accomplishing benchmark. A more analysis of these BPs shows that all key BPs were in the dimension of *Promoting a quality culture*. A key aspect from this analysis is that in the *Promoting a quality culture* dimension 15 BPs (1 PC-2, 4 PC-3 and 10 PC-4) which, for quality management, is a significant factor that will reflect negatively on Promoting a quality culture in the healthcare environment. It is remarkable that hospital's leaders are not developing a confidential process for staff to bring forward concerns and complaints. Consequently, the hospital has to focus on correcting the problems from category 1 PC-2 before fixing the other 4 PC-3 and 10 PC-4.

In the *Planning and designing* sub-module, a total of 29 KB rules were asked of which 22 was GPs. However, there were 7 KB rules, which were not met (BPs), representing a gap in pre-requisites for accomplishing benchmark. A more analysis of these BPs shows that major key BPs were in the dimensions of *Understanding community health status change*. A key aspect from this analysis is that in the in this dimension 4 BPs (1 PC-2, 2 PC-3 and 1 PC-4) which, for quality management, is a significant factor that will reflect negatively on *community health status*. It is

remarkable that hospital's information about the community is not maintained in a format that is easy to understand and the leaders does not share the information about the community with the clients and families. Consequently, the hospital has to focus on correcting the problems from category 1 PC-2 before fixing the other 2 PC-3 and 1 PC-4.

In the *Planning for disasters* sub-module, a total of 11 KB rules were asked of and all of them are GPs.

In the *Improving quality* sub-module, a total of 29 KB rules were asked of which 23 was GPs. However, there were 6 KB rules, which were not met (BPs), representing a gap in pre-requisites for accomplishing benchmark. A more analysis of these BPs shows that major key BPs were in the dimension of *implementing a quality management system*. A key aspect from this analysis is that in this dimension 5 BPs (1 PC-2, 2 PC-3 and 2 PC-4) which, for quality management, is a really significant factor that will reflect negatively on implementing a quality management. It is remarkable that hospital's leaders does not monitor service, unit, or program areas to monitor their own process and outcome measures that align with the broader organizational strategic goals and objectives. Consequently, the hospital has to focus on correcting the problems from category 1 PC-2 before fixing the other 2 PC-3 and 1 PC-4.

Level 3: Healthcare Organization's Resources

This section shows how the *Healthcare Organization's Resources* Level (Figure 5) will help in capturing data about the human, capital and technical resources of the hospital. It shows also how the rules set in the module will launch relationships, transforming that data into information (Al Khamisi et al., 2018e). The *Level 3: Healthcare Organization's Resources* of the KB-QMHE model contains three sub-modules: *human resources, physical capital and technical resources* as

shown in Figure 5. In KB-QMHE *Healthcare Organization's Resources*, the KB System calculates the competence of these three sub-modules.

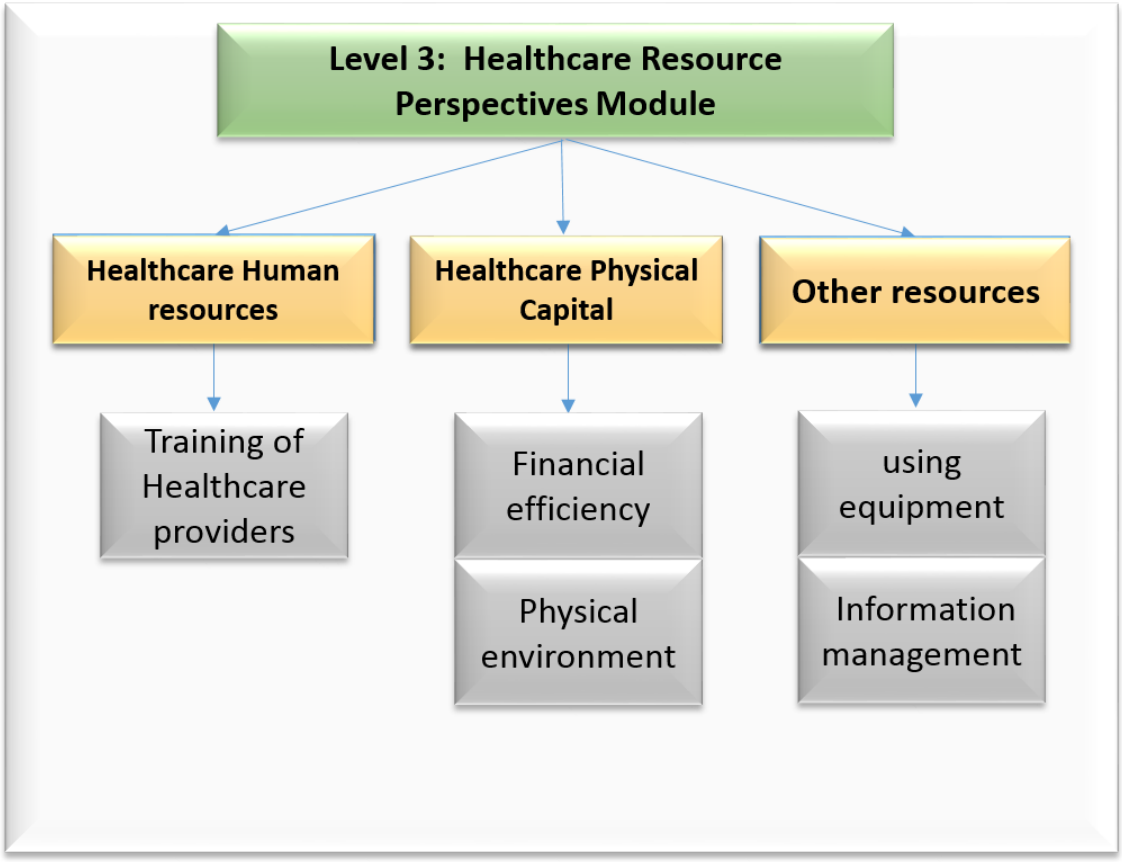

Figure 5 Level 3, Module of Healthcare Resources

Level 3 of the KB-QMHE model needs the user to provide some basic information as shown in Table 5. The *Healthcare physical capital* and *Healthcare technical resources* sub-modules contain two dimensions under each to be evaluated. The *human resources* sub-modules contain one dimension to be evaluated The *Healthcare human resources* is assessed based on *training of healthcare providers*. The *Healthcare physical capital* is assessed based on two dimensions; *financial efficiency* and *physical environment*. The *Healthcare technical resources* is assessed based on two dimensions; *using of equipment* and *information management*. This module contains a total of 62 KB rules that have been developed for the KB. Based on the

answers from the user of the hospital, the GAP analysis results of the *Level 3: Healthcare Organization's Resources* can be summarized as organized in Table 5.

Table 5 GAP analysis results of hospital's resources

Level 3: Healthcare Organization's Resources									
Sub-module	**Dimensions**	**No. of KB rules**	**Good Points (GP)**	**Bad Points (BP)**	**Bad Points Problem Category (PC)**				
					1	**2**	**3**	**4**	**5**
Human resources	Training of Healthcare providers	**21**	**7**	**14**	**0**	**1**	**5**	**8**	**0**
	Sub-total	**21**	**7**	**14**	**0**	**1**	**5**	**8**	**0**
Physical Capital	Financial efficiency	**14**	**12**	**2**	**0**	**1**	**0**	**1**	**0**
	Physical environment	**11**	**11**	**0**	**0**	**0**	**0**	**0**	**0**
	Sub-total	**25**	**23**	**2**	**0**	**1**	**0**	**1**	**0**
Technical resources	Using equipment	**10**	**7**	**3**	**0**	**0**	**1**	**2**	**0**
	Information management	**6**	**5**	**1**	**0**	**0**	**0**	**1**	**0**
	Sub-total	**16**	**12**	**4**	**0**	**0**	**1**	**3**	**0**
Total		**62**	**42**	**20**	**0**	**2**	**6**	**12**	**0**

Conclusions

The aim of this paper was to present a Knowledge-Based (KB) system integrated with Gauging Absence Pre-requisite (GAP) to improve QMHE. To achieve this aim, a literature review was conducted in the field of KBS and GAP analysis. A total of 354 KB rules generated via a knowledge acquisition process conducted with experts in the field of healthcare quality management in Oman. These rules have been used to build the model of KB-QMHE to assess the quality management system status in healthcare organization. It was built based on four levels; *Healthcare Environment, Governance, Leadership and Resources.* This model was validated in October 2017 at a tertiary hospital in Oman.

As Table 6 shows, Out of 354 KB rules answered, the system has categorised 225 as GPs and the remaining 128 as BPs. The 128 bad points are categorised into different problem categories (20 PC-1, 34 PC-2, 34 PC-3, 40 PC-4, and 0 PC-5) where they represent the actions that need to be enhanced to reach the desired level of quality management.

Table 6 Summary of GAP Analysis Results for the hospital

Level	Sub-module	No. of KB rules	Good Points (GP)	Bad Points (BP)	Bad Points Problem Category (PC)				
					1	2	3	4	5
Level 0: Organization's Environment	Organization's Statement	**29**	**15**	**14**	**6**	**4**	**4**	**0**	**0**
	Quality Dimensions	**38**	**1**	**37**	**0**	**13**	**10**	**14**	**0**
	Sub-total	**67**	**16**	**51**	**6**	**17**	**14**	**14**	**0**
Level 1: Healthcare	Effective Governing Body	**40**	**33**	**7**	**5**	**2**	**0**	**0**	**0**
	Supporting	**25**	**21**	**4**	**4**	**0**	**0**	**0**	**0**

Governance	Sustainable Results	**34**	**15**	**19**	**7**	**9**	**3**	**0**	**0**
	Sub-total	**98**	**69**	**29**	**14**	**11**	**4**	**0**	**0**
Level 2: Healthcare Leadership	Creating a caring culture	**57**	**42**	**15**	**0**	**1**	**4**	**10**	**0**
	Planning and designing	**29**	**22**	**7**	**0**	**1**	**4**	**2**	**0**
	Planning for disasters	**11**	**11**	**0**	**0**	**0**	**0**	**0**	**0**
	Improving quality	**29**	**23**	**6**	**0**	**2**	**2**	**2**	**0**
	Sub-total	**126**	**98**	**28**	**0**	**4**	**10**	**14**	**0**
Level 3: Healthcare Resources	Human resources	**21**	**7**	**14**	**0**	**1**	**5**	**8**	**0**
	Physical Capital	**25**	**23**	**2**	**0**	**1**	**0**	**1**	**0**
	Technical resources	**16**	**12**	**4**	**0**	**0**	**1**	**3**	**0**
	Sub-total	**62**	**42**	**20**	**0**	**2**	**6**	**12**	**0**
Total		**354**	**225**	**128**	**20**	**34**	**34**	**40**	**0**

A key aspect from this analysis shows that the highest number of BPs is in *Level 0*. It has 51 BPs of which 6 PC-1, 17 PC-2, 14 PC-3 and 14 PC-4. It is a really a significant factor that hospital's statement and quality dimensions should be revised and improved. However, Level 1 has 14 PC-1 critical issues that need urgent solutions. These bad points must be solved before fixing other BPs in different PCs.

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