# CHALLENGES AFFECTING THE IMPLEMENTATION OF BUILDING MANAGEMENT SYSTEMS IN OFFICE BUILDINGS

BY

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To my *Parents*, *Wife* and *Son*

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All Praise is due to Alláh, We praise Him and we seek help from Him. We ask forgiveness from Him. We repent to Him; and we seek refuge in Him from our own evils and our own bad deeds. Peace and blessings of Alláh be upon His servant and messenger, Prophet Muhammad (peace and blessings of Alláh be upon him), his family, and companions. Many thanks to Allah, the most Merciful, the most Gracious, for guiding me and blessing me to successfully make this work.

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# LIST OF ABBREVIATIONS

| | | |
|---|---|---|
| **A/E** | : | Architectural Engineering |
| **AHP** | : | Analytic Hierarchy Process |
| **ASHRAE** | : | American Society of Heating, Refrigerating, and Air-Conditioning Engineers |
| **BAS** | : | Building Automation System |
| **BMS** | : | Building Management System |
| **CA** | : | Commissioning Authority |
| **CBA** | : | Cost Benefit Analysis |
| **CCTV** | : | Closed Circuit Television |
| **DDC** | : | Direct Digital Control |
| **DGP** | : | Data-Gathering Panel |
| **G-AHP** | : | Group Analytic Hierarchy Process |
| **HVAC** | : | Heating, Ventilation and Air-Conditioning |
| **KSA** | : | Kingdom of Saudi Arabia |
| **K-T** | : | Kepner-Tregoe Decision Analysis |
| **LAN** | : | Local Area Network |
| **MAUT** | : | Multi-Attribute Utility Theory |

| | | |
|---|---|---|
| **MCDM** | : | Multi-Criteria Decision Making |
| **MEP** | : | Mechanical, Electrical, Plumbing Design engineer |
| **O&M** | **:** | Operation and Maintenance |
| **PC** | : | Personal Computer |
| **WAN** | : | Wide Area Network |
| **CR** | : | Consistency Ratio |

# ABSTRACT

Full Name : Ameen Mabrook Bin Mohanna

Thesis Title : Challenges Affecting the Implementation of Building Management Systems in Office Buildings

Major Field : Architectural Engineering

Date of Degree : [May, 2013]

The objectives of this thesis were, 1)- to investigate and evaluate the challenges that influence the successful implementation of building management system (BMS) during the design, installation and operation and maintenance stages of projects, 2)- to utilize the methodology of the Group Analytic Hierarchy Process (G-AHP) model for developing a conceptual model for prioritizing the influential challenges that impact the successful implementation of BMS, 3)- to carry out case studies to validate the problems that face achieving full potential of BMS, and 4)- to develop a plan of action to facilitate the identified challenges. Thirty-two challenges which influence the process of implementing the BMS were identified. These challenges were evaluated through distributing a five likert questionnaire survey to A/E, construction firms and facility managers form the Eastern Province of Saudi Arabia. (G-AHP) model was utilized to prioritize the identified 32 challenges through reflecting the opinion of six experts in BMS. Eight case studies in the Eastern Province were conducted to validate the developed model. Finally, literature review and interviews were carried out to develop a proposed plan of actions to facilitate the identified challenges. This study has the potential to increase awareness among buildings owners and people in the building industry in Saudi Arabia about the challenges that influence the successful implementation of the BMS during the life cycle of office building projects.

# ملخص الرسالة

**الاسم الكامل**: أمين مبروك بن مهنا

**عنوان الرسالة:** المعوقات المؤثرة على تطبيق منظومة إدارة المبنى (BMS) في المباني الإدارية

**التخصص:** هندسة معمـــــــــــــــارية

**تاريخ الدرجة العلمية**: رجب ١٤٣٤هـــ

إن أهداف هذه الأطروحة تضمن١- تحديد وتقييم المعوقات التي تؤثر على التطبيق الامثل لمنظومة إدارة المباني (BMS) خلال مراحل التصميم ،التركيب والتشغيل وصيانة لمشاريع المباني،٢- الاستفادة من منهجية التسلسل الهرمي التحليلي المجموعي (G-AHP) لتطوير نموذج نظري لتحديد وزن وأولويات المعوقات التي تؤثر على التطبيق الامثل لـ (BMS)،٣- تنفيذ دراسه الحالة للتحقق من صحة النموذج المطور ،٤- ووضع خطة عمل للحد من المعوقات التي تم تحديدها. في هذه الأطروحة تم تحديد اثنين وثلاثين معوق يؤثر على عملية التطبيق الأمثل لـ (BMS). تم تقييم هذه المعوقات من خلال توزيع استبيان على شركات البناء والمكاتب الهندسة ومدراء المرافق في المنطقة الشرقية من المملكة العربية السعودية. بعد ذلك تم استخدم منهجية التسلسل الهرمي التحليلي المجموعي لإعطاء وزن وأولويات للمعوقات الاثنين والثلاثين المحددة من خلال أراء ستة من خبراء منظومة إدارة المبنى في المنطقة الشرقية من المملكة العربية السعودية.كما أجريت دراسة حالة لثمانية مباني إدارية في المنطقة الشرقية للتحقق من صحة النموذج المطور. وأخيرا، ومن خلال الإطلاع على الدراسات المنشورة والمقابلات تم وضع خطة عمل مقترحة للحد من المعوقات التي تم تحديدها. إن هذه الدراسة لديها القدرة على زيادة الوعي بين ملاك المباني والمساهمين في صناعة البناء في المملكة العربية السعودية عن طريق تحديد وتقيم وترتيب المعوقات المتؤثر على التنفيذ الناجح لـ (BMS) خلال دورة حياة مشاريع المباني الإدارية.

# CHAPTER 1

# INTRODUCTION

## 1.1 Background

Over the last decades, the construction industry has witnessed substantial progress in the adoption of new technologies in the development of buildings. The adoption of these technologies led to create a new concept in construction industry called ' Intelligent buildings'. Intelligent buildings combine innovation and systems with skillful management to maximize the return on investment (Clements-Croome, 2004). Intelligent building systems are mainly managed and controlled though one single system which is called Building Management System (BMS). Building management systems (also known as Buildings Automation Systems, (BAS) are one of the vital intelligent building systems (Wang, 2010).

a building management system comprises of various subsystems which are connected in several ways to form an integrated system. With the development of the modern computer in the 1940s, BMS witnessed its beginning in the late 1960s. Nowadays, advances in technology have reduced the cost of building management systems compared to the price of conventional (pneumatic and electric) control systems. Due to their ability in increasing efficiency in buildings management, building management systems would seem to be an optimal choice for effective management for all types of buildings (Wang, 2010).

The adoption of intelligent technologies in Saudi Arabia's buildings industry has gradually increased. The rapid construction boom and the competitive environment in Saudi Arabia are highly encouraging the buildings industry to integrate the intelligent building technology in commercial and multifunctional buildings. At present, the major implementation of this technology is mostly reflected in large scale and high budgeted projects. However, intelligent buildings technology vendors and companies that service professional consultancy in this field are beginning to establish a stable market for this technology in KSA (Reffat, 2010b).

## 1.2 Statement of the Problem

State-of-art-buildings are not only unique in their architectural design only, but also by their functionality importance. The modern BMSs have offered clients, occupants and facilities managers a multitude of functional benefits. Some of these benefits include increasing the occupant's level of comfort and ensuring their safety, resolving operational problems quickly, improving the performance of the building and reducing energy and water consumption.

The development in building management systems has witnessed rapid growth over the last 30 years. However, during the life cycle of the buildings projects there have been a set of issues that must be considered for achieving the optimal level of the BMS. Such issues include, involvement of the client and end users in briefing process to determine the BMS performance requirement, proper selection of the supplier and the sub-contractor to install the BMS and ensure appropriate initial and continued training for the BMS personnel (Ehrlich and Goldschmidt, 2008; Lowry, 2002). Achieving optimal level of such issues will often lead to decreased BMS investment costs, more significantly appropriate design, installation and operation and maintenance.

Nowadays, the building industry in Saudi Arabia is witnessing a growth in the application of BMS in various types of buildings projects especially in office buildings projects (Reffat, 2010b). However, the level of satisfaction with the performance of these systems is influenced by a number of challenges that could take place during the life cycle of building projects. Therefore, there is a need to identify and investigate these important challenges that influence the successful implementation of the BMS.

## 1.3 Research Objectives

The objectives of this research are as follows:

- To investigate and evaluate the challenges that influence the successful implementation of BMS during the life cycle of office building projects.
- To develop Group Analytic Hierarchy Process (G-AHP) model for prioritizing the influential challenges that impact the successful implementation of BMS during the life cycle of office building projects.
- To carry out a series of case studies to validate the developed model.
- To develop a plan of action to facilitate the identified challenges.

## 1.4 Scope and Limitations

Based on the objectives of this study, the scope and limitations are as follow:

- The questionnaire survey distribution and interviews zones were limited to the major cities in the Eastern Province of Saudi Arabia (namely Dammam, Khobar and Dhahran).
- The questionnaire survey and interview participants were limited to building designers, facility mangers or BMS operators (owner representatives) and contractors.
- Six BMS (two designers, two contractors, and two facility managers) experts in the Eastern Province were asked to weight the challenges by using Saaty's 1-9 scale of pairwise comparison.
- Eight office buildings equipped with BMS (that integrate at least four subsystems, which including HVAC systems, plumbing systems, lighting systems and security systems) in the Eastern Province of Saudi Arabia were studied to validate the developed model.
- In this study, the influential challenges that impact the successful implementation of BMS were covered only during the  three stages of life cycle of the office buildings project (namely design, installation, and operation and maintenance stages).

## 1.5 Significance of the Study

Unsuccessful implementation of building management systems can lead to a series of problems that have to be dealt with by the buildings' owners and managers. Therefore, the significance of the study stems from the following:

- The study has the potential to increase the awareness within the building industry parties about the challenges that influence the successful implementation of the BMS during the design, installation, and operation and maintenance stages.
- The study provides building designers, contractors, owners and managers with the most influential challenges influencing the successful implementation of BMS.
- The findings of the study are directly relevant and applicable to intelligent buildings and green buildings in KSA.

## 1.6 Research Methodology

The research methodology includes three main stages which are subdivided into phases and parts. The stages, phases and parts of the methodology pave the way to achieve the objectives of the study and are described as follows:

### 1.6.1 Objective 1-Investigation and Evaluation of the Challenges Influencing the Successful Implementation of BMS during Design, Installation, Operation and Maintenance Stages

The first objective of the research was achieved through the following phases as illustrated in Figure 1:

#### 1.6.1.1 Literature Review

The purpose of this phase is to review the state-of-the-art literature in the field of BMS to:

- Investigate the challenges that influence the successful implementation of BMS during design, Installation, operation and maintenance phases.

#### 1.6.1.2 Interviews

In this phase, interviews were conducted with four selected samples of building designers, contractors, and facility mangers in the Eastern Province of Saudi Arabia to investigate the challenges that influence the successful implementation of BMS during design, Installation, operation and maintenance. a list of the interview questions is shown in **Appendix I**.

#### 1.6.1.3 Evaluation of Identified Challenges

In this phase, evaluation of the identified challenges that influence the successful implementation of BMS during design, installation, operation and maintenance phases was carried out. Questionnaire survey technique was conducted to evaluate the identified challenges and it consists of the following parts:

- **Part one:** Development of the questionnaires survey.
- **Part two:** Pilot-testing of the questionnaires survey.
- **Part three:** Distribution of the questionnaires survey.
- **Part four:** Analysis of the questionnaire's survey results.

##### 1.6.1.3.1 Part one: Development of the Questionnaires Survey

Three different questionnaires surveys were developed, each one was filled out by either A/E firms (designers) or construction firms (contractors) or facility managers. The developed questionnaires survey of A/E and construction firms are composed of three main sections; the first section collects general information about the participants. In the second section respondents were asked to determine the office buildings equipped with BMS that they designed or constructed them .The third section of the questionnaire survey allows the participants to assign the degree of effect of each of the identified challenges by using a five point likert scale and also allows them to add any other challenges that are not included in the questionnaire survey.

The questionnaire survey of facility managers is composed of two main sections. The first section collects general information about the participants. The second section of the questionnaires survey allows the participants to assign the degree of effect of each of the identified challenges by using a five point likert scale and also allows them to add any other challenges that are not included in the questionnaires survey. Samples of questionnaire survey are shown in **Appendix II**.

#### 1.6.1.3.2 Part two: Pilot-Testing of the Questionnaires Survey.

The developed questionnaire survey was pilot-tested with six samples of A/E firms (designers), construction firms (contractors) and facility managers in the Eastern Province of Saudi Arabia and the benefits of the Pilot-testing were:

- Checking the adequacy of the survey's questions.
- Determine locations of ambiguity in the survey.
- Estimating the time needed to complete the survey.
- Checking the level of editing the survey theme pages (space for answering, font's size ...etc.).

#### 1.6.1.3.3 Part Three: Distribution of the Questionnaires Survey.

Three cities of the Eastern province of Saudi Arabia were chosen to distribute the questionnaire survey, namely: Dammam, Khobar and Dhahran. The calculation of the questionnaire survey respondents' samples size were as follows:

### I. A/E Firms Sample Size:

The first sample of respondents that assessed the identified BMS design challenges consisted of A/E firms from Dammam, Khobar and Dhahran. A list of A/E firms was obtained from the Chamber of Commerce in the Eastern province of Saudi Arabia. After determining the population size of A/E firms, the following equation (Kish, 1995) was used to calculate the sample size of A/E firms.

$$no = (p*q)/v2\text{..................} \ (1.1)$$
$$n = no/ [1+ (no/N)]\text{...........} \ (1.2)$$

Where:

$\boldsymbol{n_o}$: First estimate of sample size

p: The proportion of the characteristic being measured in the target population.

***q*** : Completion of p or 1-p.

**V**: The maximum percentage of standard error allowed (10% for this study)

**N**: The population size.

**n**: The sample size.

**Note**: To maximize the sample, both p and q are each set at **0.5**.

### II. Construction Firms Sample Size:

The second sample of respondents that assessed the identified BMS installation challenges consisted of construction firms Dammam, Khobar and Dhahran. A list of construction firms was obtained from the Chamber of Commerce in the Eastern province of Saudi Arabia. After determining the population size of construction firms, the following equation (Kish, 1995) was used to calculate the sample size of construction firms.

$$no = (p*q)/v2 \ldots\ldots\ldots\ldots\ldots\ldots (1.3)$$
$$n = no/ [1+ (no/N)] \ldots\ldots\ldots\ldots (1.4)$$

Where:

$\boldsymbol{n_o}$: First estimate of sample size

p: The proportion of the characteristic being measured in the target population.

***q*** : Completion of p or 1-p.

**V**: The maximum percentage of standard error allowed (10% for this study)

**N**: The population size.

**n**: The sample size.

**Note**: To maximize the sample, both p and q are each set at **0.5**.

**III. Facility Mangers Sample Size:**

The third sample of respondents that assessed the identified BMS operation and maintenance challenges consisted of facility mangers of buildings equipped with BMS in Dammam, Khobar and Dhahran. 16 facility managers or BMS operators were included in this study to answer the five likert scale survey.

### 1.6.1.3.4 Part four: Analysis of the Questionnaire's Survey Results.

In this part, the questionnaire's survey results were statistically analyzed to calculate an important index that determines the level of effect of the challenges and the variances among the participants' evaluation results. In order to calculate an important index the following equation (Dominowski, 1980) was used to calculate an effect index, that reflect the level of effects of the identified challenges that influence the successful implementation of BMS during design, installation, operation and maintenance. Microsoft Excel was used to facilitate the process of applying this equation to all identified challenges.

$$\text{Importance index I} = \frac{\sum_{4}^{i=0} \text{aixi}}{4 \sum \text{xi}} \times 100\ \% \ldots\ldots\ldots\ldots\ldots\ldots (1.5)$$

Where:

*i* = Response category index where*i*= 0, 1, 2, 3, 4

*ai*= Wight given to *i* response where *i*= 0, 1, 2, 3, 4

*xi* = variable expressing the frequency of *i* is as illustrated in the following:

$x_0$ = frequency of “**Extreme Effect**” response corresponding to a0 = 4.

$x_1$ = frequency of “**Strong Effect**” response corresponding to a1 = 3.

$x_2$ = frequency of “**Moderate effect**” response corresponding to a2 = 2.

$x_3$= frequency of “**Slight Effect**” response corresponding to a3 = 1.

$x_4$ = frequency of “**Does Not Effect**” response corresponding to a4 = 0.

The importance index of 0–<12.5% is categorized as ‘‘**Does Not Effect**; 12.5–<37.5% is categorized as ‘‘**Slight Effect**’’; 37.5–<62.5% is categorized as ‘‘**Moderate effect**’’; 62.5–<87.5% is categorized as ‘‘**Strong Effect**; and 87.5–100% is categorized as ‘‘**Extreme Effect**’’ The categorizations reflect the scale of the respondents’ answers to the questionnaire.

The output of this stage was the influential challenges and sub-challenges that influence the successful implementation of BMS.

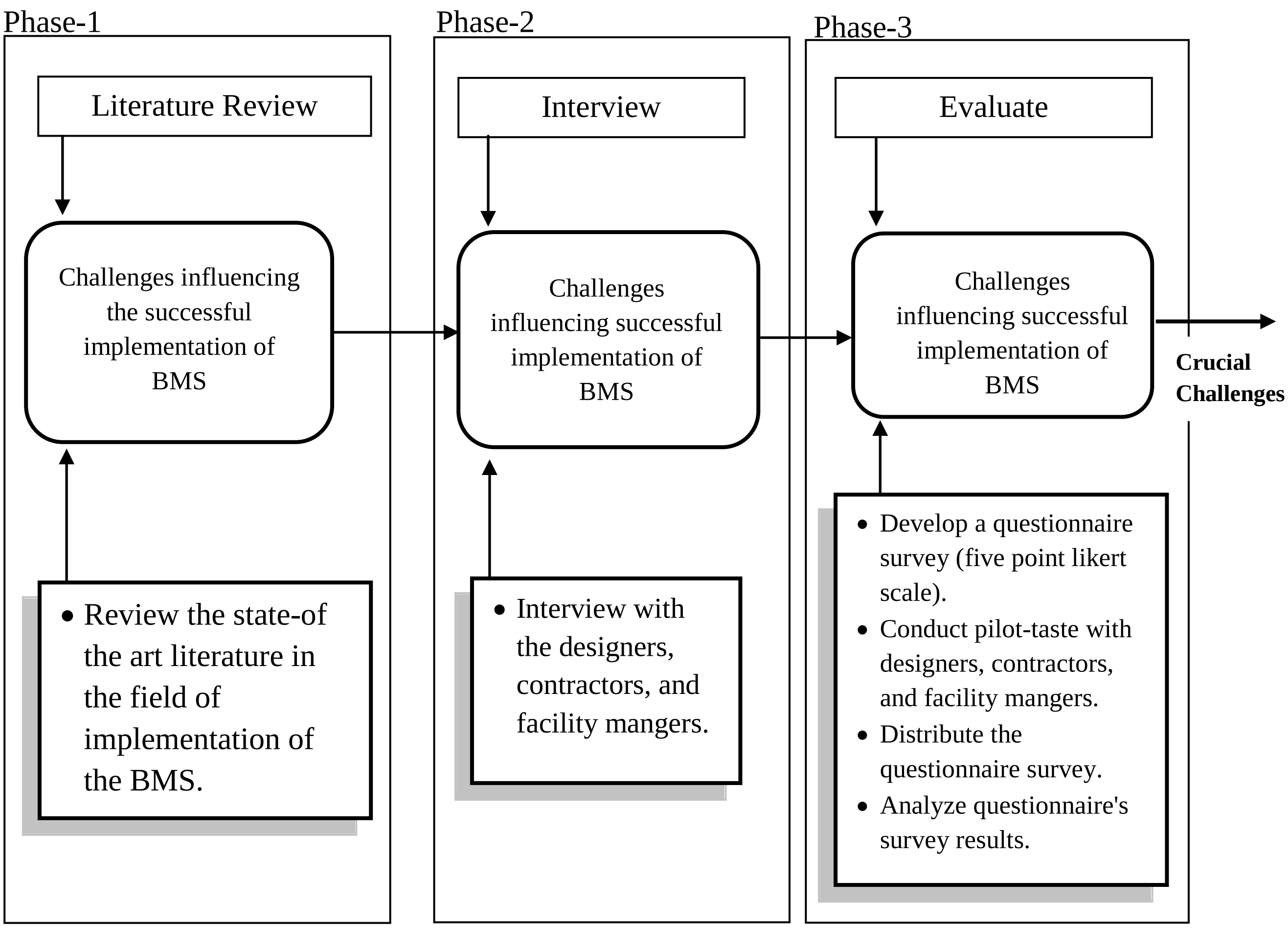


**Figure 1 Methodology Chart for Achieving the First Objective**

### 1.6.2 Objective 2 -Developing A Group Analytic Hierarchy Process (G-AHP) Model for Prioritizing the Influential Challenges that Impact the Successful Implementation of BMS during the Design, Installation and Operation and Maintenance Stages

The second objective of the study was achieved through the following two phases as illustrated in Figure 2:

#### 1.6.2.1 Structuring Hierarchy

The purpose of this phase was to structure a hierarchy and arrange the influential challenges that were identified in the previous stage from top level (goal) to the intermediate levels (challenges) and the lowest level (sub-challenges).

#### 1.6.2.2 Pairwise Comparison

In this phase, pairwise comparison method was used to develop a GAHP conceptual framework for prioritizing the influential challenges and sub-challenges that influence the successful implementation of BMS. In order to do this, pairwise comparison method consists of the following parts:

- **Part one:** development of pairwise comparison matrixes survey.
- **Part two:** Distribution of pairwise comparison matrixes survey.
- **Part three:** analysis of pairwise comparison's survey results.

#### 1.6.2.2.1 Part One: Development of Pairwise Comparison Matrixes Survey

The developed pairwise comparison matrixes survey are composed of two main sections. The first section collects general information about the BMS experts .The second section of the comparison matrixes (four matrixes) survey allows the BMS experts to assign the degree of effect of each of the identified challenges in terms of which challenge or sub-challenge dominates the other by using Saaty's 1-9 scale. Samples of the pairwise comparison matrixes questionnaires survey are shown in **Appendix III**.

#### 1.6.2.2.2 Part Two: Distribution of Pairwise Comparison Matrixes Survey.

Six experts in BMS design, installation, and operation and maintenance in the Eastern province of Saudi Arabia were asked to assign the weights for each challenges and sub-challenges with respect to upper levels by using Saaty's 1-9 scale. The determination of the questionnaire survey respondents (BMS experts) was based on questionnaires survey of the previous stage by selecting six respondents with largest number of years of experience.

#### 1.6.2.2.3 Part Three: Analysis of Pairwise Comparison's Survey Results.

The analysis of the pairwise comparison's survey results lead in developing a (G-AHP) conceptual framework (model) for prioritizing the influential challenges and sub-challenges that influence the successful implementation of BMS. The following steps were conducted to analyze the pairwise comparison's survey results:

- **Group-AHP**

The development of the GAHP conceptual framework for prioritizing the influential challenges and sub-challenges that influence the successful implementation of BMS requires the weights of each challenge and sub-challenge for each BMS expert to be calculated in a geometrical average (Anvari et al., 2011). The following geometrical average was used (Kazemi and Allahyari, 2010):

$$\mathrm{Xij}\left(\prod_{\mathrm{I}=1}^{\mathrm{k}} \times \mathrm{ijI}\right)^{1/\mathrm{k}} \ldots\ldots\ldots\ldots\ldots\ldots \text{(1.6)}$$

$$\mathrm{i, j} = 1,2, \ldots., \mathrm{n}, \mathrm{i} \neq \mathrm{j}, \mathrm{I} = 1,2,3, \ldots, \mathrm{k}$$

Where I = Decision maker number, and k = the number of decision maker

The output of this step is used in the next step.

- **Calculation of the Consistency Ratio**

The consistency ratio mainly describes the degree of consistency with the judgments. The higher the consistency ratio, the lesser the consistency with the judgments, while the lower the consistency ratio, the higher the consistency of the collected judgments (Kazemi and Allahyari, 2010) . Several professional commercial software-s have been developed to estimate the consistency ratio, such as **Super Decisions** and **Expert Choice**.

In this study **Expert Choice** was used to calculate the consistency ratio and prioritize the influential challenges and sub-challenges that influence the successful implementation of BMS.

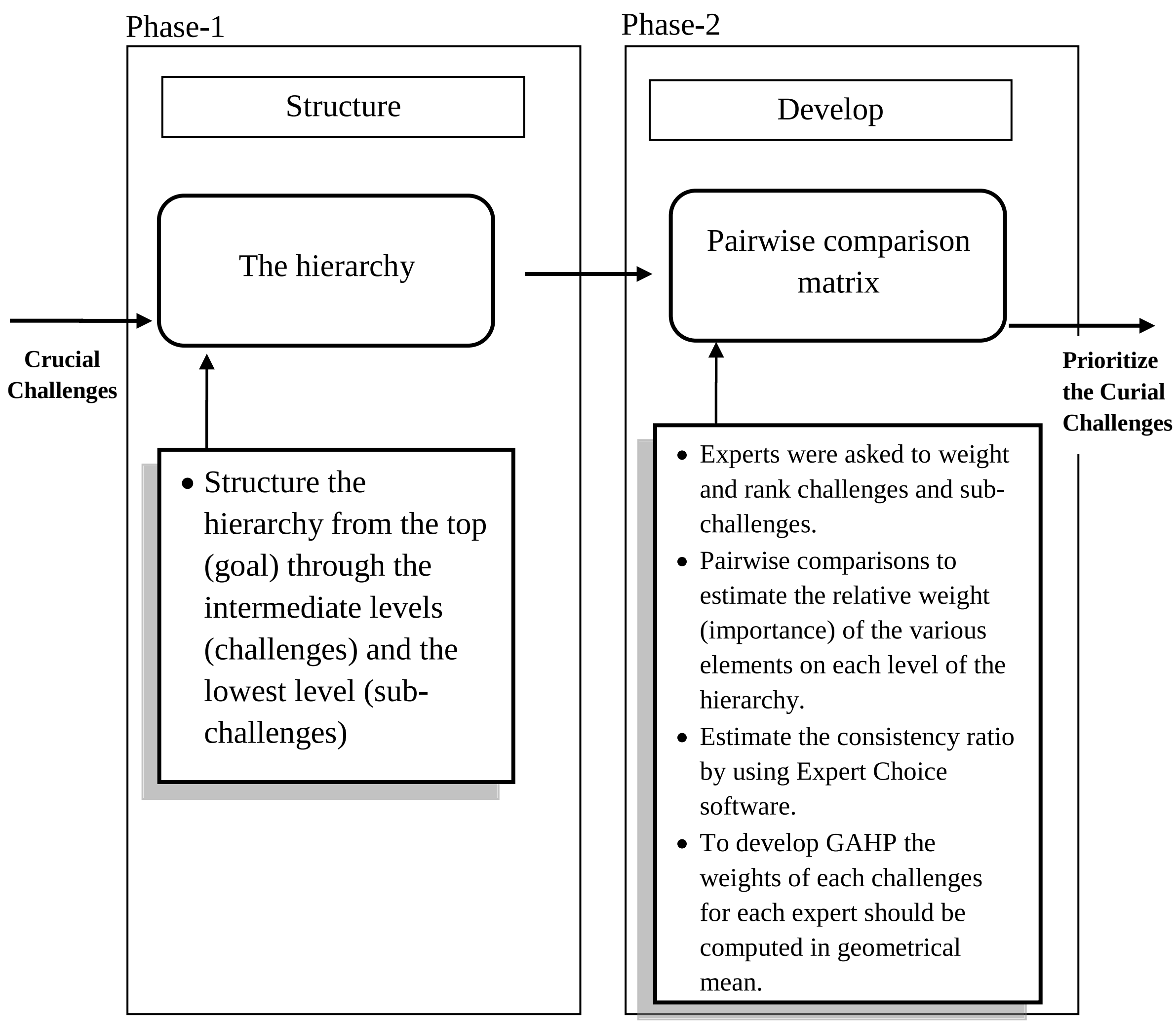


**Figure 2 Methodology Chart for Achieving the Second Objective**

### 1.6.3 Objective 3-Carrying out a Series of Case Studies to Validate the Developed Model

The third objective of this study was achieved through the following three phases as illustrated in Figure 3:

#### 1.6.3.1 Selecting Office Buildings Samples

In this phase eight office buildings equipped with BMS in the Eastern Province of Saudi Arabia were selected. The basic prerequisite that must be met in BMS of the selected case studies is controlling or monitoring at least for subsystems.

#### 1.6.3.2 Conducting Interviews

In this phase interviews were conducted with selected buildings owners, facility managers and BMS operators to identify and prioritize the challenges that occur in BMS operation and maintenance in their buildings.

#### 1.6.3.3 Validation of the Developed Model

The purpose of this phase was to validate the developed model through comparing the identified challenges in the previous phase with the developed model of BMS operation and maintenance challenges in 1.6.2.2.3 phase. Spearman's rank correlation coefficient (**$r_s$**) has been developed to determine and test the level of agreement between the ranking of both the model and case studies. The formula used to compute Spearman's Rank is shown below (Bartz, 1976).

$$r_S = 1 - \frac{6 \times \sum d^2}{n(n^2 - 1)} \quad \text{..................} \; (1.7)$$

Where: $d$ = the difference between variables, and $n$ number of the variables.

Interpret the Spearman's rank correlation coefficient is described below (Bartz, 1976).

For values of $r_s$ of **0.9** to **1**, the correlation is "**very strong**"

For values of $r_s$ between **0.7**and **0.89**, correlation is "**strong**"

For values of $r_s$ between **0.5** and **0.69**, correlation is "**moderate**"

For values of $r_s$ between **0.3** and **0.49**, correlation is "**moderate to low**"

For values of $r_s$ between **0.16** and **0.29**, correlation is "**weak to low**"

For values of $r_s$ below **0.16**, correlation is "**too low to be meaningful**"

A negative value of $r_s$ indicates a negative relationship.

### 1.6.4 Objective 4-Developing a Plan of Action to Facilitate the Identified Challenges

The fourth objective of this study was achieved through the literature review and interviews as shown in **Appendix I**.

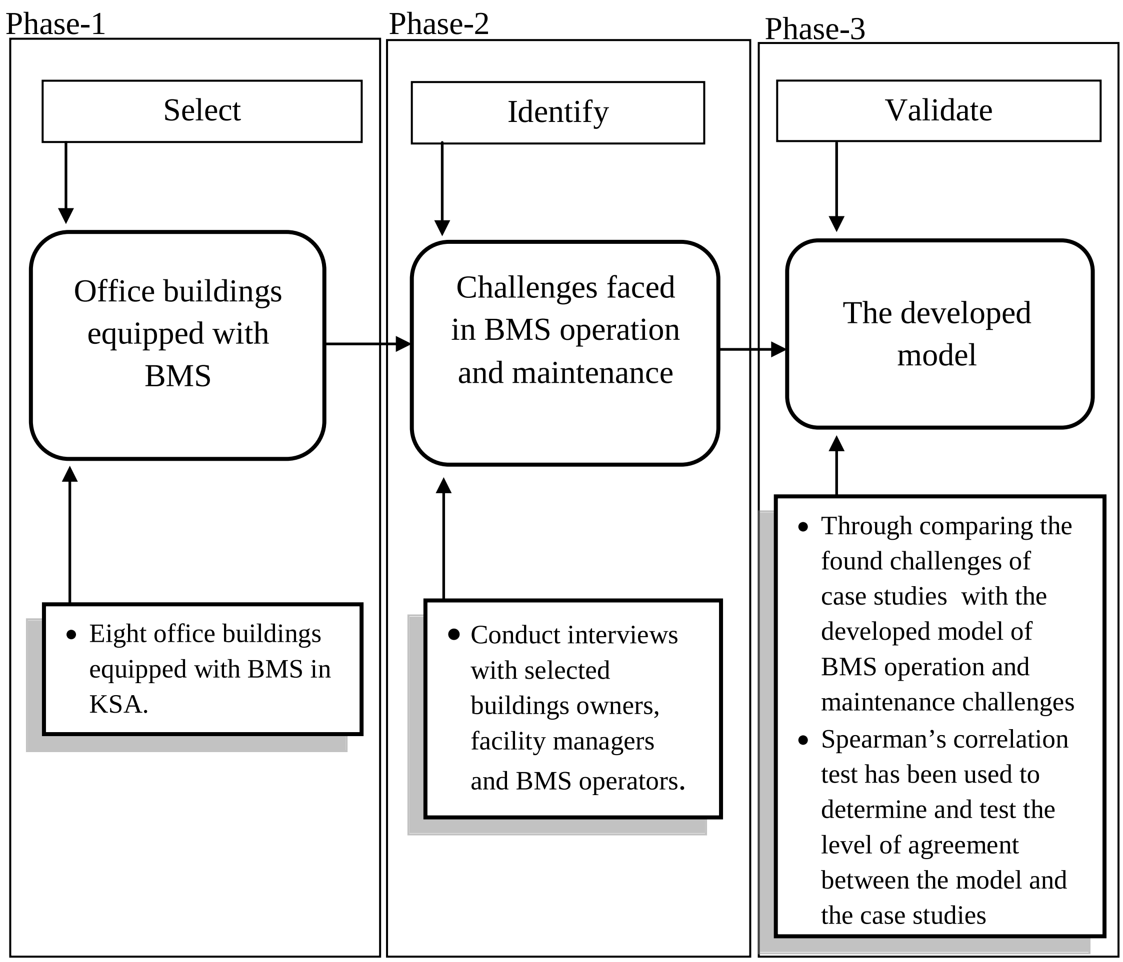


**Figure 3 Methodology Chart for Achieving the Third Objective**

## 1.7 Thesis Organization

The thesis is organized into six chapters to achieve the main objectives in accordance with the developed research methodology as follows:

### 1.7.1 CHAPTER ONE: Introduction

A general background information on building systems and the building management systems are provided in this chapter. It also includes a statement of the problem, the objectives of the study, its scope and limitations, significance of the study, research methodology and thesis organization.

### 1.7.2 CHAPTER TWO: Literature Review

This chapter reviews the literature related to BMS, the definitions, development, functions and benefits. It also reviews the status of the intelligent buildings technologies in Saudi Arabia, decision making techniques and methods as well as international practice of building management systems implementation.

### 1.7.3 CHAPTER THREE: Local Current Practices of BMS Implementation during the Life Cycle of the Office Buildings

This chapter summarizes an inclusive coverage of local current practices of BMS implementation during the life cycle of the office buildings in Saudi Arabia.

### 1.7.4 CHAPTER FOURE: Challenges Affecting the Implementation of BMS in Office Buildings

This chapter summarizes an inclusive coverage of the challenges that affect the implementation of BMS in office buildings.

### 1.7.5 CHAPTER FIVE: Data Analysis

This chapter provides an analysis of the data received for the five likert questionnaire survey, pairwise comparison questionnaire survey as well as case studies data.

### 1.7.6 CHAPTER SIX: Recommended Plan of Action

This chapter provides the proposed plan of action that aims to facilitate and enhance the successful implementation of BMS in office buildings in Saudi Arabia. The chapter also includes conclusions and summary of the study and recommendations for future studies.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Buildings Management Systems (BMS)

### 2.1.1 Definition of Buildings Management Systems

Nowadays, the term intelligent building is getting more popular and this concept has generated a good deal of excitement during the last decade, much of which has subsequently dissipated once the limits and complexities of building intelligence were discovered. Typically, the intelligent building concept involves the implementation and use of advanced and integrated buildings technology systems which are Building Management Systems (BMS), telecommunication systems, life safety systems, user systems and facility management system.

Building Management Systems (BMS), (also known as Buildings Automation Systems, BAS) is one of the most important intelligent building systems because it comprises of various subsystems which are connected in several ways to create an integrated system. Here are some of the definitions of building management systems from a few selected sources.

"*Building Management Systems (BMS) (also called Automation or BAS) are used in buildings for automatic monitoring and control of services such as lighting, plumbing, fire services, heating and air conditioning systems. The term refers to a system that uses sensors, controls and activators. All these use an electronic digital processor to* *implement control algorithms and have the capability of communicating with other controls. The BMS term covers all control elements, including hardware, controllers, any linking network and central controllers*"(Mustafa and Bansal, 2002).

"*Building automation systems (BAS) is an umbrella terms (and is also Known as building management system, BMS). It is used to refer to a wide range of computerized buildings control systems, from special- purpose controllers, to standalone remote stations, to large systems including central computer stations and printers*" (Wang, 2010).

BMS is also defined as "*a complex, multi-level, multi-objective, integrated, interrelated and complete intelligent design management information capable of assisting building design process from the inception phase through management and maintenance phases."* (Cser et al., 1997).

"*A Building Automation Systems can be considered a tool in the hands of building operations personnel to provide more effective and efficient control over all building systems*" (Wong and So, 1997).

### 2.1.2 Development of Buildings Management Systems

Traditionally, mechanical equipment has been used as building environment controls through pneumatic or electro-mechanical devices. More recently, due to rapid development of Direct Digital Control (DDC) technology and the use of microprocessor-based systems, building management systems are replacing the conventional controls and have become a major control systems. Nowadays, more and more buildings services systems have been introduced with built in control components (Wang, 2010).

The early beginning of BMS evolution can be traced back to the 1940s. The following stages represent the most important development in BMS evolution (Wang, 2010):

- *Centralized control and monitoring panel*
- *Computerized centralized control and monitoring panel*
- *BMS with data-gathering panel(DGP) based on minicomputer*
- *Microprocessor-based BMS using LAN*
- *Open BAS compatible with Internet/ intranet*

#### 2.1.2.1 Centralized Control and Monitoring Panel

In this stage (also known as pre-BMS stage) the centralized control and monitoring panels are used to operate some basic tasks such as read the sensors readings and start/stop or reset systems at one central location. In this stage the numbers of switches and sensors connected to centralized control and monitoring panels are less than the current BMS which may include thousands of input/outputs.

#### 2.1.2.2 Computerized Centralized Control and Monitoring Panel

This stage witnessed the emergence of the first computerized building automation control center late in1960s (the first BMS generation), as a result of the development of the modern computer in the 1940s. Coaxial cable or two wire digital transmission is used to connect remote multiplexers and control panels to a computer which allows all messages, sensors and devices to communicate easily. Several functions are performed by the systems in this stage such as schedule programming of controllable devices, automatic reset of analogue outputs, high and low alarm limits and reports. The main drawbacks of this generation are the high cost and its complexity to use.

### 2.1.2.3 BMS with Data-Gathering Panel (DGP) based on Minicomputer

This stage (also known as the second BMS generation) brought dramatic changes to BMS. Energy management software packages such as duty cycle, demand control, optimum start\stop, day night control and enthalpy control were incorporated into BMS. Rapid increases in the use of minicomputer, central processing units and programmable logic controllers in buildings management systems was observed. Another important change in the generation was introducing data gather units which helped to use fewer wires to transmitted data between points. These changes were attributed to several reasons, the most significant being the decline in the cost of hardware during the 1970s. Computers and programs interface also became easier to use with no need for specialist users.

### 2.1.2.4 Microprocessor-based BMS using LAN

This stage witnessed the birth of a new generation of the building management systems due to the use of microprocessors and the personal computer (PC). The continued decline in the price of microprocessors and chips was the major reason of the development of new technology in BMS. Microprocessors-based control stations integrated using Local Area Network (LAN) represented the typical system architecture of BMS at this stage which is still in existence today.

### 2.1.2.5 Open BAS Compatible with Internet/ Intranet

Since 1980s, several researches have been conducted to come up with a solution for incompatible problems of BMS by developing and promoting standards. By the mid of 1990s, BMS industry had witnessed the adoption of several technologies which still exist today such as open protocol, standard technologies, communication and software technologies commonly used by Internet/ intranet or within the computing networking area.

## 2.2 Office Buildings and Building Management Systems

For many industrial countries, the office building is a place for transacting building work (Zhang, et al. 2011). The concept of the modern office building is initiated based on the scientific-management theories that initiated in the late nineteenth and early twentieth century's. One of the most important scientific-management theories was developed by Frederick Taylor. He believed that the best way to complete the work is by being divided down into its simplest segments to the extent that people are treated as units of production. Larkin company headquarters in Buffalo was the first and most famous physical example of such theory. More lately, the scientific-management theories have been gradually superseded by a new concept called 'management by objectives'. (Markland, 1995).

The energy consumed in the typical office building took up 30% of overall operation cost. Therefore, the energy consumption in the office buildings in one of the most important field of interest for many researchers (Piet et al., 2009). In office buildings, there several elements provide a critical roles in reducing energy consumption. Such elements include energy management policies, electric equipment and appliances energy user's behaviors and the most important is energy management technology (Zhang, et al., 2011). The interaction among the four elements are illustrated the following Figure.

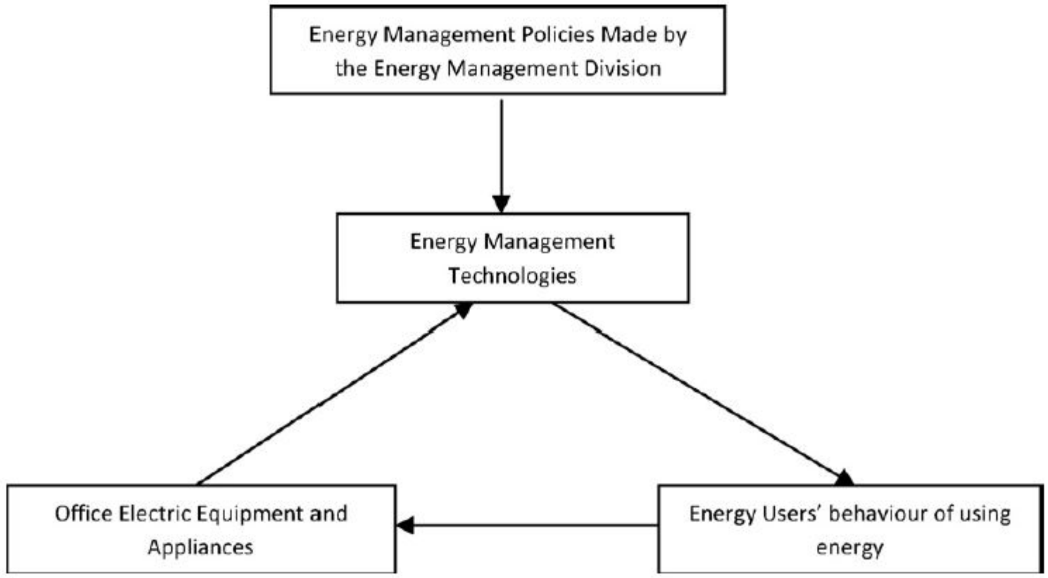


**Figure 4 The Four Elements in Office Energy Consumption (Zhang, et al., 2011)**

BMSs are the most important energy management technology in the large functional buildings such as office buildings. The conventional and sill core area of the BMS in large functional buildings is the controlling and monitoring of heating, ventilation and air-conditioning systems. Their main objective is to provide noteworthy savings in energy and decrease operation cost (Kastner et al., 2005).

### 2.2.3 Benefits of Building Management Systems in Office Buildings

The rapid developments of the BMS provide several benefits not just for the facility manager, but all different users involved with the facility. Many factors appear to influence the achievement of full benefits of BMS in office buildings. These factors are related to BMS design, installation, commissioning, or BMS operation and maintenance. Figure 5 illustrates some of these benefits (Mustafa and Bansal, 2002):

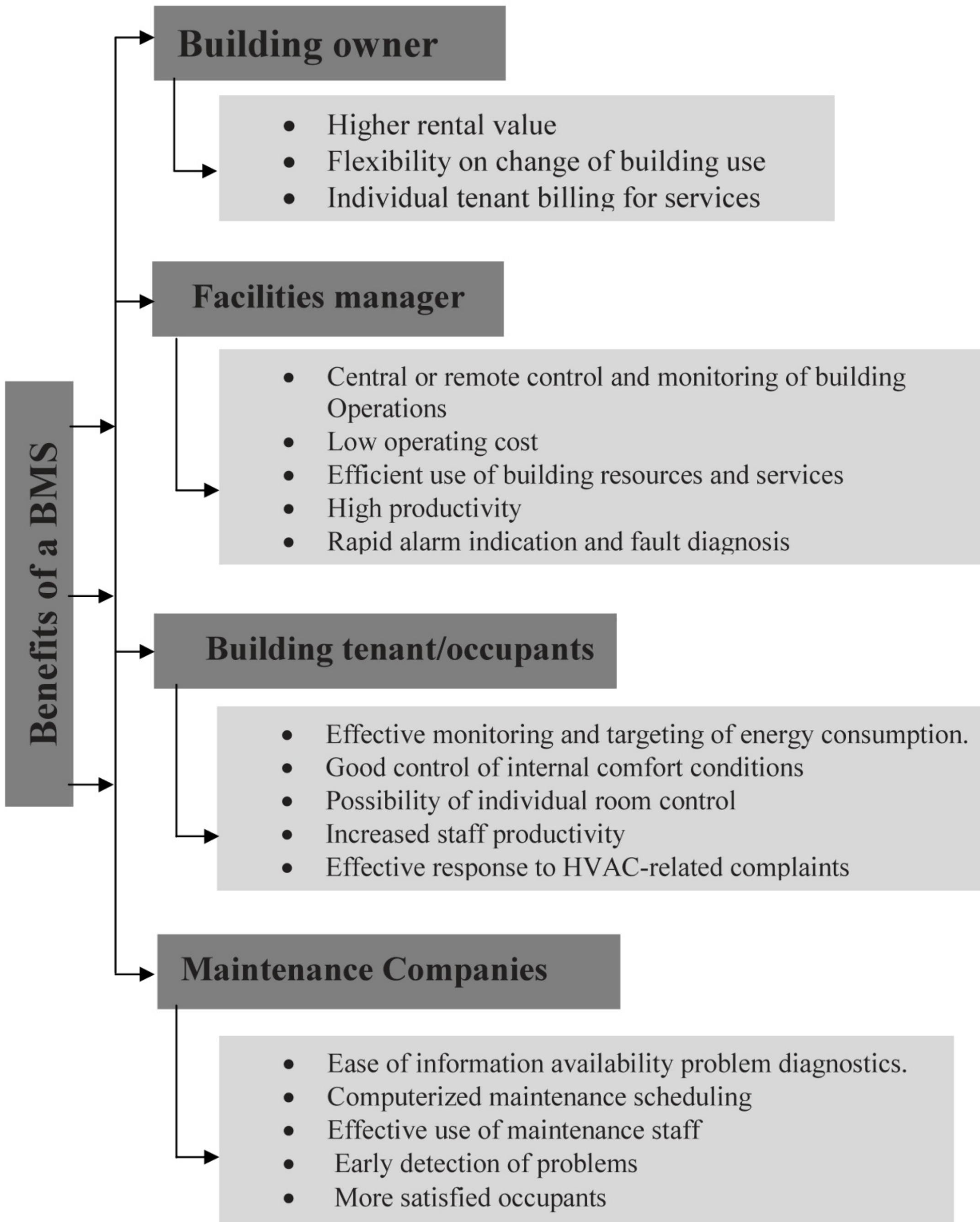


**Figure 5 Benefits of Building Management Systems (Mustafa and Bansal, 2002)**

### 2.2.4 Functions of Building Management Systems in Office Buildings

The basic functions of the BMS in office buildings can be highlighted by the following bullets:

- Control functions:
    - Installation-management and control (local control) functions
    - Energy management (supervisory control) functions
- Risk management functions
- Information processing functions
- Facility management functions
- Performance monitoring and diagnosis
- Maintenance management.

#### 2.2.4.1 Control Functions

Control function of the BMS can be spilt into two groups: local (installation-management and control) functions and Energy management (supervisory control) functions. Local control functions form the essential control and automation functions of building management system that helps building service systems to perform their basic functions in an adequate way. Local control functions include two categories: sequencing control and process control. There are several examples of sequencing control for buildings systems such as chill, pump and fan sequencing control. The typical process control in buildings include temperature control, air and water flow rate control and static pressure control. For most of the building owners, the economic justification for implementing BMS is improving energy management in their buildings. BMS can manage energy consumption by reducing the energy consumed by starting or stopping plants depending on the correct or the optimal timing. Secondly, it reduces energy consumption by running plants in energy-efficient conditions by setting local process control to the optimal level (Wang, 2010).

#### 2.2.4.2 Risk Management Functions

BMS can create an excellent degree of personal safety in the buildings. This can be achieved through  integrating fire safety system with building management system and thus, the ability of BMS to automatically close fire doors, open fans and close others and pressurizing some zones of the buildings with respect to other. These actions reflect positively to prevent the spread of fire and smoke(Wang, 2010).

#### 2.2.4.3 Information Processing Functions

BMS can generate precious information for forward services and costing through creating summaries, logs and reports. This data can also offer value added services to tenants such that the perceived worth of the tenancy is increased (Wang, 2010).

#### 2.2.4.4 Performance Monitoring and Diagnosis, Maintenance Management

Fault detection and diagnostic of buildings systems are the inevitable result of buildings management systems ability to record monitoring data, which help to anticipate future failures and leave that building systems in an acceptable operating state. Modern BMS are able to apply fault detection and diagnostic technology online. This capability allows detecting and analyzing faults while the system is running. One of the most significant jobs of the modern BMS is effective maintenance. This maintenance is proposed based on the monitoring data, which provides information on the equipment conditions (Wang, 2010).

### 2.2.5 Integrated Building Management System

Recent years have witnessed a huge interest in the development and implementation of a variety of intelligent building control products. Improve building ‘monitor and control’ performance and environmental sustainability, and achieve  a variety of human desires are the main reasons for developing such intelligent systems Wong and Li (2009).The number of the building systems that can be integrate and interoperate with BMS is increasing over years. For office buildings, the following Figure illustrate the most important building systems that can be integrate and interoperate with BMS (Shirley, 2001; Sinopoli, 2010).

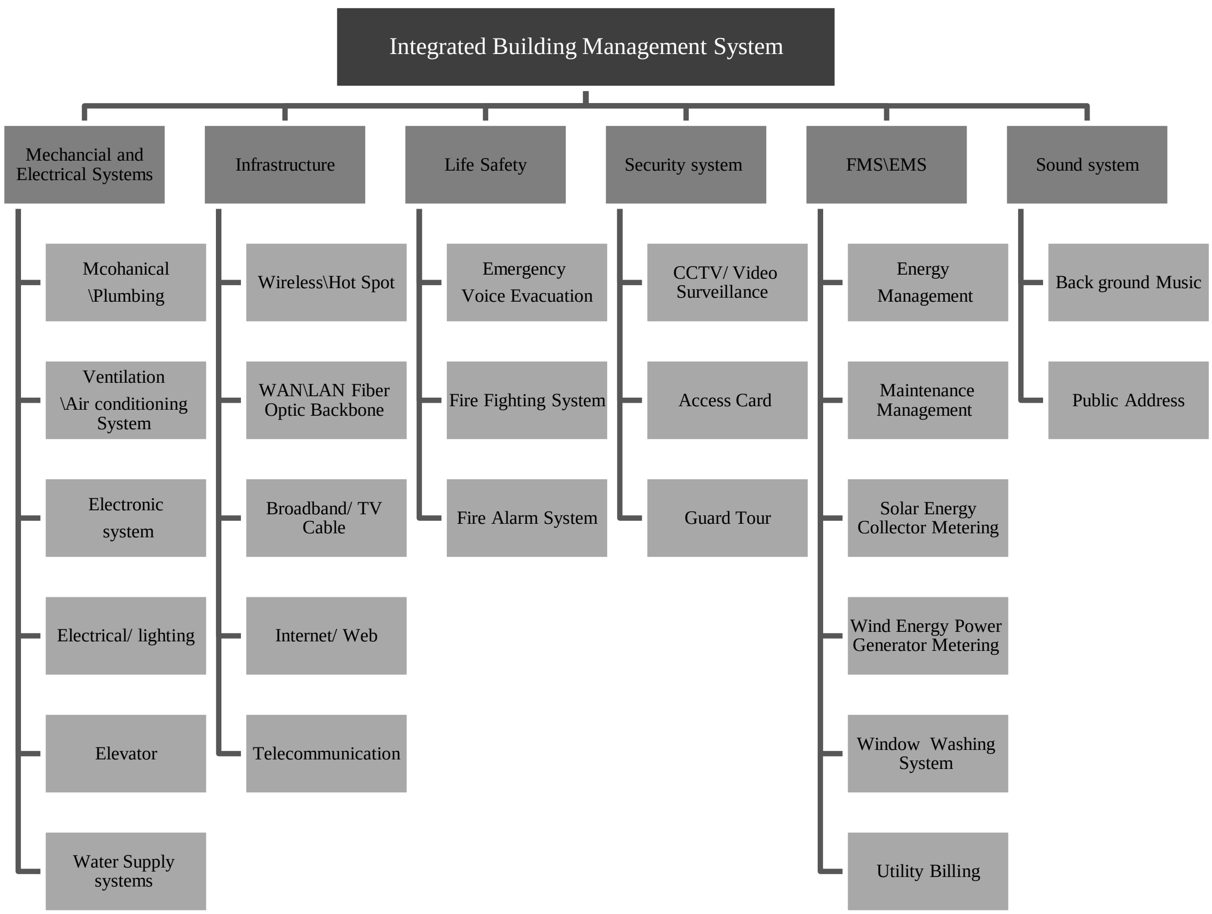


**Figure 6 Integrated Building Management System**

### 2.2.6 Intelligent Office Building Technologies in Saudi Arabia

The rapid construction boom and the competitive environment in Saudi Arabia are highly encouraging the building industry to integrate the intelligent building technology in commercial and multifunctional buildings. At present, the major implantation of this technology is mostly reflected in large scale and high budgeted projects however, intelligent buildings technology vendors and companies that service professional consultancy in this field are beginning to establish a stable market for this technology in KSA (Reffat, 2010b).

By conducting an online survey (Reffat, 2010a) investigated the market requirements of intelligent building technologies for high-rise office buildings in Saudi Arabia and some of the major finding of this survey are as follows:

- About 77% of the survey participants agreed that the intelligent buildings technologies are important for office buildings in Saudi Arabia as shown in Figure 7.

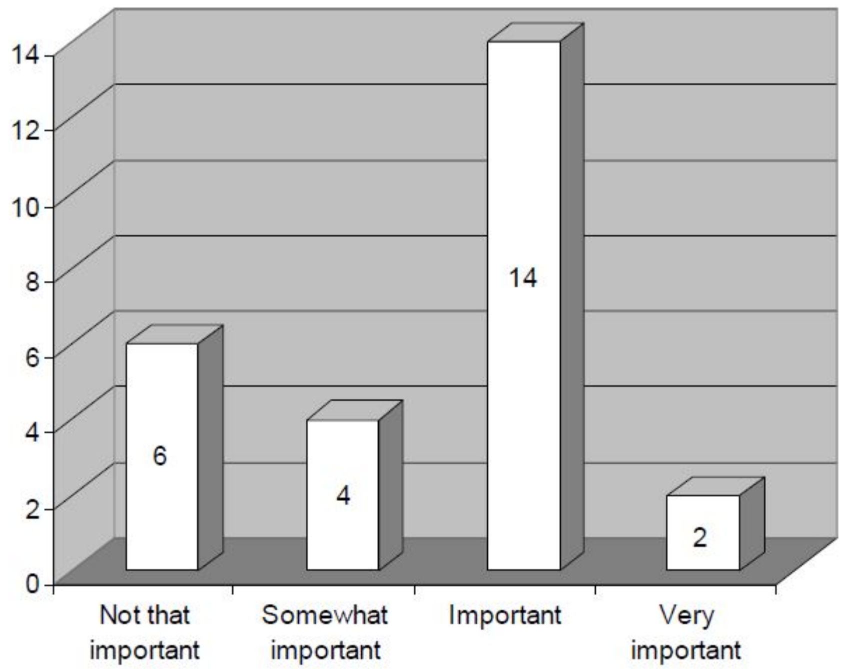


**Figure 7 Importance Levels of Intelligent Building Technologies for Office Buildings in Saudi Arabia (Reffat, 2010a)**

- The degree of appropriate utilization of hi-tech intelligent technologies for surveyed office building is low (85 % without appropriate utilization).
- Reducing energy consumption, increasing occupant safety and security, and improving the operation and maintenance are the major benefits of hi-tech intelligent buildings technologies for office buildings in Saudi Arabia as shown in Figure 8.

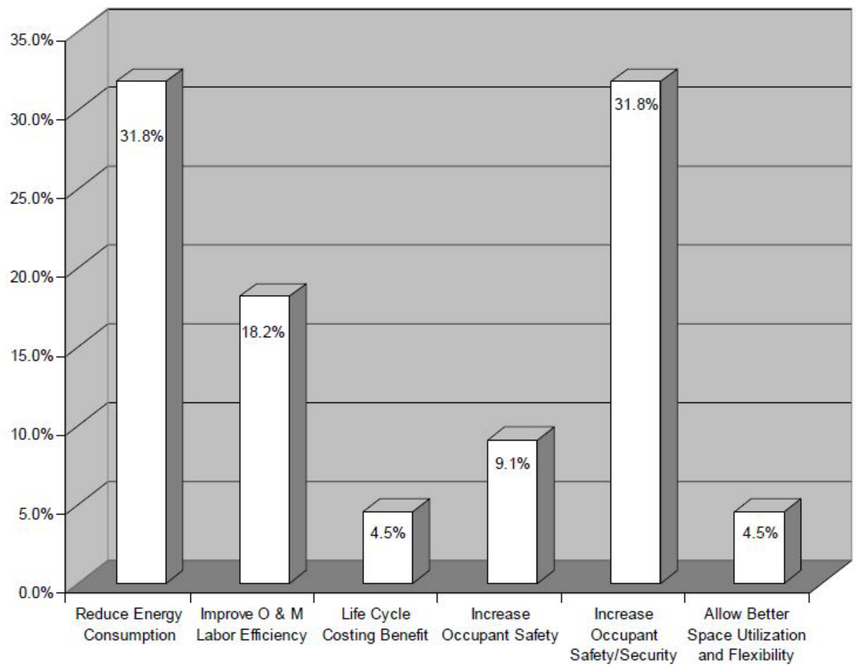


**Figure 8 The Major Benefits of hi-tech Intelligent Buildings Technologies for Office Buildings in Saudi Arabia (Reffat, 2010a)**

- According to survey results, 50% of surveyed office buildings have intelligent building technologies that are either fully or partially integrated. While the other 50% have intelligent building technologies that are not integrated with each other and work as standalone systems to manage the operation of office building services and functions.

## 2.3 Decision Making Techniques and Methods

Many techniques and methods have been developed to solve the decision making problems (Baker et al., 2001). Normally, the decision making problems have two main parts the first part reflects the factors and sub factors that directly related to the decision making problem and the second part reflects the alternatives of the decision making problem (Sipahi and Timor, 2010). The following bullets represent some of the decision making techniques and methods (Baker et al., 2001):

- Kepner-Tregoe (K-T) Decision Analysis,
- Multi-Attribute Utility Theory (MAUT),
- Pros and Cons,
- Cost Benefit Analysis (CBA),
- Custom tailored tools and,
- Analytic Hierarchy Process (AHP)

### 2.2.7 Analytic Hierarchy Process (AHP)

The analytic hierarchy process is a theory for prioritizing both tangible and intangible factors based on the experts' judgment (Anvari et al., 2011). AHP is one of the best-known multi-criteria decision making (MCDM) technique developed by AL Saaty in 1980 and it was designed to solve decision-making problems by breaking down each problem into a hierarchy and prioritizing all factors in a systematic way. Due to its numerous features, The AHP method is widely used in many fields such as engineering, ecology, food, business, health and government sectors.

#### 2.2.7.1 AHP Method Advantages

Many researchers use AHP methods instead of other (MCDM) methods due to many reasons, some of which are:

- AHP method allows researchers to include both quantitative and qualitative factors in the decision making.
- AHP method allows researchers to consider a large number of factors.
- Mathematical simplicity and flexibility of AHP method.
- AHP method allows researchers to structure the large problems into a hierarchic structure.

#### 2.2.7.2 Structure Hierarchy

Development of the decision-making problem hierarchy is the most important part of the decision-making problem. Many things must be considered in developing the decision-making problem hierarchies such as the correct identification of the factors, sub-factors and alternatives with respect to the overall goal, appropriate arrangement of the factors on their levels as well as the number of hierarchy levels must be determined by the level of the complexity of problem and the amount of the detail required (Al-Nehmi, 2009).

#### 2.2.7.3 Pairwise Comparison

The pairwise comparison matrix is a part of the AHP method. Pairwise comparisons matrix gives the experts the opportunity to assign the importance of each factors and sub-factors against each other by using Saaty's 1-9 scales as shown in the Table 1.

**Table 1 Saaty's 1-9 Scale of Pairwise Comparisons (Anvari et al., 2011)**

| Intensity Of Importance | Definition |
|---|---|
| 1 | Equal importance |
| 2 | Weak or Slight |
| 3 | Moderate Importance |
| 4 | Moderate Plus |
| 5 | Strong Importance |
| 6 | Strong Plus |
| 7 | Very  plus |
| 8 | Very,very strong |
| 9 | Extreme importantce |

Expert's judgment technique is widely used in many different areas of research. "*The main difficulty is to reconcile the inevitable inconsistency of the pairwise comparison matrix elicited from the decision makers in real-world applications*" (Anvari et al., 2011).

### 2.2.7.4  Group –AHP

The AHP is a multi-criteria decision making (MCDM) technique. It is considered to be well suited for group decision making. Due to complexity of the some studies the need for more than one expert judgment becomes very necessary and this called group decision (Dalal et al., 2010). There are four suggested ways to set the priority setting in the context of group decision:

- Consensus that refers to the achievement of a consensus of group participants in constructing a hierarchy and making judgments.
- Vote or compromise.
- Geometric mean of the individual's judgments.
- Single or multiple models.

## 2.4 Previous Research

Many studies and articles have been developed on various aspects of BMS implementation. A few examples are listed below.

Petze (1996) in this study the authors present a number of factors that influence the successful implementation of the BMS. These factors are involvement of personnel that will live with the system, development of BMS design alternatives by sub-contractors, adequate initial and continued training for BMS facility personnel, and good project management by sub-contractors.

Lowry (2002) states that there are many factors affecting the successful implementation of the BMS in plants facility. these factors are end user involvement in determine the requirement of the BMS, good usability of the end user interface, proper selection of the BMS vendor(s), and proper training for BMS facility personnel.

Hydeman (2004) states that the effective direct digital control (DDC) systems retrofits project is influenced by a number of factors such as proper selection of the subcontractors, proper review of the plans and submittals provided by sub-contractors and complete requirement and specification of the project.

VanDoren (2009) indicates that BMS project may fail due to several reasons. These reasons are lack of client involvement, sub-optimal requirement, frequently changing order due to client's demands, lack of end user involvement during briefing process, and poor project management by sub-contractors.

Runde et al. (2010) revealed that there are several challenges facing the current engineering process of the BMS. These challenges resulted in an unnecessary increase in engineering and utilization costs. In this study the authors divided BMS engineering challenges to organizational and structural challenges and software challenges.

Piper (2004) presented a number of factors that affect the successful operation and maintenance of the BMS. These factors are lack of training, insufficient staffing and improper BMS re-commissioning.

Schneider (2005) Indicated that the best way to achieve full potential of BMS comes through a proper commissioning of BMS during the design stage of the buildings project. In building design stages, BMS commissioning begins with determining the exact owner's performance requirements, but given the vast choice of BMS options available and the varying levels of technical experience of an owner's personnel, this can be a difficult task. The author in this article stated that the commissioning authority (CA) plays a vital role in BMS commissioning through:

- Proving adequate assistance to owners by determining realistic expectations of the completed system.

- Ensuring that the requirements of the building owner are well documented.
- Ensuring that the basis of the design document is correctly developed.
- Reviewing the contract documents during the various stages of completion.
- Reviewing all BMS drawings developed by the controls contractor and compare them with owner's project requirements and basis of design documents.
- Carrying out visits to the project site on a regular basis to validate BMS installation procedures.
- Furnishing operation staff with detailed instructions for operating the system in various operating conditions.

Kastner et al. (2005) stated that the cost of investment in BMS is too high therefore, it is very important to select a building concept that ensures optimal life-cycle cost and not minimum investment cost.

Piper (2002) indicated that inappropriate selection of BMS may cause a series of problems such as installed capabilities may go unused, needed functions are never installed, projected cost savings are never fully achieved and they eventually will never achieve their full potential.

Ehrlich and Goldschmidt (2011) stated that “*the best continuous commissioning comes from a diligent operator who is using the BMS on a regular basis as a tool to optimize the facility. Unfortunately, we find many buildings engineers who aren’t regularly using these systems. There are many reasons for this, including challenges with training, time, and the usability of systems*”.

Makarechi and Kangari (2011) stated that building management systems (BMS) are mainly implemented in commercial buildings to increase their systems performance and operational effectiveness. They revealed that user needs, simplicity, and availability (of service maintenance) are the most important challenges that impact the BMS performance.

Burns (2005) stated that E SOURCE in 2004 conducted interviews with representatives of large companies or institutions to investigate their concerns and day to day issues about building automation and controls systems. This study covers fifty four persons managing facilities from universities campuses to supermarkets and from airports to hotels in North America, Europe, and Asia. The finding of these interviews demonstrated that the facility managers are still facing with yesterday's problems with limited budgets, staff, communication, and time.

Poeling (2000) stated that there are two main sides of the successful implementation of BMS. The first side is about building users comfort and the other side is about operating buildings with minimum energy consumption. In this study the authors presented some common problems of the BMS:

1. The maintenance staffs do not have time to identify BMS problems.
2. The BMS is improperly programmed by the installer.
3. The BMS operators disable the energy conservation features.
4. The installer fails to verify control performance.
5. Failed components are not replaced.
6. The BMS operators do not have a good understanding of energy conservation.

Kazemi and Allahyari (2010) presented a conceptual framework for prioritizing the most important factors influencing successful implementation of Knowledge Management in organizations. The developed framework is based on utilizing Group analysis process (GAHP) model to analyze and prioritize the identified factors that influence successful implementation of Knowledge Management in organizations. They stated that the finding of this study represents guidelines for top managers and leaders of organization to implement knowledge management successfully in their organizations.

Anvari et al. (2011) developed a model for analyzing and prioritizing the identified factors that support the implementation process of learning manufacturing in the automotive industries. The used methodology consists of two stages. In stage 1 (qualitative), factors that support the implementation process of learning manufacturing in the automotive industries were identified from literature. In stage 2 (quantitative), the authors utilized group analysis process (GAHP) model to analyze and prioritize the identified factors in the first stage. They stated that the finding of this study will pave the way for learning managers, experts and senior managers on implementing learn in their companies.

# CHAPTER 3

# CURRENT LOCAL PRACTICES OF BMS IMPLEMENTATION DURING THE LIFE CYCLE OF OFFICE BUILDINGS

## 3.1 Introduction

An inquiry of current local practices of BMS implementation in office building in the Eastern Province of Saudi Arabia is presented in this chapter. It focuses on investigating the procedures followed in the design, installation and operation and maintenance of BMS in office buildings. Interviews were conducted with a selected sample of BMS designers, contractors and operators in the Eastern Province of Saudi Arabia. The purpose of conducting the interviews was to understand the current local practices of investigating the procedures followed in designing, installation and operating and maintaining the BMS and identifying the most important challenges affecting the successful implementation of the BMS during the life cycle of office buildings.

## 3.2 Methodology of Interviews

Interviews were conducted with 12 BMS' designers, contractors and operators in the Eastern Province of Saudi Arabia. Information about these interviewees is shown in Table 3. The interviews focused on:

- Investigating the procedures followed in designing, installing and operating and maintaining BMS in office buildings in Saudi Arabia.
- Investigating the challenges affecting the successful implementation of the BMS during the life cycle of office buildings.

A set of developed standard questions (as shown in Appendix I) were followed to carry out the interviews

**Table 2 Interviewed BMS' Designers, Contractors and Operators**

| No. | Name of the Interviewed Person | Place of work | Date of the Interview | Method of the Interview |
|---|---|---|---|---|
| 1. | Mr. Eisa S. Al-Dossary<br>Manger, Operation & Projects Dept. | Asharqia Chamber<br>Dammam | 28/5/2012 | Face- to -Face |
| 2. | Mr.Othman Adowia<br>Facility Manger | Al Turki Towers<br>Dhahran | 28/5/2012 | Face- to -Face |
| 3. | Mr. Hamzeh Al Titi<br>Senior Electrical Engineer | Fawz Abdulaziz Al Hokair Real Eatatw Co. Ltd.<br>Khabar | 30/5/2012 | Face- to -Face |
| 4. | Mr. Mohammad Rafi Patel<br>Projects Management leader | Honeywell Automation & Control Solution<br>Dhahran | 4/6/2012 | Face- to -Face |
| 5. | Mr. Mohammad A. Mofrah<br>Senior Mechanical Engineer | Modern Design for Consulting Engineering<br>Khabar | 4/6/2012 | Face- to -Face |
| 6. | Mr. Mohammad Abdul Waris<br>Projects Supervisor | KFUPM<br>Dhahran | 2/6/2012 | Face- to -Face |
| 7. | Mr. Mohammad W. Bahieldeen<br>Senior Mechanical Engineer | Modern Design & Engineering Consulting<br>Khabar | 5/6/2012 | Face- to -Face |
| 8. | Mr. Rami Abdullah Diab<br>Electrical Section Manager | ATCM Construction<br>Dammam | 10/6/2012 | Face- to -Face |
| 9. | Mr. Efren H. Acal<br>BMS Operators | Eastern Cement Towers<br>Dammam | 12/6/2012 | Face- to -Face |
| 10. | Mr. Arnohd N. Alejo<br>BMS Operators | Al Rashd Towers<br>Khabar | 13/6/2012 | Face- to -Face |
| 11. | Mr. Moaaz Izzat Yaseen<br>Facility Manager | Al Sehamyiah Towers<br>Khabar | 19/6/2012 | Face- to -Face |
| 12. | Mr. Moaid Al Katranji<br>System Projects Manager | Johnson Controls<br>Khabar | 23/6/2012 | Face- to -Face |

## 3.3 Finding of the Local Practice

In order to get a clear understanding of the practice of designing, installing and operating BMS the in construction industry, several structured interviews were conducted and their results are presented as follows:

### 3.3.1 BMS Design Procedure

After developing the client and end user requirements throughout the briefing process, the brief program forms the basic line for the (MEP) design engineer (Mechanical, Electrical, Plumbing design engineer) to develop the BMS plans and specifications. The MEP plans and specifications mainly contain the sequence of operations and the location of the control elements and sensors. This data is then provided to the supplier to develop the required shop drawing & Submittals to the BMS contractor. Figure 9 illustrates the BMS design procedures followed in Saudi Arabia.

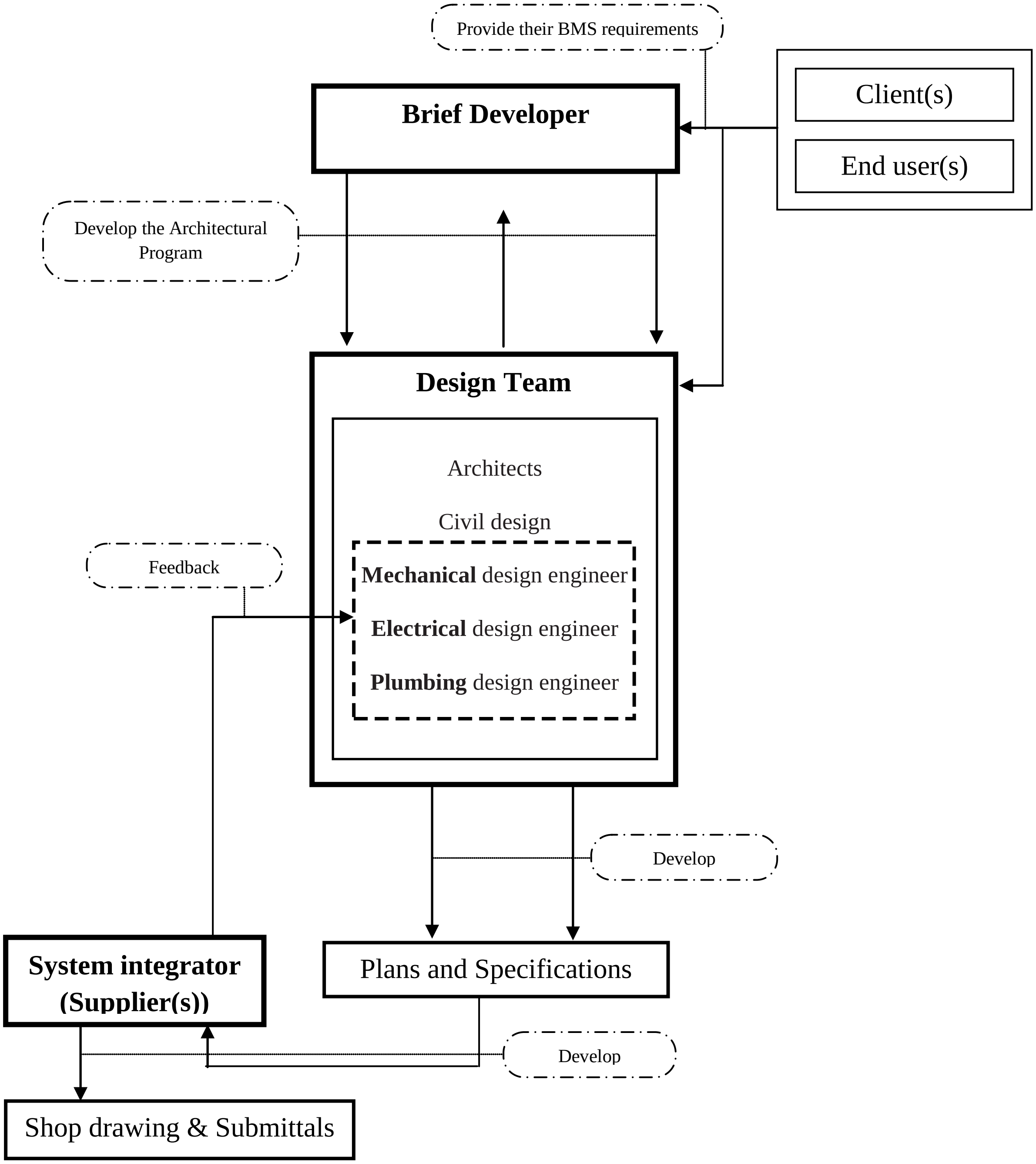


**Figure 9 BMS Design Procedure**

### 3.3.2 BMS Installation Procedure

The BMS installation procedures usually begin with selection of the BMS sub-contractor. This selection is carried out by the client either through the bidding process or direct selection. In many cases, the consultant and the design team play a critical role in the BMS sub-contractor selection process by providing their clients with all necessary advice. After that, the BMS sub-contractor selects the BMS supplier under the direct supervision of the consultant and client. The BMS supplier in turn develops shop drawing and submittals based on the plans and specifications provided by the (MEP) design engineers. The developed shop drawing and submittals are usually revised by the consultant and are mainly used by the sub-contractor to install the BMS components. The installation process of the BMS components normally starts with the mechanical and electrical works of the project. Testing and commissioning practices of the BMS components are mainly divided into two parts; the first part is carried out during the installation process where the sub-contractor and the supplier test the BMS components after installation and this testing is called the primary testing, the second part is conducted after completing the whole project and it is called final testing and commissioning.

During the warranty period the sub-contractor provides the initial training for the BMS operators and free maintenance services. By the end of the warranty period, the sub-contractor delivers 'as built' drawing & manuals to the building owner. Figure 10 illustrates the BMS installation procedures followed by construction industry in Saudi Arabia.

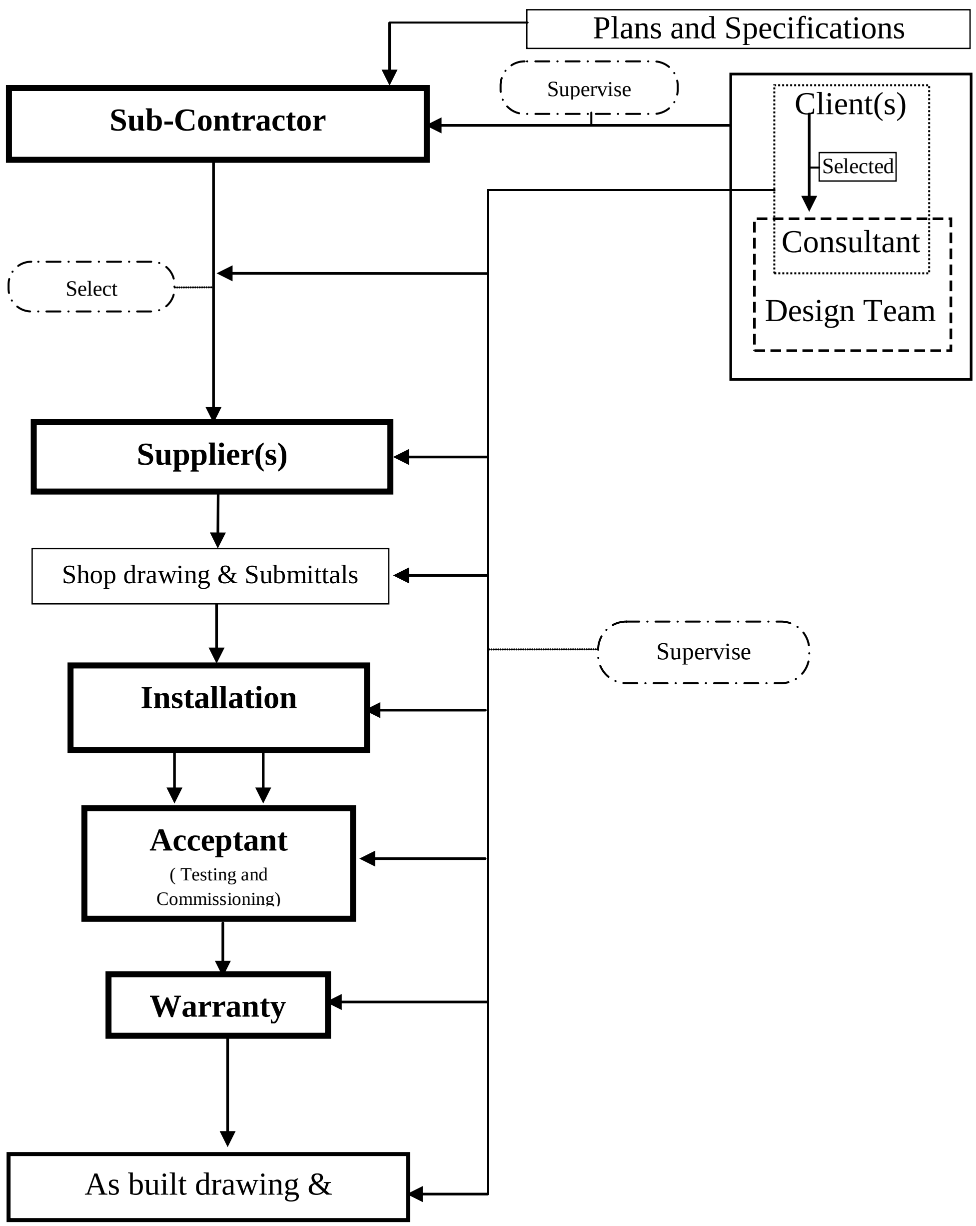


**Figure 10 BMS Installation Procedure**

### 3.3.3 BMS Operation and Maintenance Procedure

The BMS operation and maintenance procedure of the BMS usually begin after completing the acceptance stage of the project and handing over it to the client. Facility personnel (including operators, maintenance staff, and facility manger) are basically selected by the client to manage, operate, and maintain his/her facility. The BMS personnel could be hired to work in the facility as in-house staffs or outsource them. The BMS operators usually do their daily activities in alternating shifts ranging from two to three depending on the office building work patterns. Two types of maintenance namely preventive and corrective maintenance are carried to keep BMS in a good condition. The outsourcing of the BMS operation and maintenance services are carried out by the main suppliers of the BMS. Figure 10 illustrates the BMS O&M procedures followed by construction industry in Saudi Arabia.

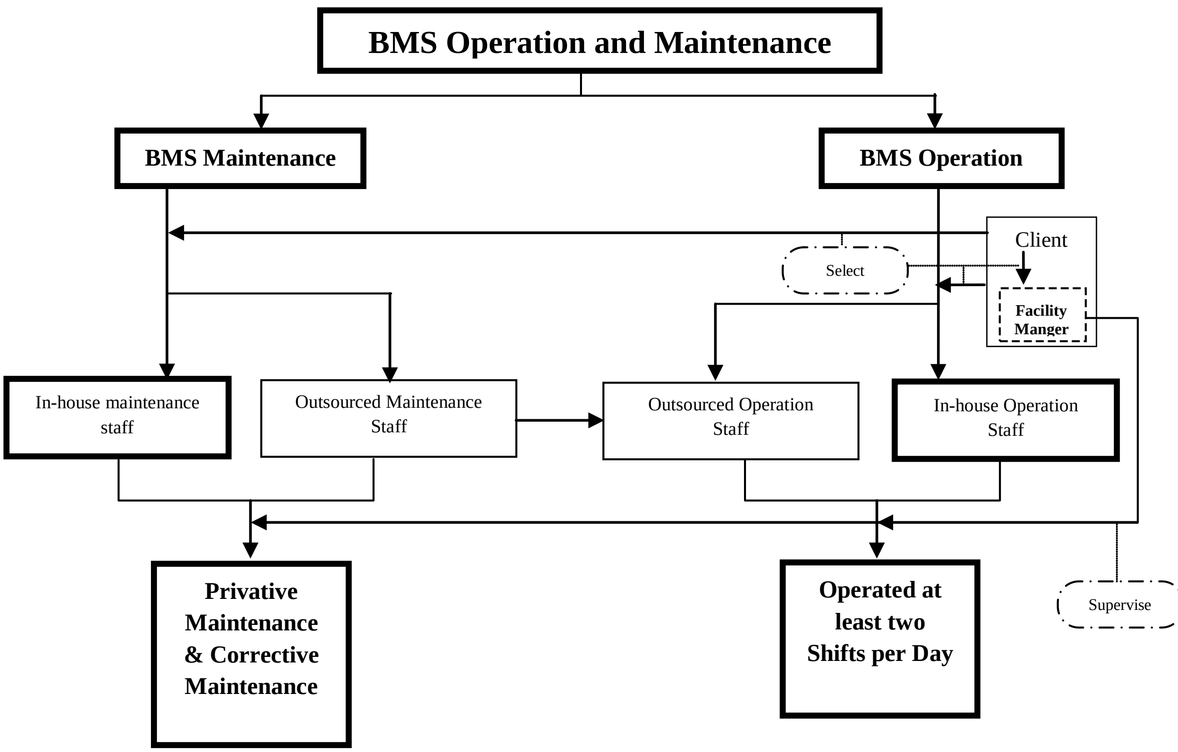


**Figure 11 BMS Operation and Maintenance Procedure**

### 3.3.4 The Most Significant Challenges Facing the Implementation of the BMS

The interview's findings described that the current practices of the implementation of BMS in Saudi Arabia are facing several challenges that could take place during design, installation, or operation and maintenance stages. The most critical challenges are described as follows

#### 3.3.4.1 Inappropriate selection of sub-contractor to install the BMS

Interview's finding confirmed that one of the most critical challenges for the successful implementation of the BMS during the installation stage is the inappropriate selection of the sub-contractor to install the BMS. Many studies indicated that the quality of the installation of the BMS by the subcontractors is as more important as the systems itself. Unfortunately, for many clients in the construction industry in Saudi Arabia, installation cost is the most important factor for selecting sub-contractors to install the BMS. As a result the selection of the sub-contractors with lowest cost to install the BMS is done. From the results of interviews, it was found that such clients face many problems during and after the installation, in some cases they may receive the project without the final testing and commissioning because they select the lowest bidder.

#### 3.3.4.2 Inadequate initial training for BMS facility personnel

As important as the design and installation are to a building management system, they aren’t the only important things for the success of the BMS. If the BMS operation personnel don't receive adequate training, even the best BMS in the market may not achieve its long term success. The BMS subcontractors\suppliers usually provide the initial training for the BMS facility personnel during acceptance phase of the project. The interviews finding indicated that the quality and quantity of the initial training provided by BMS subcontractors\suppliers is not enough. It usually covers technical attributes of the installed system and it is carried out in a short period of time with a limited number of operators (maximum two).

#### 3.3.4.3 Lack of continued training for BMS facility personnel

Adequate training for BMS personnel including building managers and operation and maintenance staffs is necessary to ensure its successful operation and maintenance. Interviews findings revealed that an inadequate initial training is one of the most critical challenges that affect the success of the BMS project. The next important challenge for long term success of the BMS is lack of the ongoing training for its personnel. Unfortunately, the majority of BMS personal in Saudi Arabia do not receive ongoing training by BMS specialists. The main reasons are building owner's tendency and the high cost of such training. Continued training is essential for several reasons such as, turnover of the BMS facility personnel, addition of new features and functions, and change of the utilization and physical characteristics of the building.

#### 3.3.4.4 Provision of incomplete plans and specifications of the BMS

One of the most important challenges affecting the successful implementation of the BMS during installation stage is the provision of incomplete plans and specifications of the BMS. Basically, at the end of the building management systems design process, the mechanical, electrical, and plumbing (MEP) design engineer in A/E firm produce the BMS plans and specifications. Failure in providing these sections or ignoring some of them, opens ways for the BMS's contractors and supplies to make their interpretations.

This can lead to a series of problems during installation phase such as, cost overruns, disputes and most importantly the BMS does not match the client's requirements.

## 3.4 Discussion

The current local practices of BMS implementation in office building in the Eastern Province of Saudi Arabia is presented in this chapter. It focuses on investigating the procedures followed in designing, installation and operating and maintaining the BMS in office buildings. A series of structured interviews were carried out with 12 BMS' designers, contractors and operators in the Eastern Province of Saudi Arabia.

The findings of the interviews are presented in this chapter mainly in two parts. The first part describes and illustrates the procedures followed in designing, installation and operating and maintaining the BMS in office buildings, while the second part describes the most significant challenges faced during the implementation of the BMS during the life cycle of office buildings.

- **The design procedures of the BMS**: the interviews confirm that the BMS design normally begins after the development of the plans and specifications by MEP engineers. This data is provided to the supplier(s) to create the shop drawing & submittals.
- **The installation procedures of the BMS**: the interviews indicated that several parties are working together to complete the BMS installation namely, sub-contractors, suppliers, clients and consultants. After selecting the BMS sub-

contractors and suppliers, the shop drawing and submittals developed by the suppliers are usually used by sub-contractors to install the BMS under direct supervision of the consultant.

- **The operation and maintenance procedures of the BMS**: the interviews revealed that the operation and maintenance services of the BMS could be carried out through well trained in-house staff, or through outsourcing. BMS operators usually conduct their daily activities in alternating shifts ranging from two to three depending on the office building works patterns. Two types of maintenance named preventive and corrective maintenance are carried to keep BMS in a good condition.

The results of the interviews indicated that the most significant challenges faced during implementation of the BMS are the inappropriate selection of sub-contractor to install the BMS, inadequate initial training for BMS facility personnel, lack of continued training for BMS facility personnel and provision of incomplete plans and specifications of the BMS.

The next chapter presents the challenges influencing the successful implementation of the BMS during the life cycle of the office buildings. Identification of these challenges was carried out through literature review, observed professional practice and through five likert scale questionnaire.

# CHAPTER 4

# CHALLENGES AFFECTING THE IMPLEMENTATION OF THE BUILDING MANAGEMENT SYSTEMS IN OFFICE BUILDINGS

## 4.1 Introduction

The next chapter presents the challenges influencing the successful implementation of the BMS during life cycle of the office buildings. Identification of challenges was carried out through literature review, observed professional practice and through five likert scale questionnaire.

Building management systems (BMS) are mainly implemented in commercial buildings such as office buildings to increase their systems performance, operational effectiveness and occupant's satisfaction. Unfortunately, the effective implementation of this system faces several challenges that may occur during the life cycle of the office building project. Based on the international literature sources and interviews conducted, this study presents these challenges that effective the successful implementation of the building management systems. Thirty-two challenges are identified and are classified into three main categories namely; briefing and design phase, installation, acceptance, and warranty phases and operation and maintenance phases.

## 4.2 Challenges Pertaining to the Briefing and Design Phases

This category of challenges includes 11 different challenges. Description of each is provided as follows:

### 4.2.1 Lack of Clients' Involvement in the Briefing Process

The client's involvement in the briefing process is a critical factor for the success of the project due to its importance in reflecting the client's objectives, needs and requirements to the design team (Juaim and Hassanain, 2011). A BMS is a blend of several building sub-systems throughout a connection of various ways to develop an integrated building system (Wang, 2010). The developed integrated building system throughout BMS depends on the specific client’s objectives, needs and requirements for the new building project. This client could be the owner of either private or public-sector buildings (Sinopoli, 2010). The lack of clients' involvement in the briefing process is one of the major reasons that cause failure of the integrating building technology systems (VanDoren, 2009; Sinopoli, 2010).

### 4.2.2 Lack of End-User' Involvement in the Briefing Process

The end users, being more than one entity, are considered to be one of the significant sources of information for the briefing team in determining building projects' requirements. The end users may represent the client organization, the employees of the organization, or its visitors (Juaim and Hassanain, 2011). One of the most significant challenge that affects the successful implementation of the BMS is the lack of end user' involvement in specifying their requirements (Lowry, 2002; Petze, 1996). The most notable entity of end users that could potentially provide significant contribution to identifying and formulating the requirements of BMSs are the operation and maintenance staff (HPAC, 2007; Sinopoli, 2010). However, as the operation and maintenance staff would be usually selected after the construction of the building has been completed, the opportunity to involve them in defining and formulating their requirements for the BMS is minimal (Petze, 1996).

### 4.2.3 Unfamiliarity of the Briefing Developer with the Technical Requirements of BMS

The developed brief for designing the BMSs requires the identification and understanding of the methodology of integrating the various technical sub-systems in the building. Examples include the integration and the interface between the heating, ventilating and air conditioning systems and the fire protection systems. Shen and Chung (2006) indicated that architects, usually being the project brief developers are expected to possess the working knowledge about all technical systems that would be installed in the building. However, architects in Saudi Arabia may not be acquainted with the basic technical requirements for developing a user friendly interface for the BMS. As a result; the developed project brief may lack significant technical details that reflect the basic requirements of the BMS (Al-Katranji, 2012).

### 4.2.4 Insufficient Technical Experience of the Client with the BMS

The client's vast technical experience with BMSs is a significant resource for determining the detailed performance requirements of the demanded functionalities of the systems. A client who possesses a limited experience with BMSs may overlook their essential performance requirements. This would result in developing a design brief that lacks significant details, and hence the specification of a BMS that does not reflect the client’s and end users’ actual needs and requirements (Petze, 1996; Schneider, 2005; VanDoren, 2009). Alejo (2012) revealed that, in some occasions, clients may not fully understand the technical requirements of BMSs. As clients would be mainly focusing on the cost of the BMSs, the final product would be reflective of the client’s and end uesrs’ intended functionalities for the BMSs.

### 4.2.5 Absence of Commissioning Practices during the Briefing Process

The appropriate commissioning practice is one of the most significant factors that affect the success of the BMS (Bourassa and Johson, 2007). The commissioning practice is defined by ASHRAE (2005) as “a quality-focused process for enhancing the delivery of a project. The process focuses upon verifying and documenting that the facility and all of its systems and assemblies are planned, designed, installed, tested, operated, and maintained to meet the owner’s project requirements”. Sam (2010) defines building commissioning as a "systematic process that ensures all building systems are installed and perform interactively according to the design intent and meet the client's operational requirements". While the general understanding of the commissioning practice is that it is a simple testing of the BMS components at the end of the construction phase, Ellis (2004) emphasized that this is not a proper commissioning practice for the BMS. The commissioning practice should start early at the briefing phase to develop the design documents and continue throughout construction and startup processes. Schneider (2005) indicated that commissioning of the BMS at the briefing phase serves to determine and document the owner and end users’ expectations and performance requirements.

### 4.2.6 Poor Communication between the Client and the Brief Developer

Effective communication between the brief developer and the client is one of the critical aspects that affect the success of the briefing process. Active listening during the briefing process provides an excellent mean for facilitating effective communication between the brief developer and the owner (Yu et al., 2007). Runde et al., (2010) emphasized that communication problems between the client and brief developer due to the use of different vocabularies is one of the challenges that affect the success of the BMS. The use of different vocabularies may lead to misunderstanding of the demanded performance requirements.

### 4.2.7 Provision for Sub-Optimal Requirements of the BMS

The developed design brief serves as a reference document for all participants in the building project (Yu et al., 2007). The development of an optimal design brief in influenced by several factors pertaining to clients, end users, time allocated for the briefing process, available budget, communication between the various project participants, experience of the brief developer with the project type and control and management of the briefing process (Juaim and Hassanain, 2011). There are two significant factors which could potentially impact upon the development of an optimal brief for BMSs. These factors include lack of communication between the client and the brief developer and lack of software support for programming the interface and integration between the various sub-systems in the building (Runde et al., 2009).

### 4.2.8 Inappropriate Selection of the A/E Team

The selection of an appropriate architecture-engineering (A/E) firm is one of the most significant tasks that property owners makers face to ensure the success of their construction project. Parameters that have to be considered during the decision making process include the site conditions, design requirements and complexity, and available resources (Nguyen et al., 2008).To ensure the proper selection of the A/E team in the design of BMSs, the team should possess adequate knowledge, training and experience to develop the required detailed design package, including the plans and specifications (Ehrlich and Goldschmidt, 2009). In the BMS plans and specifications, the design professionals, being the mechanical, electrical, and plumbing design engineers, determines the BMSs' equipment and their locations as well as the sequence of operations (Schein, 2007).

### 4.2.9 Lack of Sub-Contractor's Involvement in the Design of the BMS As "a Design-Assist"

Efficient design of BMSs requires up-to-date exposure to the recent development in the BMSs technology. However, this exposure might not be feasible due to limitations inherent in the academic programs. Provision of feedback from the sub-contractors to the A/E team adds considerable value in the process of designing BMSs. The feedback contributes to avoiding the repetition of design errors. It also contributes in briefing the A/E about the recent developments in the domain of building automation and control systems (Ehrlich and Goldschmidt, 2009).

### 4.2.10 Absence of Commissioning Practices during the Design Process

Appropriate commissioning of the BMS during the design process is one of the most significant factors that affect the success of the BMS in achieving its full potentials (Bourassa and Johson, 2007). The commissioning of the BMS during the design stage focuses on the development of the preliminary design and construction documents.

During design process of the BMS, the commissioning activities serve to provide an ongoing assistance in the development of the preliminary design documents, and ensure that the construction documents cover both the client's project requirements and the basis of design documents (Schneider, 2005).

### 4.2.11 Inappropriate Selection of the BMS

Modern BMSs provide a variety of benefits and features. Nevertheless, some of the installed BMSs do not achieve their full potential, as some of the required functions are not included, or some of the available functions are never used. There are many reasons behind these shortfalls. One of the reasons could be traced back to the inappropriate selection of the installation contractor. However, the most important reason is that the selected BMS does not match the functional and technical requirements of the project (Piper, 2002). Wong and Li (2006) stated that "any erroneous selection of systems can seriously affect the durability, service life, sustainability, and cost of repair and refurbishment of the building, and in turn, additional liabilities would be incurred to the building owners".

## 4.3 Challenges Pertaining to the Installation, Acceptance and Warranty Phases

This category of challenges includes 11 different challenges. Description of each is provided as follows:

### 4.3.1 Inappropriate Selection of Subcontractors to Install the BMS

The quality of the installation of the BMS could be considered as important as the quality of the BMS itself (Hydeman, 2004: Hillebrand, 2007). Selection of a subcontractor for the installation of the BMS is usually based on the lowest price received. However, the lowest price contract may not provide for a proper installation of the BMS. One of the main reasons for the improper installation is the subcontractor's lack of experience in this highly technical field (Arslan et al., 2008; Bahieldeen, 2012). Ehrlich and Goldschmidt (2008) emphasized on the process of pre-qualifying subcontractors, especially in projects that require extensive integration of critical systems throughout single as well as multiple buildings, to ensure the proper installation of the BMS by competent subcontractors.

### 4.3.2 Inappropriate Selection of BMS Suppliers

The careful selection of the most appropriate supplier is a critical decision exercised collectively by the owner, A/E team and the installation contractor. The decision would be usually based on a wide range of factors (Ho et al., 2010). These factors include the cost of the product, quality of the product, after-installation service, provision of training to the in-house facilities staff and compatibility with various other products (Mustafa and Bansal, 2002; Ehrlich and Goldschmidt, 2008).

### 4.3.3 Inadequate Review of the BMS Submittals and Shop Drawing Provided by the Subcontractors

The development of high quality plans and specifications might not be enough for the successful installation of the BMS. Several problems could surface up during the installation process of the BMS, such as the procurement and installation of the incorrect equipment on the project site. The subcontractor should be requested to prepare the necessary shop drawings for the review and the approval of the consultant and the client, to ensure that the design details as well as the equipment required for the BMS match the requirements of the owner (Cosiol, 2001). Therefore, the review of the submittals and shop drawing provided by the subcontractors is a critical task during the construction phase of the projects (Garrett and Lee, 2010).

### 4.3.4 Frequent Change Orders due to Client's Demands

Change orders serve the purpose of modifying the contract documents during the course of the construction phase. Modifications in the contract documents could arise from several causes. One of the significant causes for change orders is the client's instructions to modify the original design due to the inappropriate reflection of the client's requirements during the design phase. Another significant cause for change orders is the updated definition of the client’s requirements during the installation phase (Alnuaimi et al., 2010). In BMS projects, the implementation of these frequently demanded work orders by the client usually results in delays, cost overruns and sometimes decrease in the quality of the installed systems (VanDoren, 2009; Patel, 2012).

### 4.3.5 Provision of Incomplete Plans and Specifications of the BMS

The development of the final set of plans and specifications for the BMS marks the full completion of the BMS design phase (Schein, 2007). The specifications of the BMS are often arranged in three sections. These sections are titled general, products and execution. The general section provides a detailed description of the requirements for developing as-built drawings, applicable codes and submittals. The products section presents a detailed description of the operational capabilities and the specifications of the equipment. The execution section elaborates on the installation, testing, and acceptance requirements. Partial development of any of these specifications' sections may lead to cost overruns, disputes, and most importantly mismatch between the client's and end users' requirements and the installed BMS (Cosiol, 2001).

### 4.3.6 Absence of Alternative Design Proposals Provided by the BMS Contractors

Development of alternative design proposals is facilitated by the type of the contract between the client and the BMS contractor. While some projects do not allow or encourage potential contractors to develop alternative design proposals, other projects encourage BMS contractors to propose alternative solutions and share in the savings realized. The main drawback in projects where the development of alternative design proposals is not encouraged is the tendency of the contractors to just propose a price quotation without worrying about the actual specifications for the BMS. In fact, the specifications may not available for contractors to examine during the bidding process. This situation may pose a significant challenge to the successful installation of the BMS (Petze, 1996: Piper 2005). Providing alternative design proposals by the BMS contractors offer clients the added benefits of ensuring the quality of the BMS installation and cost reduction (Petze, 1996). The developed alternative design proposals reflect the contractor's field experience and acquaintance with the state-of-the art technology in BMS integration and interfacing (Al-Dossary, 2012).

### 4.3.7 Lack of Involvement of the Commissioning Agent during the Installation, Acceptance and Warranty Processes of the BMS

The commissioning agent, also known as the commissioning authority, is a term that refers to a team of senior specialists hired by the client to direct and oversee the building commissioning process. The specific duties of the commissioning agent are to carry out functional performance testing, provide support personnel training, documentation, project hand over to the client, and periodical monitoring of the BMS (Sam, 2010). Proper commissioning of the BMS is critical for achieving its full potential and ensuring its optimal operation (Schneider, 2005). However, the commissioning service requires an additional contract between the client and the commissioning agent, which clients sometimes avoid due to the expenses involved (Al-Dossary, 2012).

### 4.3.8 Improper Selection of the Commissioning Agent

The commissioning agent is the leader of the commissioning team. The commissioning agent carries out the responsibilities of facilitating the entire commissioning process on behalf of the client (Sam, 2010). The client's selection of the commissioning agent is a significant decision. The selected commissioning agent should possess the required technical knowledge and experience in the type of buildings and systems to be commissioned (Elzarka, 2009). In addition, the commissioning agent should possess the team-building and coordination skills with diverse technical specialty groups. A weak commissioning team leader lacking these skills could be the cause for an ineffective commissioning process (Sohmen, 1992).

### 4.3.9 Lack of End User Involvement during the Commissioning Practices

The most influential end users that could provide an effective contribution to the commissioning practices of the BMSs are the operation and maintenance staff (Petze, 1996; Horwitz-Bennett, 2009). Commissioning practices of the BMS components during the installation phase are carried out over two stages. The first stage is called primary commissioning. This stage takes place during the installation process where the sub-contractor and supplier test the BMS components after their installation. The second stage is called final commissioning. This stage takes place after the completion of the project (Al-Katranji, 2012). The operation and maintenance staff should be involved in all commissioning practices, so that they can develop the needed experience with the operation of the BMS before its actual use (Kutsmeda, 2008). Nevertheless, few operation and maintenance staff are actually involved in all commissioning practices, as the majority of them are typically hired after handing over the project to the client (Abdul-Waris, 2012).

### 4.3.10 Consultant's Supervisors May not Posses Collective Experience about BMS Installation

Experienced consultants play a significant role in the execution of construction projects. Consultants' lack of management and technical experience on the type of construction work constitute an important cause of delay in construction projects (Alaghbari, et al., 2007; Alnuaimi, et al., 2010). Consultant's lack of experience on the type of construction work may not only result in project delays, but also in handing over a BMS with poor quality (Abdul-Waris, 2012).

### 4.3.11 Lack of Coordination and Collaboration among the Project Team Members

The building construction industry is a highly fragmented industry compared to other industries. One of the most significant consequences of this fragmentation is the lack of coordination and collaboration among the project team members (Alnuaimi et al., 2010). In BMS project installation, lack of coordination and collaboration among the project team members could lead to low levels of productivity, cost and time overruns, conflicts and disputes, resulting in claims and most importantly low quality of construction (Piper, 2005).

## 4.4 Challenges Pertaining to the Operation and Maintenance Phase

This category of challenges includes 10 different challenges. Description of each is provided as follows:

### 4.4.1 Inadequate Initial Training for the BMS Facility Personnel

Adequate training in the field of BMS applications and functions is necessary for the effective performance of the installed systems (Piper, 2004; Horwitz and Bennett, 2009). Operation and maintenance personnel should receive the necessary initial training from the contractor and the supplier during the acceptance phase of the project. This training enables the operation and maintenance staff to learn about the technical attributes of the installed systems (Bourassa and Johnson, 2007; Sam, 2010). The duration of the provided training to the operation and maintenance personnel should be proportional to the complexity of the installed systems (Acal, 2012).

### 4.4.2 Lack of Continued Training for the BMS Facility Personnel

Continued training should be provided to the operation and maintenance personnel to ensure the effective operation of the installed BMS on the long run (Piper 2004, 1996; Lewis et., 2010). Continued training is essential for several reasons. One reason could be the addition of new features and functions that the existing BMS facility personnel may not aware about them. Another reason could be changing the utilization and physical characteristics of the building, which will impact upon the existing BMS. A third reason could be the accommodation of the turnover of the existing BMS facility personnel to acquaint the new facility personnel with the necessary skills for the operation of the installed systems (Petze, 1996; Yaseen, 2012).

### 4.4.3 Lack of Adequate Technical Documentations Provided by Contractors and Suppliers

Technical documentation of the BMS such as the operation and maintenance manuals and as- built drawings serve to provide guidance for the operation and maintenance personnel during the service life of the building. These documents are usually developed, modified and provided by the contractors and suppliers during construction and acceptance phases of the project (Sam,2010). However, these technical documents may not be developed adequately to enable the operation and maintenance personnel to use them effectively (Schneider, 2005; Adowia, 2012). This results in wasting a substantial amount of time to locate the necessary information to carry out the required operation and maintenance activities (Zeitoon, 2011).

### 4.4.4 Insufficient Staffing for the BMS Operation

A general misconception about the BMS is that it operates itself. The result of this misconception is the understanding that the BMS is a labor-saving system. However, all BMSs require an adequate number of personnel to frequently inspect the operation of the system and solve deficiencies as they feature (Piper, 2004). In addition to the regular operation and maintenance personnel, it is recommended that a designated staff is assigned to monitor, control, verify and benchmark the energy consumption in the facility through the use of the BMS (Zeitoon, 2011).

### 4.4.5 Poor Usability of the BMS User Interface

BMS consists of two main parts. These parts are the hardware and the software. A common challenge encountered during the operation of BMSs is the usability of its user interface (Penner and Steinmetz, 2002). Usability is defined by Bevana et. al. (1991) as "*the ease of use and acceptability of a system or product for a particular class of users carrying out specific tasks in a specific environment; where 'ease of use' affects user performance and satisfaction, and 'acceptability' affects whether or not the product is used*". Poor usability of the user interface could derive facility users away from using the capabilities of the BMS on a regular basis as a technique for optimizing the performance of buildings (Ehrlich and Goldschmidt, 2011: Makarechi and Kangari, 2011; McKew, 2001).

### 4.4.6 Lack of Service and Technical Support after Installation by Suppliers

The availability of service and technical support by suppliers after installation is one of the most important parameters that affect the successful performance of the BMS (Makarechi and Kangari, 2011).The service and the technical support that could be provided by suppliers include repair and replacement of parts, upgrading, training, and re-commissioning (Katzel, 1998).

### 4.4.7 Poor Operations and Maintenance Activities

Effective operation and maintenance programs ensure reliability, energy efficiency, and minimization of workplace disruption. Operation and maintenance programs consist of five elements. These elements are operations, maintenance activities, engineering support, training and administration. Operation and maintenance activities include day-to-day and long-term activities such as budget preparation, conducting preventive maintenance, processing of material requests and processing of work orders (Sullivan et. al., 2010). (Zeitoon, 2011) emphasized that effective operation and maintenance activities is a pre-requisite for ensuring the successful operation and maintenance of the BMS.

### 4.4.8 Lack of Adequate BMS Retro-commissioning

The retro-commissioning practice of existing buildings focuses on the process of commissioning buildings that have never been commissioned before. These un-commissioned buildings were handed over to the operation and maintenance personnel with operating deficiencies in place, incomplete technical information, and inadequate operator training for critical building systems such as BMSs (Sullivan et al. 2010). The systems that usually undergo the process of retro-commissioning are the mechanical and electrical systems. The practice of retro-commissioning is essential for meeting the intended design potential and ensuring the effective performance of facilities over time (Sam, 2010).

### 4.4.9 Inadequate Re-commissioning of BMS

Re-commissioning is the process of commissioning existing building systems that have previously been commissioned or retro-commissioned. The main advantage of the building systems' re-commissioning is ensuring that the benefits gained from the initial commissioning or retro-commissioning remain effective (Sam, 2010). Several practitioners in the field of BMS indicated that re-commissioning for BMS should be carried out periodically to ensure the effective performance of the BMS during the service life of the building (Katzel, 1998; Piper, 2004; Zeitoon, 2011).

### 4.4.10 Lack of Certified and Trained BMS Operators

A growing concern that facility owners and managers are facing is the lack of certified and well trained BMSs operators. Basic qualities demanded in BMS operators include comfort with technology, good command of the English language, adequate level of computer proficiency (Lewis et al., 2010). Practitioners in Saudi Arabia in the field of facilities management pointed out to the shortage of certified and well trained BMS operators in the construction industry market. This shortage is mainly attributed to the lack of institutes that provide training programs for facility operation (Acal, 2012; Yaseen, 2012).

# CHAPTER 5

# DATA ANALYSIS AND RESULTS

## 5.1 Part-One: A Five Point Likert Scale Questionnaire Survey

### 5.1.1 Introduction

The first objective of this study is to identify and assess the challenges that adversely affect the implementation of the BMS during the life cycle of the office buildings. This objective has been achieved through two phases described as follows:

**Phase-I:** Identifying thirty two challenges from literature review, interviews with designers, contractors, facility managers and operators of the BMS in the Eastern province of Saudi Arabia. The identified challenges have been discussed in chapter three.

**Phase-II:** Assessing the identified challenges by analyzing the data obtained through the questionnaire survey (Appendix II) as described in the following:

### 5.1.2 Development of the Questionnaire Survey

A five point likert scale questionnaire survey (Appendix II), is developed and distributed to a representative sample of A/E firms (designers), construction firms and facility mangers in the Eastern Province of Saudi Arabia (namely Dammam, Khobar and Dhahran). It is divided into three categories, each category is administered to a representative sample of A/E firms (designers), or construction firms or facility managers. Each category consists of two parts described as follows:

**Part-I:** This part requested the respondents to provide their contact information, positions, years of experience.

**Part-II:** This part focused on the assessment of the identified challenges by using a five point likert scale questionnaire survey.

## 5.1.3 Determination of the Population and Sample Sizes

For this study, three types of groups who have direct involvement with the implementation of BMS for building projects are selected. Population estimates were based on data contained mainly in the Chambers of Commerce in the Eastern Province of Saudi Arabia. This data included a list of 145 A/E and 815 construction firms registered in the Eastern Province. The sample size of the respondents is determined as follows:

### 5.1.3.1 The Sample Size of the A/E Firms

A list of 145 A/E firms (population size N) was obtained from the Chambers of Commerce in the Eastern Province of Saudi Arabia. Equations 1.1 and 1.2 included in chapter one, are used to calculate the sample size (n) of the A/E firms as follows:

- ✓ **Sample size (n)** = 25/ [1+ (25/145)] = **22** A/E firms

#### 5.1.3.2 The Sample Size of the Construction Firms

A list of 817 construction firms (population size N) was obtained from the Chambers of Commerce in the Eastern Province of Saudi Arabia. Equations 1.1 and 1.2 included in chapter one, are used to calculate the sample size (n) of the construction firms as follows:

- ✓ **Sample size (n)** = 25/ [1+ (25/815)] = **25** Construction firms

#### 5.1.3.3 The Sample Size of the Facility Managers

Sixteen facility managers of the office buildings equipped with BMS located at Dammam, Khobar and Dharan, were selected to assess the identified challenges pertaining to the operation and maintenance phases of the office buildings.

### 5.1.4 Pilot-Testing of the Questionnaire Survey

The developed questionnaire surveys were pilot-tested with a samples of A/E firms (designers), a samples of construction firms (contractors) and a samples of facility managers in the Eastern Province of Saudi Arabia and the benefits of the Pilot-testing will be:

- Checking the adequacy of the survey's questions.
- Determining locations of ambiguity in the survey.
- Estimating the time needed to complete the survey.
- Checking the level of editing the survey themes pages (space for answering, font's size ...etc.).

### 5.1.5 Distribution of the Questionnaire Survey

After conducting the questionnaires pilot-testing, the tested questionnaires were distributed to the respondents (including 30 A/E firms, 30 Construction firms and 20 facility mangers) in the Eastern Province of Saudi Arabia to assess the importance of the identified challenges based on their areas of specialization.

Using five point likert scales questionnaire survey, the respondents were asked to indicate their perceived relative degree of effect for each of the identified challenges by selecting one of the five evaluation scales; **“Extreme Effect (1)”, “Strong Effect (2)”, “Moderate effect (3)", "Slight Effect(4)” and “Does Not Effect(5)”**.

The responses to the questionnaire survey were collected from 24 A/E firms, 28 Construction firms and 16 facility managers in the Eastern Province.

### 5.1.6 Questionnaire Survey Analysis

Based on the nature of the developed questionnaire survey, the analysis of the data obtained from the respondents (22 A/E firms, 27 Construction firms and 16 facility managers) is divided into two sections as follows:

- Section One: General information of the respondents.
- Section Two: Assessment of the Identified challenges.

#### 5.1.6.1 Section One: General Information of the Respondents

This section of the questionnaire survey contains questions about respondent's information, his position in the firms and his number of years of experience. Simple descriptive statistical methods (namely percentages simple graphics and summaries of the findings) were used to analyze the data that was received from the respondents.

##### 5.1.6.1.1 Respondent’s Number of Years of Experience

The number of years of experience is determined by allowing the respondents to choose one out of four ranges of years of experience as follows: “Less than 5 years”, “5 – 10 years”, “10 – 20 years” and “over 20 years”. The following sections present a brief description of the respondent's numbers of years of experience.

- **A/E Firm's Respondent's Number of Years of Experience**

As shown in Figure 12, 63 % of the respondents (14 A/E Firm's respondents out of a total of 22) have been working in their areas of specialization for more than 10 years. The results presented that about 36% of the respondents (8 A/E firm's respondents) have ten to twenty years of experience, 27% of the respondents (6 A/E firm's respondents) have more than twenty years of experience, about 23% of the respondents (5 A/E firm's respondents) have five to ten years of experience and about 14 % (3 A/E firm's respondents) have an experience of less than 5 years.

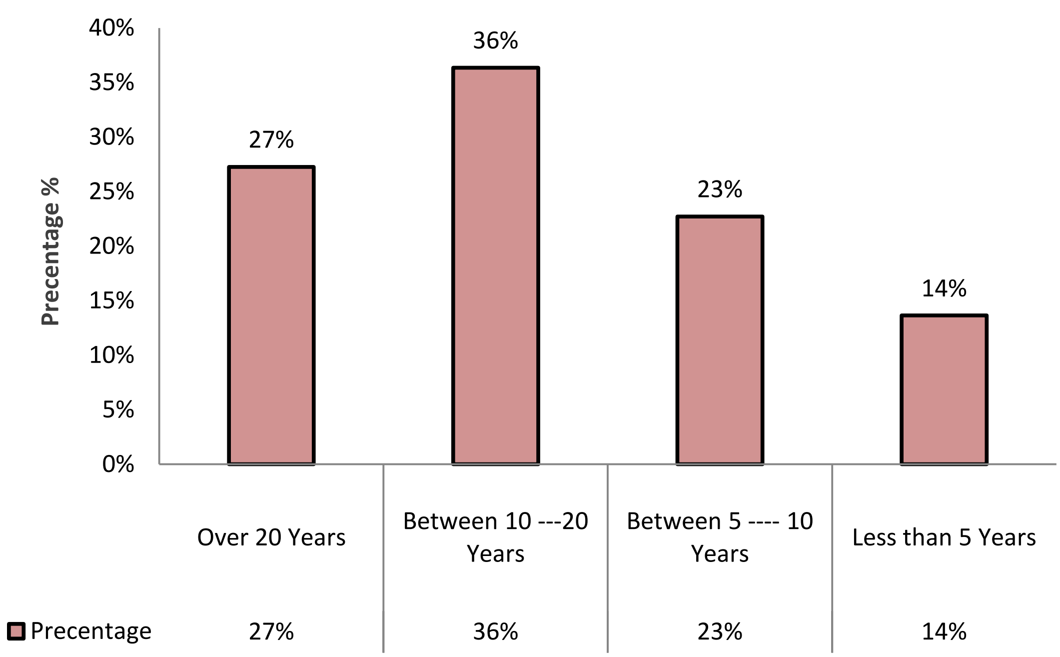


**Figure 12 A/E Firm's Respondent's Number of Years of Experience**

- **Construction Firm's Respondent's Number of Years of Experience**

As shown in Figure13, 66 % of the respondents (18 construction firm's respondents out of a total of 27) have been working in their areas of specialization for more than 10 years. The results presented that about 44% of the respondents (12 construction firm's respondents) have ten to twenty years of experience, 22% of the respondents (6 construction firm's) have more than twenty years of experience, about 26% of the respondents (7 construction firm's respondents) have five to ten years of experience and about 8 % (2 construction firm's respondents) have an experience of less than 5 years.

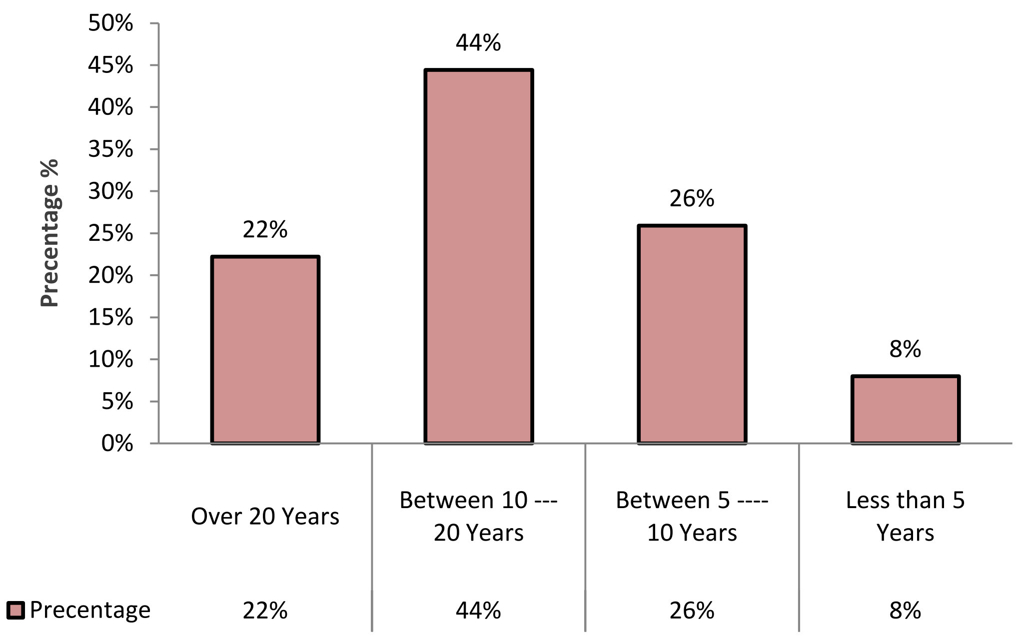


**Figure 13 Construction Building's Respondent's Number of Years of Experience**

- **Office Building's Respondent's Number of Years of Experience**

As shown in Figure 14, 62 % of the respondents (10 office building's respondents out of a total of 16) have been working in their areas of specialization for more than 10 years. The results presented that about 31% of the respondents (5 office building's respondents) have ten to twenty years of experience, 31% of the respondents (5 office buildings' respondents) had more than twenty years of experience, about 31% of the respondents (5 office buildings' respondents) have five to ten years of experience and about 7% (1 office buildings' respondents) have an experience of less than 5 years.

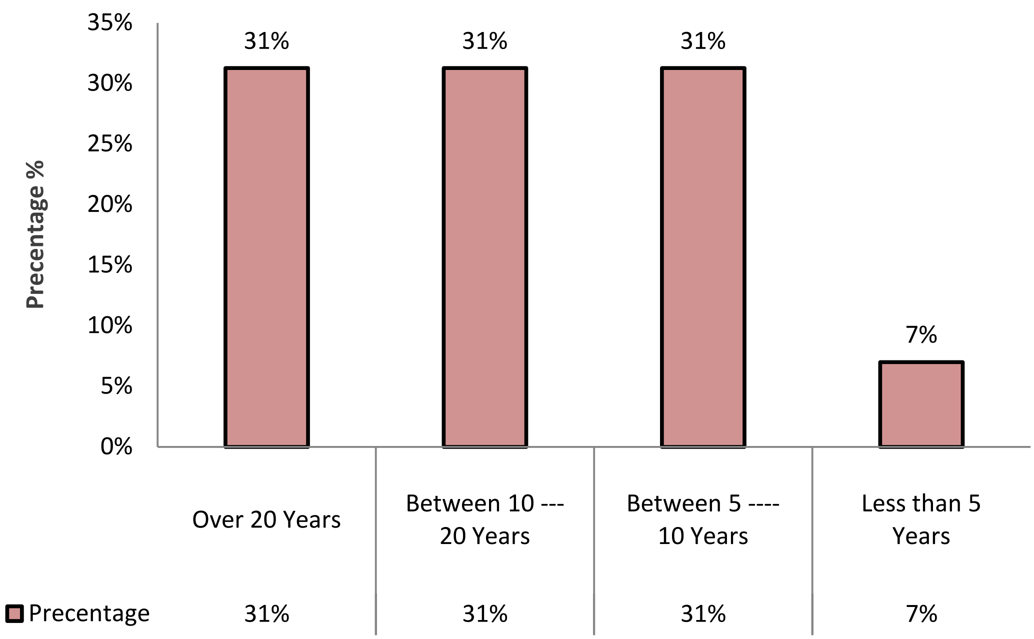


**Figure 14 Office Building's Respondent's Number of Years of Experience**

#### 5.1.6.1.2 Respondents' Position in their Organizations

All the respondents were asked to determine their position in their organizations (A/E, construction firms and office buildings) by specify one of the provided options or specified other if needed.

- **A/E Firm's Respondent's Positions in their Organizations**

As presented in Figure 15, 77 % of the respondents (17 A/E firm's respondents out of a total of 22) are practicing as electrical engineers or mechanical engineers. The results of the questionnaire survey indicate that about 41% of the respondents (9 A/E firm's respondents) are practicing as electrical engineers, 36% of the respondents (8 A/E firm's respondents) are practicing as mechanical engineers, 14% of the respondents (3 A/E firm's respondents) are practicing as project managers and about 9% (2 A/E firm's respondents) are practicing as architectural engineers.

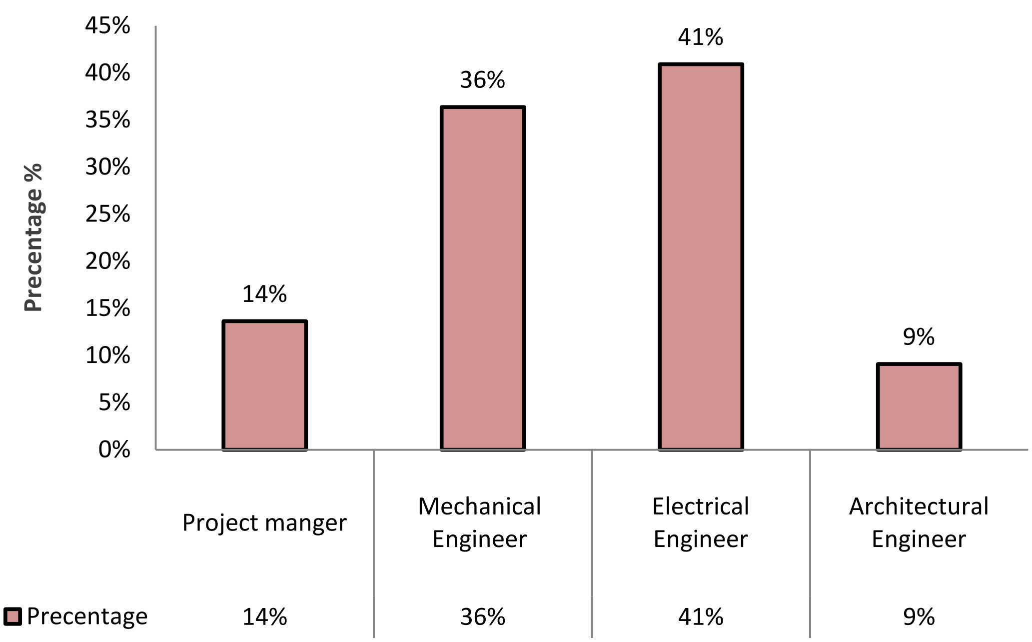


**Figure 15 A/E Firm's Respondent's Positions in their Organizations**

- **Construction Firm's Respondent's Positions in their Organizations**

As presented in Figure 16, 71 % of the respondents (19 construction firm's respondents out of a total of 27) are practicing as electrical engineers or mechanical engineers. The results of the questionnaire survey shown that about 56% of the respondents (15 construction firm's respondents) are practicing as electrical engineers, 15% of the respondents (4 construction firm's respondents) are practicing as mechanical engineers, about 22 % (5 construction firms' respondents) practicing as project managers and about 7 % (2 construction firm's respondents) are practicing as civil engineers.

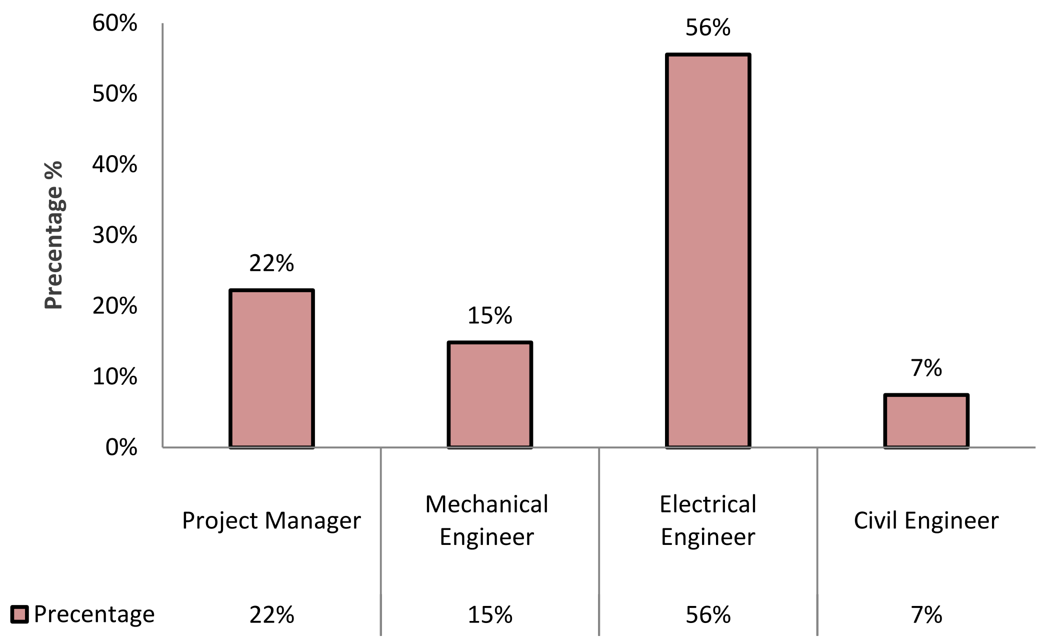


**Figure 16 Construction Firm's Respondent's Positions in their Organizations**

- **Office Building's Respondent's Positions in their Organizations**

As presented in Figure 17, 56% of the respondents (9 office building's respondents out of a total of 16) are practicing as facility managers and about 44 % (7 office buildings' respondents out of a total of 16) are practicing as maintenance department managers or BMS operators.

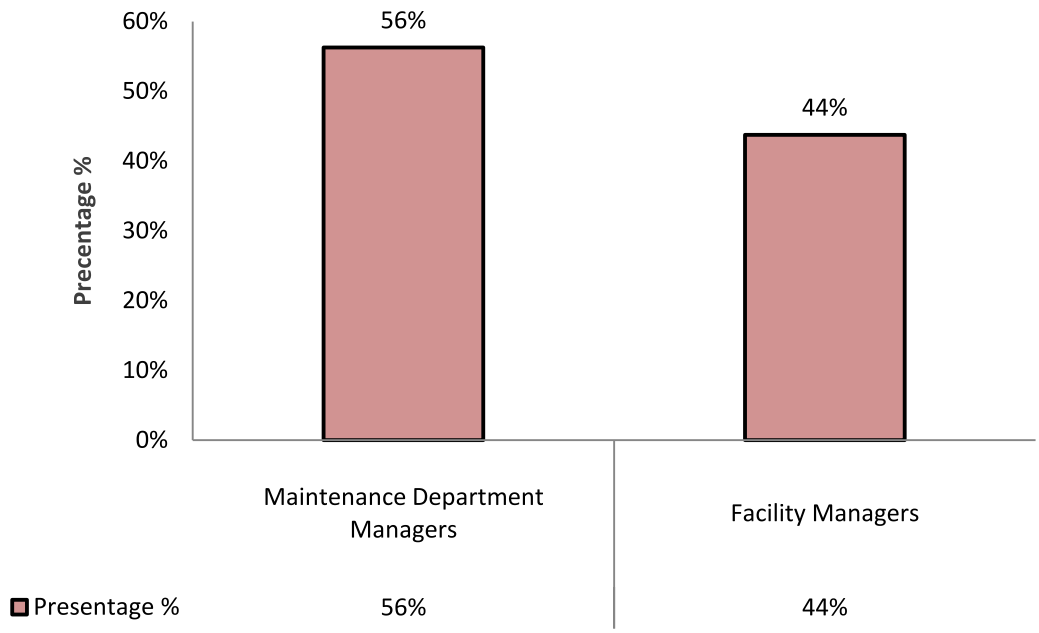


**Figure 17 Office Building's Respondent's Positions in their Organizations**

### 5.1.6.2 Section Two: Assessment of the BMS' Challenges

The second section of the questionnaire focused on the evaluation of the identified thirty two challenges that could potentially affect the implementation of the building management during the life cycle of the office buildings. These challenges were arranged in three categories. Based on their areas of specialization (design engineers, contractor engineers and facility management personnel), the respondents were asked to determine the importance of the identified challenges by selecting one of five assessment terms namely; **“Extreme Effect (1)”, “Strong Effect (2)”, “Moderate effect (3)", "Slight Effect(4)” and “Does Not Effect(5)”**.

The received data is analyzed to calculate the importance index and the rate of importance for each identified challenge by using the following formula (Dominowski 1980):

$$\textbf{Importance index } I = \frac{\sum_{4}^{i=0} aixi}{4\sum xi} \times 100\ \% \ldots\ldots\ldots\ldots\ldots\ldots (5.1)$$

To determine the degree of importance according to the respondents’ answers to the questionnaire, the following calibration is used:

The importance index of 0–<12.5% is categorized as ‘‘**Does Not Effect**’’; 12.5–<37.5% is categorized as ‘‘**Slight Effect**’’, 37.5–<62.5% is categorized as ‘‘**Moderate effect**’’, 62.5–<87.5% is categorized as ‘‘**Strong Effect**’’, and 87.5–100% is categorized as ‘‘**Extreme Effect**’’.

Microsoft Excel was used to facilitate the process of applying the previous equation to all identified challenges. Table 3 illustrates a summary of the assessed challenge's importance index values and their rate of importance.

**Table 3 Assessed Challenges' Importance Indexes and Rate of Importance**

| Challenges Influencing the Successful Implementation of BMS | | A/E Firms' Respondents | | Construction Firms' Respondents | | Office Buildings' Respondents | |
|---|---|---|---|---|---|---|---|
| | | Importance Index | Rate of Importance | Importance Index | Rate of Importance | Importance Index | Rate of Importance |
| A. Challenges pertaining to the design and briefing phases | | | | | | | |
| 1 | Lack of clients' involvement in the briefing process. | 93.2 | **Extreme Effect** | | | | |
| 2 | Lack of end-user' involvement in the briefing process. | 77.3 | **Strong Effect** | | | | |
| 3 | Unfamiliarity of the brief developer's with the technical requirements of BMS. | 63.6 | **Strong Effect** | | | | |
| 4 | Insufficient technical experience of the client with the BMS. | 62.5 | **Strong Effect** | | | | |
| 5 | Absence of commissioning practices during the briefing process. | 54.5 | **Moderate Effect** | | | | |
| 6 | Poor communication between the client and the brief developer | 54.5 | **Moderate Effect** | | | | |
| 7 | Provision of sub-optimal requirements of the BMS. | 87.5 | **Extreme Effect** | | | | |
| 8 | Inappropriate selection of the A/E team. | 95.5 | **Extreme Effect** | | | | |
| 9 | Lack of sub-contractor's involvement in the design of BMS as "a design-assist". | 63.6 | **Strong Effect** | | | | |
| 10 | Absence of commissioning practices during the design process. | 53.4 | **Moderate effect** | | | | |
| 11 | Inappropriate selection of the BMS. | 95.5 | **Extreme Effect** | | | | |
| B. Challenges pertaining to the installation, acceptance, and warranty phases | | | | | | | |
| 1 | Inappropriate selection of subcontractors to install the BMS. | | | 93.5 | **Extreme Effect** | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 2 | Inappropriate selection of the BMS suppliers. | | | 89.8 | **Extreme Effect** | | |
| 3 | Inadequate review of the BMS submittals and shop drawing provided by subcontractors. | | | 79.6 | **Strong Effect** | | |
| 4 | Frequent change orders due to client's demands | | | 73.1 | **Strong Effect** | | |
| 5 | Provision of incomplete plans and specifications of the BMS. | | | 73.1 | **Strong Effect** | | |
| 6 | Absence of alternative design proposals provided by the BMS contractors. | | | 53.7 | **Moderate Effect** | | |
| 7 | Lack of involvement of the commissioning agent during the installation, acceptance and warranty phases. | | | 56.5 | **Moderate Effect** | | |
| 8 | Improper selection of the commissioning agent. | | | 55.6 | **Moderate Effect** | | |
| 9 | Consultant’s supervisors may not possess collective experience about BMS installation. | | | 73.1 | **Strong Effect** | | |
| 10 | Lack of coordination and collaboration among the project team members. | | | 87.0 | **Strong Effect** | | |
| 11 | Lack of end user involvement during commissioning practices. | | | 67.6 | **Strong Effect** | | |
| | C. Challenges pertaining to the operation and maintenance phases | | | | | | |
| 1 | Inadequate initial training for the BMS facility personnel. | | | | | 85.9 | **Strong Effect** |
| 2 | Lack of continued training for the BMS facility personnel. | | | | | 59.4 | **Moderate effect** |
| 3 | Lack of adequate technical documentation by contractors and suppliers. | | | | | 76.6 | **Strong Effect** |
| 4 | Poor usability of BMS user interface. | | | | | 53.1 | **Moderate effect** |
| 5 | Insufficient staffing for BMS operation. | | | | | 54.7 | **Moderate effect** |
| 6 | Lack of adequate BMS retro-commissioning practice | | | | | 59.4 | **Moderate effect** |
| 7 | Inadequate re-commissioning of BMS. | | | | | 54.7 | **Moderate effect** |
| 8 | Poor operations and maintenance activities. | | | | | 85.9 | **Strong Effect** |
| 9 | Lack of service and technical support after installation by supplies. | | | | | 76.6 | **Strong Effect** |
| 10 | Lack of certified and trained BMS operators | | | | | 67.2 | **Strong Effect** |

### 5.1.7 Result Analysis and Findings of Part One

As discussed in chapter three, the challenges that potentially affect the successful implementation of the BMS are divided into three categories based on their nature. Each category has several challenges, the respondents to the questionnaire survey did not suggest additional significant or relevant challenges to the questionnaire survey. Discussion of the result of the assessment with brief description for each challenge is presented in the following sections.

#### 5.1.7.1 Category–A: Challenges Pertaining to the Briefing and Design Phases

This category includes eleven challenges namely, lack of client's involvement in the briefing process, lack of end-user' involvement in the briefing process, unfamiliarity of the brief developer's with the technical requirements of BMS, insufficient technical experience of the client with the BMS, absence of commissioning practices during the briefing process, poor communication between the client and the brief developer provision of sub-optimal requirements of the BMS, inappropriate selection of the A/E team, lack of sub-contractor's involvement in the design of the BMS as "a design-assist" and inappropriate selection of the BMS. The results of evaluation of challenges related to this category are discussed as follows:

##### 5.1.7.1.1 Lack of Clients' Involvement in the Briefing Process

Integrating building systems throughout BMS is not a "cookie cutter" deal, because there are different building types and different business objectives for private and public-sector building clients. Therefore, it is the business drivers of client that shape the approach for successfully integrating building systems (Sinopoli,2010).As illustrated in Table 3, this challenge comes with an overall importance index of 93.2%.

##### 5.1.7.1.2 Lack of End-User' Involvement in the Briefing Process

End users might be the representatives of the client organization, or they may be individuals or groups upon whom the organizations activities depend on, such as their clients or visitors (Juaim and Hassanain, 2011). The most important end users that have the authority and ability to provide significant contributions in the development the BMS are operation and maintenance staffs and facility mangers (Lowry, 2002; Petze, 1996 and Sinopoli, 2010). As illustrated in Table 3, this challenge comes with an overall importance index of 77.3%.

##### 5.1.7.1.3 Unfamiliarity of the Brief Developer's with the Technical Requirements of BMS

Usually the architect is the brief developer and has the responsibilities to develop the briefing program for the project as well as generate the architectural design of the project. However, not all architects have the knowledge and experiences to be good brief developers, Shen and Chung, 2006; Juaim & Hassanain, 2011 stated that "*architects, being responsible for developing the briefing program, should possess adequate experience in other professional disciplines*". As illustrated in Table 3, this challenges comes with an overall importance index of 63.6%.

##### 5.1.7.1.4 Insufficient Technical Experience of the Client with the BMS

The client's high level of technical experience with BMS tends to determine detailed, sometimes meticulous performance requirements; on the other hand the essential client's performance requirements of the BMS may be overlooked due to the client's low level of technical experience with BMS (Schneider, 2005). As illustrated in Table 3, this challenge comes with an overall importance index of 62.5%.

##### 5.1.7.1.5 Absence of Commissioning Practices during the Briefing Process

The old understanding of the commissioning practices is a simple testing at the end of the construction phase and off course this is not commissioning. The commissioning practices should start early at the building briefing to design processes and continue throughout construction and startup processes. Appropriate commissioning of the building management system is one of the most significant factor that affects the success of the BMS (Ellis, 2004; Bourassa and Johnson, 2007). As illustrated in Table 3, this challenge comes with an overall importance index of 54.5%.

##### 5.1.7.1.6 Poor Communication between the Client and the Brief Developer

Effective communication between the brief developer and the client is one of the critical issues that affect the success of the briefing process. Communication problems between building clients and the briefing developer due to using different vocabularies is one of the challenge that affect the success of the building management systems during the briefing process of building management systems (Runde et al., 2010 ; Runde et al., 2009). As illustrated in Table 3, this challenge comes with an overall importance index of 54.5%.

##### 5.1.7.1.7 Provision of Sub-Optimal Requirements of the BMS

There are many cases that might limit the development of the optimal briefing program of the BMS. Some of these cases are; non-uniform documentation of the briefing, communication problems between the client and the briefing developer, lack of the software support briefing process of the BMS. The development of the optimal client and user requirements for BMSs is a significant issue for the future engineering phases of the building management systems (Runde et al., 2010 ; Runde et al., 2009). As illustrated in Table 3, this challenge comes with an overall importance index of 87.5 %.

#### 5.1.7.1.8 Inappropriate Selection of the A/E Team

The success of the BMS design requires specialized controls knowledge at the level of A/E firm's engineers. This knowledge is usually gained throughout adequate hands-on training (Ehrlich and Goldschmidt, 2009). Therefore, the selection of the A/E firm that has well trained engineers in the context of the BMS is a critical factor that may drive the BMS design to the success. As illustrated in Table 3, this challenge comes with an overall importance index of 95.5%.

#### 5.1.7.1.9 Lack of Sub-Contractor's Involvement in the Design of the BMS as "a Design-Assist"

Unfortunately, the conventional university programs of mechanical or architectural engineering degree don't have adequate training on the intricacies of modern building management systems. However, due to their daily practices, engineers and control technicians of the subcontractors receive this training (Ehrlich and Goldschmidt, 2009). As illustrated in Table 3, this challenge comes with an overall importance index of 63.6%.

#### 5.1.7.1.10 Absence of Commissioning Practices during the Design Process

stated that appropriate commissioning of the building management system is one of the most significant factors that affects the success of the BMS. During design process of the BMSs, the commissioning agent plays a critical role throughout: a) providing ongoing assistance in the development of the basis of the design document, b) ensuring that the construction document covers both the client's project requirements and the basis of the design documents (Bourassa and Johnson ,2007). As illustrated in Table 3, this challenge comes with an overall importance index of 53.4%

#### 5.1.7.1.11 Inappropriate Selection of the BMS

Unfortunately, some installed BMS don't achieve their full potential. Some of the required functions are not included and some of the functions are never used. Expected cost saving is not achieved. Obviously, there are many reasons behind these problems and one of them can be traced back to the inappropriate selection of the contractor, and the most important reason is that the system selected was does not match functional and technical requirements of the project (Piper, 2002). As illustrated in Table 3, this challenge comes with an overall importance index of 95.5%

### 5.1.7.2 Category–B: Challenges Pertaining to the Installation, Acceptance, and Warranty Phases

This category includes eleven challenges, namely inappropriate selection of the subcontractors to install the BMS, inappropriate selection of the BMS suppliers, inadequate reviewing of the BMS submittals and shop drawing provided by subcontractors, frequent change orders due to client's demands, provision of incomplete plans and specifications of the BMS, absence of alternative design proposals provided by BMS contractors, lack of involvement of the commissioning agent during the installation, acceptance, and warranty phases of the BMS, improper selection of the commissioning agent, consultant's supervisors may not possess collective experience about BMS installation, lack of coordination and collaboration among the project team members and lack of end user involvement during the commissioning practices. The results of evaluation of challenges related to this category are discussed as follows:

#### 5.1.7.2.1 Inappropriate Selection of the Subcontractors to Install the BMS

The quality of installing the BMS by subcontractors is more important than the systems itself. Selecting the most appropriate subcontractor for installing the BMS is different from one project to other (Hillebrand, 2007). As illustrated in Table 3, this challenge comes with an overall importance index of 93.5%.

#### 5.1.7.2.2 Inappropriate Selection of the Suppliers to Install the BMS

During the selection of the BMS suppliers' many factors should be considered such as cost, service, support, quality, and compatibility to open standards. In the paper the authors emphasize that for long term success of the BMS, careful and appropriate selection of the BMS supplies must be taken into account (Ehrlich and Goldschmidt, 2008;Mustafa and Bansal, 2002). As illustrated in Table 3, this challenge comes with an overall importance index of 89.8%.

#### 5.1.7.2.3 Inadequate Reviewing of the BMS Submittals and Shop Drawing Provided by Subcontractors

Many problems might arise during installation process of the building management system. One of the most important of the many is installing or even delivering incorrect equipment to the project site. The main reason behind this is irresponsible approvals for submittals provided by subcontractors without adequate reviewing (Cosiol, 2001). As illustrated in Table 3, this challenge comes with an overall importance index of 79.6%

#### 5.1.7.2.4 Frequent Change Orders Due to Client's Demands

For BMSs change orders during installation phases, Re-identifying or changing BMS specification during installation phases can be as much a sign of trouble as beginning the project without clear requirements for client and user (VanDoren, 2009). As illustrated in Table 3, this challenge comes with an overall importance index of 73.1%.

#### 5.1.7.2.5 Provision of Incomplete Plans and Specifications of the BMS

Failure in providing of complete plans and specifications of the BMS opens ways for the BMS's contractors and supplies to provide their interpretations. This can lead to a series of problems during installation phases such as cost overruns, disputes, and most importantly the BMSs do not match the client's requirements (Cosiol, 2001). As illustrated in Table 3, this challenge comes with an overall importance index of 73.1%.

#### 5.1.7.2.6 Absence of Alternative Design Proposals Provided by the BMS Contractors

Providing alternative design proposals by the BMS contractors can be a huge advantage to the client such as ensuring the quality of the BMS installation and reducing its cost. As illustrated in Table 3, this challenge comes with an overall importance index of 53.7%.

#### 5.1.7.2.7 Lack of Involvement of the Commissioning Agent during the Installation, Acceptance, and Warranty Phases of the BMS

During construction, acceptance, and warranty phases, the commissioning agent plays a vital role to carry out proper commissioning of the BMS. This role requires to carry out functional performance testing, provide support personnel training, documentation, and handing it over to the client, and periodically monitor the BMS (Sam, 2010;Schneider, 2005). As illustrated in Table 3, this challenge comes with an overall importance index of 56.5%.

#### 5.1.7.2.8 Improper Selection of the Commissioning Agent

Sam (2010) indicated that the selected commissioning agent should have a technical knowledge in the type of buildings and systems to be commissioned. In addition to technical knowledge, the commissioning agent should have a comprehensive experience in the commissioning process, and team-building skills that are essential to lead and coordinate the commissioning team. Sohmen (1992) stated that a weak commissioning team leader is a key factor that contributes to ineffective commissioning process. As illustrated in Table 3, this challenge comes with an overall importance index of 55.6%.

#### 5.1.7.2.9 Lack of Coordination and Collaboration Among the Project Team Members

The building project industry is categorized as being a highly fragmented industry, especially if it is compared it to other engineering industry. One of the most important consequence of the fragmentation problem is lack of coordination and collaboration among the project team members. This may cause significant low productivity, cost and time overruns, conflicts and disputes, resulting in claims and more important the quality of the project (Caballero, 2002). As illustrated in Table 3, this challenge comes with an overall importance index of 87%.

##### 5.1.7.2.10 Consultant’s Supervisors may not Possess Collective Experience about BMS Installation

Consultants are one of the most important parties in the construction industry. However, lack of experience on the supervisory personnel of the consultant is one of the most important factors that can case delay in construction projects which is the most common, costly, complex and risky problem encountered in construction industry (Alaghbari, et al., 2007). As illustrated in Table 3, this challenge comes with an overall importance index of 73.1%.

##### 5.1.7.2.11 Lack of End User Involvement during the Commissioning Practices

It is very important that the O&M personnel be involved in all commissioning practices, so that they can get experience with the BMS before the operation and maintenance phase starts and even before the initial training for them begins (Kutsmeda, 2008). As illustrated in Table 3, this challenge comes with an overall importance index of 67.6%.

#### 5.1.7.3 Category– C: Challenges Pertaining to Operation and Maintenance Phase

This category includes ten challenges, namely inadequate initial training for the BMS facility personnel, lack of continued training for the BMS facility personnel, lack of adequate technical documentation provided by contractors and suppliers ,poor usability of the BMS user interface, insufficient staffing for BMS operation, lack of adequate BMS retro-commissioning practice, inadequate re-commissioning of BMS, poor operations and maintenance activities, lack of service and technical support after installation by suppliers , lack of certified and trained BMS operators. The results of evaluation of challenges related to this category are discussed as follows:

##### 5.1.7.3.1 Inadequate Initial Training for the BMS Facility Personnel

The initial training of the BMS facility personnel is usually provided by the BMS subcontractor/supplier during the acceptance phase of the project (Sam, 2010). The training provided by the BMS subcontractor is usually covered technical attributes of the installed system such as how access to the system or how to change operating features and this is not adequate training (Bourassa and Johnson, 2007). As illustrated in Table 3, this challenge comes with an overall importance index of 85.9%.

##### 5.1.7.3.2 Lack of Continued Training for the BMS Facility Personnel

Improper subcontractors, and inadequate initial training are critical challenges that limit the success of the BMS project. The next important challenge for long team success of the BMS is the lack of ongoing training for its personnel (Petze, 1996). As illustrated in Table 3, this challenge comes with an overall importance index of 59.4%.

#### 5.1.7.4 Lack of Adequate Technical Documentations Provided by Contractors and Suppliers

All too often for BMS, as-built drawings are not modified, staying the same as original submittal drawings, and O&M manuals are only copies of the general information of the installed equipment (Schneider, 2005). Availability of adequate technical documentations is critical information for successful operation and maintenance of the BMS (Zeitoon, 2011). As illustrated in Table 3, this challenge comes with an overall importance index of 76.6%.

#### 5.1.7.5 Insufficient Staffing for the BMS Operation

One of the common misconceptions is that the BMS operates by itself. The result of this misconception is an extensive belief that the BMS is a labor-saving system. Although most of the BMS is automatic and the system will increase facility operational and maintenance efficiency, a BMS cannot be implemented and forgotten. As illustrated in Table 3, this challenge comes with an overall importance index of 54.7%.

#### 5.1.7.6 Poor Usability of the BMS User Interface

Poor usability of the BMS users interface is one of the challenge that affects the successful operation of the BMS. They add that many BMS users don't use it on a regular basis as a technique to optimize the buildings, and the main reasons behind that are training and usability (Ehrlich and Goldschmidt, 2011; Penner and Steinmetz, 2002; Makarechi and Kangari, 2011; McKew, 2001). As illustrated in Table 3, this challenge comes with an overall importance index of 53.1%.

#### 5.1.7.7 Lack of Service and Technical Support After Installation by Suppliers

Several service and technical support can and should be provided after installation by BMS suppliers such as repair and replacement parts, upgrading, training, and re-commissioning. Local service and technical support are a critical factor for any attempt to optimize a BMS as a successful business tool (Katzel, 1998). As illustrated in Table 3, this challenges comes with an overall importance index of 76.6%.

#### 5.1.7.8 Poor Operations and Maintenance Activities

O&M activities include day to day and long term activities such as preparing an O&M budget, carrying out preventive maintenance, processing material request forms, processing work orders, etc. The effective O&M activities are pre-requisite to ensure successful operation and maintenance of the building management system (Zeitoon, 2011). As illustrated in Table 3, this challenge comes with an overall importance index of 85.9%.

#### 5.1.7.9 Lack of Adequate BMS Retro-commissioning

Sam (2010) indicated that the results of (Lawrence Berkeley National Laboratory) study of 60 facilities showed that 25% of the BMS are not operating correctly. As a result of this, the author emphasizes that the building management systems retro-commissioning are critical to meet their intended design potential and to ensure their effective performance over time. As illustrated in Table 3, this challenge comes with an overall importance index of 59.4%.

#### 5.1.7.10 Lack of Certified and Trained BMS Operators

Facility owners and managers stated a growing concern that a lack of certified and well trained building operators is looming. The skill sets required are changing such as comfort with technology, good English skills and a level of computer proficiency are a basic requirement for facility operating with ever more complex system controls (Lewis et al., 2010). As illustrated in Table 3, this challenge comes with an overall importance index of 67.2%.

## 5.2 Part-Two: (G-AHP) Questionnaire Survey

### 5.2.1 Introduction

The second objective of this study is to prioritize the influential challenges that impact the successful implementation of BMS during the design and briefing, installation and operation and maintenance stages throughout utilizing the (G-AHP) method. This objective has been achieved through two phases. Phase one is structuring the hierarchy of the challenges. Phase two focuses on carrying out pairwise comparison of the identified challenges. The following sections include textual description of the previous phases.

### 5.2.2 Structuring the Hierarchy

The purpose of this phase is to structure a hierarchy and arrange the influential challenges that were identified in the previous objective from the top level (goal) to the intermediate levels (challenges) and the lowest level (sub-challenges). The following diagram illustrates the hierarchy of challenges.

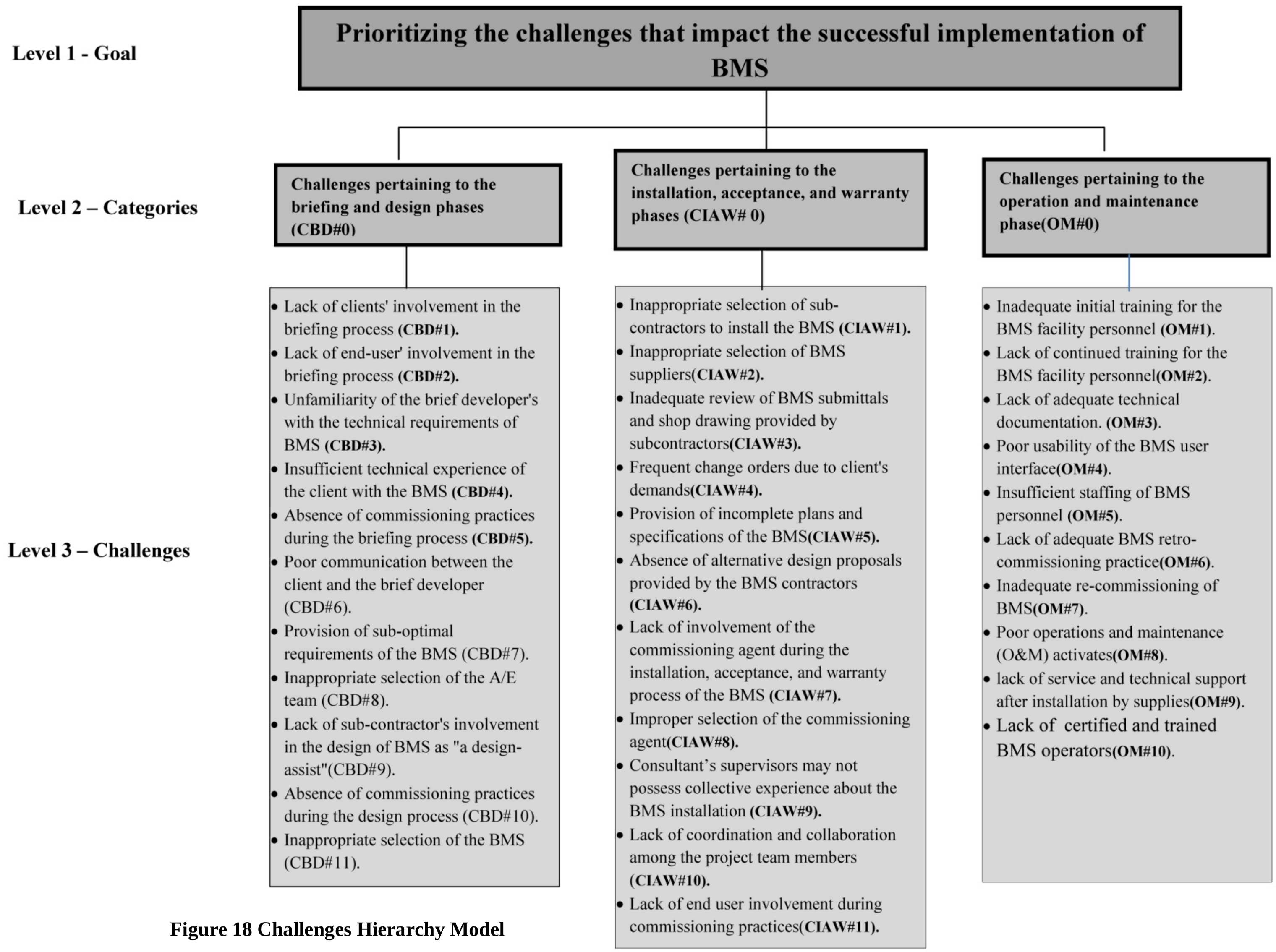


**Figure 18 Challenges Hierarchy Model**

### 5.2.3 Pairwise Comparison Matrixes Survey

In this phase pairwise comparison method was carried to develop (GAHP) conceptual framework for prioritizing the influential challenges that influence the successful implementation of BMS. In order to do this, pairwise comparison method consisted of the following parts:

- **Part one:** Development of pairwise comparison matrixes survey.
- **Part two:** Pilot-testing of pairwise comparison matrixes survey.
- **Part three:** Distribution of pairwise comparison matrixes survey.
- **Part four:** Analysis of pairwise comparison's survey results.

#### 5.2.3.1 Part One: Development of Pairwise Comparison Matrixes Survey

The developed pairwise comparison matrixes survey will be composed of two main sections. The first section gathers general information about the BMS experts .The second section of the comparison matrixes (four matrixes) survey will allow the BMS' experts to assign the degree of effect for each of the identified challenges in terms of which challenge or sub-challenge dominates the other by using Saaty's 1-9 scales. The pairwise comparison matrixes questionnaires survey are shown in Appendix III.

#### 5.2.3.2 Part Two: Pilot-Testing of the Pairwise Comparison Matrixes Survey

The developed questionnaire surveys were pilot-tested by a samples of two BMS's experts in the Eastern Province of Saudi Arabia for purposes of :

- Checking the adequacy of the survey's questions.
- Determining locations of ambiguity in the survey.
- Estimating the time needed to complete the survey.

- Checking the level of editing the survey themes pages (space for answering, font's size ...etc.).

#### 5.2.3.3 Part three: Distribution of pairwise comparison matrixes survey

Six experts in BMS design, installation, and operation and maintenance (two experts of design professionals in (A/E) firms, two experts of installation professionals in construction firms and two experts of operation and maintenance professionals in office buildings) in the Eastern province of Saudi Arabia were asked to assign the weights for each category of challenges and the sub-challenges within each with respect to upper levels by using Saaty's 1-9 scales. The determination of the questionnaire survey respondents (BMS' experts) will be based on questionnaires survey of the preview stage by selecting six respondents with the largest number of years of experience.

#### 5.2.3.4 Part Four: Analysis of Pairwise Comparison's Survey Results

The analysis of pairwise comparison's survey results led to developing (GAHP) conceptual framework (model) for prioritizing the influential challenges and sub-challenges that influence the successful implementation of BMS. Fortunately, several professional commercial software have been developed to estimate the consistency ratio and prioritize the categories of challenges and the sub-challenges within each category, such as **Super Decisions** and **Expert Choice**. In this study, **Expert Choice** was used to calculate the consistency ratio and prioritize the influential challenges and sub-challenges that influences the successful implementation of BMS. The following steps were carried out to analyze the pairwise comparison's survey results:

- **Group-AHP**

The development of the (GAHP) conceptual framework for prioritizing the influential challenges and sub-challenges that influences the successful implementation of BMS requires that the weights of each challenge and sub-challenge for each BMS' expert must to be calculated in geometrical average. The following formula is used to calculate the geometrical average will be used (Kazemi and Allahyari, 2010):

$$\mathrm{Xij}\left(\prod_{\mathrm{I}=1}^{\mathrm{k}} \times \mathrm{ijI}\right)^{1/\mathrm{k}} \ldots\ldots\ldots\ldots\ldots\ldots (5.2)$$

$$\mathrm{i}, \mathrm{j} = 1,2, \ldots., \mathrm{n}, \mathrm{i} \neq \mathrm{j}, \mathrm{I} = 1,2,3, \ldots, \mathrm{k}$$

Where *I* = Decision maker number,
and *k*= the number of decision maker

Comparing categories and challenges of the BMS' experts are reflected in Tables (4-7).

- **Calculation of the Consistency ratio** (CR)

The consistency ratio mainly describes the degree of consistency with the judgments. The higher the consistency ratio, the lesser the consistency within the judgments, while the lower the consistency ratio the higher consistency of the collected judgments. Therefore, CR value must not exceed 0.10. If it does, the judgment should be reviewed and improved (Kazemi and Allahyari, 2010). Table 8 reflect the Consistency ratio of the categories and challenges that adversely affect the implementation of the BMS during the life cycle of the office buildings.

**Table 4 Comparing Categories with Respect to Goal**

| | CBD#0 | CIAW# 0 | OM#0 |
|---|---|---|---|
| CBD#0 | 1 | 1.89485 | 1.58858 |
| CIAW# 0 | | 1 | 3.51623 |
| OM#0 | | | 1 |

**Table 5 Comparing Challenges with Respect to CIAW# 0**

| | CBD#1 | CBD#2 | CBD#3 | CBD#4 | CBD#5 | CBD#6 | CBD#7 | CBD#8 | CBD#9 | CBD# | CBD#11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| CBD#1 | 1 | 1.86441 | 2.26443 | 2.35693 | 1.63759 | 2.44949 | 1.16499 | 1.81712 | 2.63667 | 1.74846 | 2.32215 |
| CBD#2 | | 1 | 2.33801 | 3.10723 | 1.38775 | 1.08887 | 1.23799 | 1.34347 | 1.86194 | 1.16499 | 2.87694 |
| CBD#3 | | | 1 | 1.73205 | 1.7320 | 1.2849 | 2.85364 | 3.01824 | 1.90637 | 1.01982 | 3.45974 |
| CBD#4 | | | | 1 | 2.11694 | 1.08148 | 2.5099 | 3.27107 | 1.57042 | 1.44225 | 4.39929 |
| CBD#5 | | | | | 1 | 1.12246 | 2.11693 | 2.43802 | 1.08887 | 2.26493 | 3.67156 |
| CBD#6 | | | | | | 1 | 1.88597 | 4.9727 | 1.16499 | 2.90419 | 4.69802 |
| CBD#7 | | | | | | | 1 | 1.80861 | 1.94416 | 3.32447 | 3.1881 |
| CBD#8 | | | | | | | | 1 | 3.81583 | 1.42576 | 3.2666 |
| CBD#9 | | | | | | | | | 1 | 1.20094 | 4.11566 |
| CBD#10 | | | | | | | | | | 1 | 5.07128 |
| CBD#11 | | | | | | | | | | | 1 |

**Table 6 Comparing Challenges with Respect to CBD#0**

| | CIAW#1 | CIAW#2 | CIAW#3 | CIAW#4 | CIAW#5 | CIAW#6 | CIAW#7 | CIAW#8 | CIAW#9 | CIAW#10 | CIAW#11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| CIAW#1 | 1 | 1.76273 | 2.5423 | 3.22925 | 3.76206 | 4.33266 | 4.29757 | 4.29757 | 3.51623 | 3.51623 | 2.85364 |
| CIAW#2 | | 1 | 1.73205 | 2.49288 | 2.76823 | 3.47603 | 4.33266 | 3.10723 | 2.58734 | 2.37618 | 1.78549 |
| CIAW#3 | | | 1 | 1.16499 | 1.42387 | 4.3178 | 2.37618 | 2.37618 | 2.11693 | 1.34801 | 1.68021 |
| CIAW#4 | | | | 1 | 1.03789 | 2.24195 | 1.3896 | 1.03789 | 1.30326 | 1.20094 | 2.5099 |
| CIAW#5 | | | | | 1 | 3.09679 | 1.76273 | 2,2787 | 1.10292 | 1.0887 | 1.2849 |
| CIAW#6 | | | | | | 1 | 2.11693 | 1.27021 | 1.3869 | 2.96177 | 2.06171 |
| CIAW#7 | | | | | | | 1 | 1.1872 | 1.4678 | 1.9786 | 1.48678 |
| CIAW#8 | | | | | | | | 1 | 1.49579 | 1.73205 | 1.3896 |
| CIAW#9 | | | | | | | | | 1 | 2.9356 | 2.60847 |
| CIAW#10 | | | | | | | | | | 1 | 2.22004 |
| CIAW#11 | | | | | | | | | | | 1 |

**Table 7 Comparing Challenges with Respect to OM#0**

| | OM#1 | OM#2 | OM#3 | OM#4 | OM#5 | OM#6 | OM#7 | OM#8 | OM#9 | OM#10 |
|---|---|---|---|---|---|---|---|---|---|---|
| OM#1 | 1 | 2.65467 | 1.12246 | 3.0041 | 2.10982 | 1.69043 | 3.21413 | 1.5768 | 1.08887 | 1.98541 |
| OM#2 | | 1 | 1.38309 | 1.88597 | 1.20094 | 1.14235 | 1.70998 | 1.63759 | 1.52544 | 1.0 |
| OM#3 | | | 1 | 2.37618 | 2.57864 | 1.661 | 1.661 | 1.78312 | 1.12246 | 1.97195 |
| OM#4 | | | | 1 | 1.05628 | 2.03009 | 2.97977 | 5.31794 | 2.84027 | 1.59069 |
| OM#5 | | | | | 1 | 2.11693 | 1.37189 | 1.83196 | 2.57864 | 1.20094 |
| OM#6 | | | | | | 1 | 1.9786 | 2.10982 | 1.86441 | 2,22091 |
| OM#7 | | | | | | | 1 | 3.1099 | 1.93505 | 1.25992 |
| OM#8 | | | | | | | | 1 | 1.48477 | 1.83196 |
| OM#9 | | | | | | | | | 1 | 1.48477 |
| OM#10 | | | | | | | | | | 1 |

**Table 8 list of Consistency Ratio**

| Comparing categories and challenges | |
|---|---|
| **With respect to** | **Consistency ratio** |
| Goal | 0.0025 |
| CBD#0 | 0.03 |
| CIAW# 0 | 0.03 |
| OM#0 | 0.02 |

### 5.2.4 Result Analysis and Findings of Part Two

As discussed in chapter three of this study, the challenges that might potentially affect the successful implementation of the BMS are divided into three categories based on their nature. Each category has several challenges. Six experts were asked to weight and rank the categories and their relevant challenges. The opinion of the six experts is reflected in tables (4-7). Table 8 illustrates consistency ratio for categories and their relevant challenges. The value of CR (for categories and challenges) does not exceed 0.1, thus, the consistency ratio is acceptable. The overall ranking of categories is presented in Figure 19. The finding is presented in bar chart form, and its presents the ranking of the categories from the most effective to the least effective. As illustrated, the highest weight was given to challenges pertaining to the installation, acceptance, and warranty phases that had a weight of 0.555, then challenges pertaining to the briefing and design phases that had a weight of 0.278, and the lowest weight was given to challenges pertaining to the operation and maintenance phases. Discussion of assessment of the results for each categories is presented in the following sections.

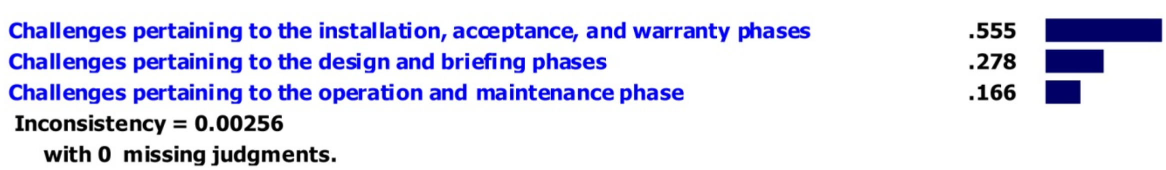


**Figure 19 The Weights of Main Categories**

### 5.2.4.1 Challenges pertaining to the briefing and design phases (CBD#0)

The overall ranking of challenges pertaining to the briefing and design phases is illustrated in Figure 20. The collected data is presented in bar chart form, and it represents the different challenges from the most effective to the least effective. As demonstrated by the BMS experts, the highest weight was given to inappropriate selection of the BMS challenges that had a weight of 0.249, then inappropriate selection of A/E team challenge that had a weight of 0.144, followed by lack of clients' involvement in the briefing process challenge that had a weight of 0.107 and the lowest weight was given to lack of sub-contractor's involvement in the design of BMS as "a design-assist" challenge that had a weight of 0.042. With this analysis, inappropriate selection of the BMS, inappropriate selection of A/E team challenges, lack of clients' involvement in the briefing process challenges are considered relatively effective with regard to challenges pertaining to the briefing and design phases category.


**Figure 20 Challenges Pertaining to the Briefing and Design Phases**

#### 5.2.4.2 Challenges Pertaining to the Installation, Acceptance, and Warranty Phases (CIAW# 0)

The overall ranking of challenges pertaining to the installation, acceptance, and warranty phases is illustrated in Figure 21. The collected data is presented in bar chart form, and represent the different challenges from the most effective to the least effective. As demonstrated by BMS experts, the highest weight was given to inappropriate selection of sub-contractors to install the BMS challenge that had a weight of 0.228, then inappropriate selection of BMS suppliers challenge that had a weight of 0.162, followed by inadequate review of BMS submittals and shop drawing provided by sub-contractors challenge that had a weight of 0.102 and the lowest weight was given to absence of alternative design proposals provided by BMS contractors challenge that had a weight of 0.034. With this analysis inappropriate selection of sub-contractors, inappropriate selection of BMS suppliers and inadequate review of BMS submittals and shop drawing provided by sub-contractors challenges are considered relatively important with regard to challenges pertaining to the installation, acceptance, and warranty phases' category. Challenges Pertaining to the Installation,Acceptance, and Warranty Phases


**Figure 21 Challenges Pertaining to the Installation, Acceptance, and Warranty Phases**

#### 5.2.4.3 Challenges pertaining to the operation and maintenance phase (OM#0)

The overall ranking of challenges pertaining to the operation and maintenance phase is illustrated in Figure 22. The collected data is presented in bar chart form, and represent the different challenges from the most effective to the least effective. As demonstrated by BMS' experts, the highest weight was given to Poor operations and maintenance (O&M) activities challenge that had a weight of 0.173, then inadequate initial training for BMS facility personnel challenge that had a weight of 0.155, followed by Non-availability of service and technical support after installation by suppliers challenge that had a weight of 0.135 and the lowest weight was given to poor usability of BMS user interface challenge that had a weight of 0.043. With this analysis, inadequate initial training for BMS facility personnel, inadequate initial training for BMS facility personnel and Non-availability of service and technical support after installation by supplies challenges are considered relatively important with regard to challenges pertaining to the operation and maintenance phase category.

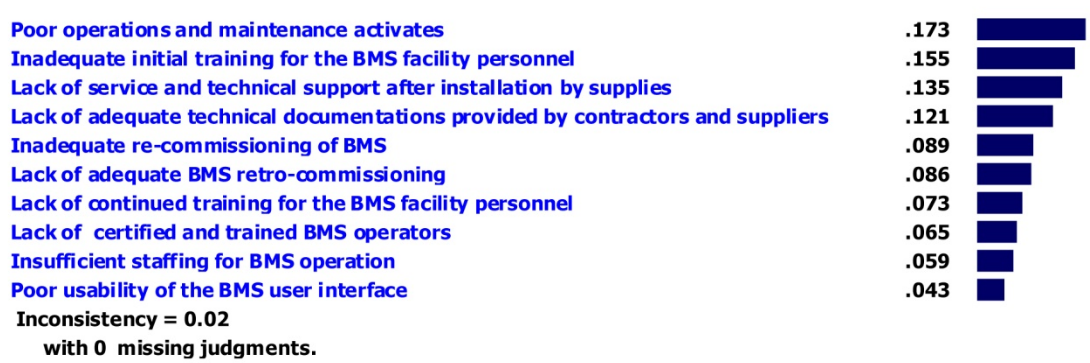


**Figure 22 Challenges Pertaining to the Operation and Maintenance Phase**

## 5.3 Part-Three: Analysis of the Case Studies to Validate the Developed Model

### 5.3.1 Introduction

The third objective of this study is to carry out a series of case studies to validate the developed model. This objective has been achieved in two phases, described as follows,

**Phase-I:** Selecting office buildings samples.

**Phase-II:** Conducting interviews with selected office building's facility managers and BMS operators.

### 5.3.2 Selecting Office Buildings Samples

Eight office buildings equipped with BMSs in the Eastern Province of Saudi Arabia were selected, the basic prerequisite that must be met in BMS of the selected case studies is the controlling and/or monitoring at least for subsystems.

### 5.3.3 Conducting Interviews

Interviews were conducted with selected building's facility managers and BMS operators to prioritize the challenges that influences BMS operation and maintenance in their buildings. The Spearman's rank correlation coefficient ($r_s$) has been used to determine and test the level of agreement between the developed model .It was calculated at a 95% confidence level. The results of the test present that, the level of the agreement between the developed model and case studies are varied from **"too low to be meaningful"** to "**Weak to low**", except two case studies represent a level of the agreement of **"strong"** and **"moderate**". Tables (9-16) show the results of the Spearman's rank correlation coefficient for the eight case studies.

#### 5.3.3.1 Case Study No.1

From Table 9, $\boldsymbol{r_s}$ value = 0.10. So, it can be noticed that the level of agreement between the developed G-AHP model and the case study is too low to be meaningful. This value of the $\boldsymbol{r_s}$ reflected that the implementation of the BMS in case study (1) is facing the challenges of the low rank in the developed G-AHP model.

**Table 9 ($r_s$) for Case Study No.(1)**

| CHALLENGES PERTAINING TO THE OPERATION AND MAINTENANCE PHASES | G-AHP RANK | CAUSE STUDY(1) | $r_s$ INTERPRETION |
|---|---|---|---|
| Poor operations and maintenance activates | 1 | 9 | |
| Inadequate initial training for the BMS facility personnel | 2 | 10 | |
| Lack of service and technical support after installation by supplies | 3 | 5 | |
| Lack of adequate technical documentation provided by contractors and suppliers | 4 | 2 | |
| Inadequate re-commissioning of BMS | 5 | 1 | |
| Lack of adequate BMS retro-commissioning practice | 6 | 3 | |
| Lack of continued training for the BMS facility personnel | 7 | 4 | |
| Lack of certified and trained BMS operators | 8 | 6 | |
| Insufficient staffing for the BMS operation | 9 | 7 | |
| Poor usability of the BMS user interface | 10 | 8 | |
| $\boldsymbol{r_s}$ | - | **0.10** | Too low to be meaningful |

### 5.3.3.2 Case Study No.2

From Table 10, $\boldsymbol{r_s}$ value = 0.70. So, it can be noticed that the level of agreement between the developed G-AHP model and the case study is strong. This value of the $\boldsymbol{r_s}$ reflected that the implementation of the BMS in case study (2) is facing the challenges of the moderate rank in the developed G-AHP model.

**Table 10 ($r_s$) for Case Study No.(2)**

| CHALLENGES PERTAINING TO THE OPERATION AND MAINTENANCE PHASES | G-AHP RANK | CAUSE STUDY(2) | $r_s$ INTERPRETION |
|---|---|---|---|
| Poor operations and maintenance activates | 1 | 4 | |
| Inadequate initial training for the BMS facility personnel | 2 | 1 | |
| Lack of service and technical support after installation by supplies | 3 | 3 | |
| Lack of adequate technical documentation provided by contractors and suppliers | 4 | 2 | |
| Inadequate re-commissioning of BMS | 5 | 9 | |
| Lack of adequate BMS retro-commissioning practice | 6 | 8 | |
| Lack of continued training for the BMS facility personnel | 7 | 6 | |
| Lack of certified and trained BMS operators | 8 | 5 | |
| Insufficient staffing for the BMS operation | 9 | 7 | |
| Poor usability of the BMS user interface | 10 | 10 | |
| $\boldsymbol{r_s}$ | **-** | **0. 70** | Strong |

### 5.3.3.3 Case Study No.3

From Table 11, $\boldsymbol{r_s}$ value = 0.18. So, it can be noticed that the level of agreement between the developed G-AHP model and the case study is weak to low. This value of the $\boldsymbol{r_s}$ reflected that the implementation of the BMS in case study (3) is facing the challenges of the low rank in the developed G-AHP model.

**Table 11 ($r_s$) for Case Study No.(3)**

| **CHALLENGES PERTAINING TO THE OPERATION AND MAINTENANCE PHASES** | **G-AHP RANK** | **CAUSE STUDY(3)** | $\boldsymbol{r_s}$ **INTERPRETION** |
|---|---|---|---|
| Poor operations and maintenance activates | 1 | 6 | |
| Inadequate initial training for the BMS facility personnel | 2 | 1 | |
| Lack of service and technical support after installation by supplies | 3 | 7 | |
| Lack of adequate technical documentation provided by contractors and suppliers | 4 | 4 | |
| Inadequate re-commissioning of BMS | 5 | 9 | |
| Lack of adequate BMS retro-commissioning practice | 6 | 5 | |
| Lack of continued training for the BMS facility personnel | 7 | 2 | |
| Lack of certified and trained BMS operators | 8 | 8 | |
| Insufficient staffing for the BMS operation | 9 | 10 | |
| Poor usability of the BMS user interface | 10 | 3 | |
| $\boldsymbol{r_s}$ | **-** | **0.18** | Weak to low |

#### 5.3.3.4 Case Study No.4

From Table 12, $r_s$ value = 0.20. So, it can be noticed that the level of agreement between the developed G-AHP model and the case study is weak to low. This value of the $r_s$ reflected that the implementation of the BMS in case study (4) is facing the challenges of the low rank in the developed G-AHP model.

**Table 12 ($r_s$) for Case Study No.(4)**

| CHALLENGES PERTAINING TO THE OPERATION AND MAINTENANCE PHASES | G-AHP RANK | CAUSE STUDY(4) | $r_s$ INTERPRETION |
|---|---|---|---|
| Poor operations and maintenance activates | 1 | 10 | |
| Inadequate initial training for the BMS facility personnel | 2 | 3 | |
| Lack of service and technical support after installation by supplies | 3 | 1 | |
| Lack of adequate technical documentation provided by contractors and suppliers | 4 | 5 | |
| Inadequate re-commissioning of BMS | 5 | 4 | |
| Lack of adequate BMS retro-commissioning practice | 6 | 7 | |
| Lack of continued training for the BMS facility personnel | 7 | 2 | |
| Lack of certified and trained BMS operators | 8 | 6 | |
| Insufficient staffing for the BMS operation | 9 | 9 | |
| Poor usability of the BMS user interface | 10 | 8 | |
| $r_s$ | - | **0.20** | Weak to low |

### 5.3.3.5 Case Study No.5

From Table 13, $r_s$ value = 0.04. So, it can be noticed that the level of agreement between the developed G-AHP model and the case study is too low to be meaningful. This value of the $r_s$ reflected that the implementation of the BMS in case study (5) is facing the challenges of the low rank in the developed G-AHP model.

**Table 13 ($r_s$) for Case Study No.(5)**

| CHALLENGES PERTAINING TO THE OPERATION AND MAINTENANCE PHASES | G-AHP RANK | CAUSE STUDY(5) | $r_s$ INTERPRETION |
|---|---|---|---|
| Poor operations and maintenance activates | 1 | 4 | |
| Inadequate initial training for the BMS facility personnel | 2 | 3 | |
| Lack of service and technical support after installation by supplies | 3 | 5 | |
| Lack of adequate technical documentation provided by contractors and suppliers | 4 | 7 | |
| Inadequate re-commissioning of BMS | 5 | 9 | |
| Lack of adequate BMS retro-commissioning practice | 6 | 10 | |
| Lack of continued training for the BMS facility personnel | 7 | 6 | |
| Lack of certified and trained BMS operators | 8 | 1 | |
| Insufficient staffing for the BMS operation | 9 | 2 | |
| Poor usability of the BMS user interface | 10 | 8 | |
| $r_s$ | - | **0.04** | Too low to be meaningful |

### 5.3.3.6 Case Study No.6

From Table 14, $r_s$ value = 0.09. So, it can be noticed that the level of agreement between the developed G-AHP model and the case study is too low to be meaningful. This value of the $r_s$ reflected that the implementation of the BMS in case study (6) is facing the challenges of the low rank in the developed G-AHP model.

**Table 14 ($r_s$) for Case Study No.(6)**

| CHALLENGES PERTAINING TO THE OPERATION AND MAINTENANCE PHASES | G-AHP RANK | CAUSE STUDY(6) | $r_s$ INTERPRETION |
|---|---|---|---|
| Poor operations and maintenance activates | 1 | 10 | |
| Inadequate initial training for the BMS facility personnel | 2 | 9 | |
| Lack of service and technical support after installation by supplies | 3 | 1 | |
| Lack of adequate technical documentation provided by contractors and suppliers | 4 | 2 | |
| Inadequate re-commissioning of BMS | 5 | 5 | |
| Lack of adequate BMS retro-commissioning practice | 6 | 6 | |
| Lack of continued training for the BMS facility personnel | 7 | 4 | |
| Lack of certified and trained BMS operators | 8 | 3 | |
| Insufficient staffing for the BMS operation | 9 | 7 | |
| Poor usability of the BMS user interface | 10 | 8 | |
| **$r_s$** | **-** | **0.09** | Too low to be meaningful |

### 5.3.3.7 Case Study No.7

From Table 15, $r_s$ value = 0.04. So, it can be noticed that the level of agreement between the developed G-AHP model and the case study is too low to be meaningful. This value of the $r_s$ reflected that the implementation of the BMS in case study (7) is facing the challenges of the low rank in the developed G-AHP model.

**Table 15 ($r_s$) for Case Study No.(7)**

| CHALLENGES PERTAINING TO THE OPERATION AND MAINTENANCE PHASES | G-AHP RANK | CAUSE STUDY(7) | $r_s$ INTERPRETION |
|---|---|---|---|
| Poor operations and maintenance activates | 1 | 10 | |
| Inadequate initial training for the BMS facility personnel | 2 | 9 | |
| Lack of service and technical support after installation by supplies | 3 | 1 | |
| Lack of adequate technical documentation provided by contractors and suppliers | 4 | 2 | |
| Inadequate re-commissioning of BMS | 5 | 5 | |
| Lack of adequate BMS retro-commissioning practice | 6 | 6 | |
| Lack of continued training for the BMS facility personnel | 7 | 4 | |
| Lack of certified and trained BMS operators | 8 | 3 | |
| Insufficient staffing for the BMS operation | 9 | 7 | |
| Poor usability of the BMS user interface | 10 | 8 | |
| $r_s$ | - | **0.04** | Too low to be meaningful |

### 5.3.3.8 Case Study No.8

From Table 16, $r_s$ value = 0.53. So, it can be noticed that the level of agreement between the developed G-AHP model and the case study is moderate. This value of the $r_s$ reflected that the implementation of the BMS in case study (8) is facing the challenges of the moderate rank in the developed G-AHP model.

**Table 16 ($r_s$) for Case Study No.(8)**

| CHALLENGES PERTAINING TO THE OPERATION AND MAINTENANCE PHASES | G-AHP RANK | CAUSE STUDY(8) | $r_s$ INTERPRETION |
|---|---|---|---|
| Poor operations and maintenance activates | 1 | 8 | |
| Inadequate initial training for the BMS facility personnel | 2 | 1 | |
| Lack of service and technical support after installation by supplies | 3 | 3 | |
| Lack of adequate technical documentation provided by contractors and suppliers | 4 | 2 | |
| Inadequate re-commissioning of BMS | 5 | 4 | |
| Lack of adequate BMS retro-commissioning practice | 6 | 9 | |
| Lack of continued training for the BMS facility personnel | 7 | 5 | |
| Lack of certified and trained BMS operators | 8 | 6 | |
| Insufficient staffing for the BMS operation | 9 | 7 | |
| Poor usability of the BMS user interface | 10 | 10 | |
| $r_s$ | - | **0.53** | Moderate |

# CHAPTER 6

# RECOMMENDED PLAN OF ACTION

## 6.1 Introduction

This chapter presents the proposed recommendations, a summary and a conclusion of the study. The last objective of this study is to develop a plan of actions to facilitate the implementation of the BMS during the life cycle of office buildings in Saudi Arabia. The developed plan of actions is based on knowledge from the literature and the interviews that were conducted with a selected sample of BMS' designers, contractors and operators in the Eastern Province of Saudi Arabia.

## 6.2 Summary of the Study

This study consists of four objectives namely, to investigate and evaluate the challenges that influence the successful implementation of BMS during the life cycle of office building projects, and to develop a Group Analytic Hierarchy Process (G-AHP) model for prioritizing the challenges, to carry out a series of case studies to validate the developed model, and to develop a plan of action to facilitate the identified challenges.

The methodology adopted to achieve these objectives consists of four main phases. **First,** the study focused on investigating and evaluating the challenges that influence the successful implementation of BMS during the life cycle of office building projects. The study focused on acquiring the challenges through extensive literature review. Then, interviews were conducted with 12 BMS' designers, contractors and operators in the Eastern Province of Saudi Arabia. The literature review and interviews resulted in identifying 32 challenges which were classified and grouped under six main categories and the current local practices of the procedures followed in designing, installation and operating and maintaining the BMS in office buildings. The identified 32 challenges were evaluated to mainly allow participants to add more challenges. This phase was conducted through the development of a five likert questionnaire survey. The questionnaire was developed, tested and distributed and then collected from 65 participants in the Eastern Province of Saudi Arabia.

**Second,** the identified 32 challenges were evaluated in order to prioritize them. This phase was conducted through the development of the pairwise comparison questionnaire survey. The questionnaire was developed, tested and distributed and then collected from 6 BMS experts from Eastern Province of Saudi Arabia.

**Third,** the developed G-AHP model aims to prioritize the identified 32 challenges and their categories. The proposed model was validated throughout conducting 8 case studies in the Eastern Province of Saudi Arabia.

**Finally,** a plan of action to facilitate the identified challenges was developed. Areas of future research are also highlighted.

## 6.3 Conclusion

The following conclusions were made:

- The results of the study indicated that due to the high fragmentation of the building industry, large numbers of challenges are inherent that could influence the process of implementing the building management system.
- Investigation of the challenges influencing the process of implementing the BMS during the life cycle of the office buildings is critical for the successful implementation of the building management system and all different smart building systems exist in the Saudi Arabia market.
- Reviewing and synthesizing various knowledge fields on the BMS implementation highlighted in international literature sources and local interviews with BMS' experts resulted in recognizing thirty-two challenges classified and grouped under three main categories.
- The five likert questionnaire survey was administered in the Eastern Province of Saudi Arabia for the purpose of evaluation of the identified challenges.
- The required sample size for evaluating the identified challenges were 22 A/E Firms, 25 construction firms, and 16 office buildings. The distributed questionnaire surveys were 30 for A/E Firms, 30 for construction firms, and 20 for office buildings' respondents. The collected questionnaire surveys were 24 from A/E Firms, 28 from construction firms, and 16 from office buildings' respondents. The analyzed questionnaire surveys were 22 for A/E Firms' respondents, 27 from construction firms' respondents, and 16 from office buildings' respondents.

- The evaluation results indicated that all challenges were evaluated as either "extreme effect" or "strong effect" or "moderate effect". It confirmed that the identified challenges can have negative influence on the implementation of the new BMS projects in office buildings in Saudi Arabia.
- The pairwise comparison questionnaire survey was developed, administered and collected from 6 BMS' experts in the Eastern Province of Saudi Arabia for the purpose of prioritizing of the identified challenges and their categories.
- The assessment results of the G-AHP model indicated that the highest weight was given to challenges pertaining to the installation, acceptance, and warranty phases that had a weight of 0.555, then challenges pertaining to the briefing and design phases that had a weight of 0.278, and the lowest weight given to challenges pertaining to the operation and maintenance phases.
- The assessment results of the challenges pertaining to the installation, acceptance, and warranty phases indicated that the highest weight was given to the inappropriate selection of sub-contractors to install the BMS challenge that had a weight of 0.228, then inappropriate selection of BMS suppliers challenge that had a weight of 0.162, followed by inadequate review of BMS submittals and shop drawing provided by sub-contractors challenge that had a weight of 0.102.
- The assessment results of the challenges pertaining to the briefing and design phases indicated that the highest weight given to inappropriate selection of the BMS challenges that had a weight of 0.249, then inappropriate selection of A/E team challenge that had a weight of 0.144, followed by lack of clients' involvement in the briefing process challenge that had a weight of 0.107.

- The assessment results of the challenges pertaining to the operation and maintenance phases indicated the highest weight was given to poor operations and maintenance activities challenge that had a weight of 0.173, then inadequate initial training for BMS facility personnel challenge that had a weight of 0.155, followed by Non-availability of service and technical support after installation by supplies challenge that had a weight of 0.135.
- The developed model of the challenges pertaining to O&M phase has been validated through the conducted eight case studies. The results of the spearman's rank correlation coefficient present that, the level of the agreement between the developed model and case studies are varied from **"too low to be meaningful"** to "**Weak to low**", except two case studies present a level of the agreement of **"strong"** and **"moderate**".
- The level of agreement between the developed model and the majority of the case studies reflected that, the implementation of the BMS in them is facing the challenges of the low rank in the developed G-AHP model.
- Despite the presence of a large numbers of studies that confirm the importance of commissioning and re-commissioning practices of the building management system for effective design, installation and operation, the findings of the study indicated that lack of commissioning and re-commissioning practices have low weight in comparison to other challenges.
- The identified challenges can be adapted and applied for any project type and not only the office building projects.

## 6.4 Recommended Plan of Action

### 6.4.1 A/E Team Selection

It is recommended that a selection method such as (fuzzy decision making method) be used as a guide in reviewing the qualifications of different A/E candidate teams. Professional Engineering and Architectural Associations (PEAA) such as AIA (American Institute of Architects) have developed performance guidelines for various disciplines, such guidelines should be considered during the selection process (Nguyen et al., 2008).

### 6.4.2 BMS Selection

It is recommended that a selection model (such as the AHP and ANP decision making model) should be used to support the selection process of the BMS. (Wong and Li, 2008) developed AHP model to analyze and select the building systems in intelligent buildings, such model can be considered by the decision maker during the selection process of the BMS.

### 6.4.3 Commissioning Practices of the BMS

Several studies indicated that appropriate commissioning of the BMS is one of the most significant factors that affects the success of the BMS (Ellis, 2004; Bourassa and Johnson, 2007). Unfortunately, the general understanding of the commissioning practices is a simple testing at the end of the construction phase and by all means this is not appropriate commissioning. So, it is recommended that the client should integrate the commissioning practices from the early stages of the project to construction and startup stages. Buildings designers, contractors and commissioning services providers should encourage their clients to start the commissioning practices from the early stages of the project.

### 6.4.4 Briefing Process

Many studies indicated that a proper standard methodology (framework model) is needed to improve the prevailing briefing process within the construction industry (Juaim and Hassanain, 2011). Therefore, it is recommended that a proper framework model (such as the IDEF0 (Integration Definition for Functional Modeling) model proposed by (Juaim, 2010)) should be adopted by project brief developers to facilitate and improve the briefing process in Saudi Arabia.

### 6.4.5 BMS Supplier Selection

It is recommended that a selection model (such as the AHP and ANP decision making model) should be used to support the selection process of the BMS suppliers (Ho et al., 2010). In this study the authors indicated that AHP model is an effective tool that can support the decision makers in meeting the challenging task of the supplier selection.

### 6.4.6 BMS Subcontractors Selection

Hydeman (2004), Hillebrand (2007) stated that the quality of the installing the building management system by subcontractors is more important than the systems itself. Therefore, it is recommended that a formal pre-qualification process coupled with an owner directed selection process should be used in the selection process of the contractors. Using such type of selection process allows for an appropriate evaluation of, experience, qualification and commitment, resulting in the selection of what will ideally be the best subcontractor (Ehrlich and Goldschmidt, 2008).

### 6.4.7 Initial Training, Involvement of BMS Personnel in the Testing and Commissioning

It is recommended that the BMS personnel should be trained in the operation and maintenance of all the controls devices, instruments and (BMS) computer equipment by a qualified control and instrument technician certificated by the automatic controls specialist. For office buildings, a minimum of two days for up to ten personnel are the fundamental requirements for BMS initial training.  BMS trained personnel should be of different technical levels, capacities and roles including technicians, building operators and maintenance engineers, and facilities management level. The training days should be carried out in isolation and it may take in one day per week over a two week period or other arrangements to suit BMS as personnel. All necessary reference and training manuals should be provided for BMS personnel as part of the training courses (Horwitz-Bennett, 2009).The initial training courses should be planned to be completed prior to test and commissioning of the BMS systems on site, after that BMS personnel must involve the test and commissioning processes, so that upon completion, BMS personnel are fully conversant with the (BMS) operation and maintenance procedure (Sam,2010).

### 6.4.8 Continuous Training

It is recommended that BMS personnel should receive appropriate ongoing training when it is required. There are a number of reasons why an ongoing training is necessary, such as turnover of operations personnel, adding new features or function to the system, extension of the system goals, and systems optimization (Petze,1996).

### 6.4.9 Plans and Specifications of BMS

It is recommended that BMS plans and specifications should embrace applicable code, documentation, warranty, quality, operational, and installation requirements. The project plans must present physical requirements such as device locations, quantities, and execution requirements. Database parameters and the sequences of operation must be presented either on the plans or in the specifications (Cosiol, 2001;Al Katranji, 2012).

### 6.4.10 Inadequate Re-commissioning of BMS

It is recommended that at least once annual re-commissioning for BMS should be carried out by specialists in the field of BMS. Adequate BMS re-commissioning is one of the most important factors that necessary to ensure their effective performance over time (Piper, 2004; Zeitoon, 2011; Abdul-Waris, 2012).

### 6.4.11 Certified and Trained BMS Operators

It is recommended to develop a two years BMS operation and maintenance Diploma program within the technology or community colleges. The curriculum of such a program should include multiple field of BMS operation and maintenance activates with prime focus on the requirements of BMS commissioning and re-commissioning (Abdul-Waris, 2012).

### 6.4.12 Technical Documentation

It is recommended that the contractors should be required by the contract documents to provide a greater degree of accuracy in the technical documentation of the project, including "as-built" and the manual for the BMS, or, a client should assign the responsibility to the design team to modify construction documents—plans and specifications— through reflecting the condition of the building “as-built” and adding BMS manuals (Bourassa and Johson, 2007; Yaseen,2012).

## 6.5 Directions for Further Research

The energy savings generated by BMS re-commissioning are easy to benchmark, measure, correct, verify, and guarantee that adequate BMS re-commissioning is one of the most important factor that is necessary to ensure their effective performance over time. Due to this reasons, there is a need to conduct more research for benchmarking, measuring and correcting the re-commissioning practice of BMS in Saudi Arabia.

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# APPENDIX I

# Investigation of the Challenges that Influence the Successful Implementation of Building Management Systems during the Design, Installation, Operation and Maintenance Stages through Interviews

**The main objective of this phase of the research is:**

- To finalize the list of the challenges that influences the successful implementation of building management systems.

## THE INTERVIEWS QUISTIONS:

### Questions for the A/E firms: BMS Designer:

1. What is your scope of practice at the A/E firm?

2. Would you please provide me with a step by step description of your current BMS design practice?

3. From your daily practice, identify all the parties that participate in the BMS design? And what is the role of each one?

4. From your daily practice, do you think the following challenges could affect the successful implementation of the BMS during the design and briefing stages?

| Challenges | Yes | No | Why? |
|---|---|---|---|
| Lack of clients' involvement in the briefing process. | | | |
| Lack of end user's involvement in the briefing process. | | | |
| Unfamiliarity of the brief developer's with the technical requirements of BMS. | | | |
| Insufficient technical experience of the client with the BMS | | | |

| | | | |
|---|---|---|---|
| Poor communication between the client and the brief developer. | | | |
| Absence of commissioning practices during the briefing process. | | | |
| Inadequate selection of the A/E firm | | | |
| Absence of commissioning practices during the design process | | | |
| Provision of sub-optimal requirements of the BMS. | | | |
| Inappropriate selection of the BMS | | | |
| Lack of sub-contractor's involvement in the design of BMS as "a design-assist". | | | |

5. From your daily practice, what are the other challenges faced during the implementation of BMS during the design process?

6. In your opinion what is the best remedies for those challenges?

## Questions for the construction firms (contractors):

1. What is your scope of practice at the construction firm?

2. Would you please provide me with a step by step description of your current BMS installation practice?

3. From your daily practice, identify all the parties that participate in the BMS construction? And what is the role of each one?

4. From your daily practice, do you think the following challenges could affect the successful implementation of the BMS during the installation, acceptance, and warranty stages?

| Challenges | Yes | No | Why? |
|---|---|---|---|
| Provision of incomplete specification of the BMS. | | | |
| Absence of alternative design proposals provided by the BMS contractors. | | | |
| Inadequate selection of subcontractors to install the BMS. | | | |
| Inappropriate selection of BMS suppliers. | | | |
| Improper selection of the commissioning agent. | | | |
| Frequent change orders due to client's demands. | | | |
| Consultant’s supervisors may not possess collective experience about BMS | | | |
| Inadequate reviewing of BMS submittals and shop drawing provided by subcontractors. | | | |
| Lack of involvement of the commissioning agent during the installation, acceptance, | | | |

| | | | |
|---|---|---|---|
| and warranty process of the BMS. | | | |
| Lack of coordination and collaboration among the project team members. | | | |

5. From your daily practice, what are the other challenges faced during the implementation of the BMS during the installation, acceptance, and warranty process?

6. In your opinion what are the best remedies for those challenges?

## Questions for the facility managers:

1. Would you please provide me with a step by step description of your current BMS operation and maintenance practice?

2. From your daily practice, identify all parties that participate in the BMS operation and maintenance? And what is the role of each one?

3. From your daily practice, do you think the following challenges could affect successful implementation of BMS during the operation and maintenance stages?

| Challenges | Yes | No | Why? |
|---|---|---|---|
| Inadequate initial training for BMS facility personals | | | |
| Lack of continued training for BMS facility personals | | | |
| Lack of adequate technical documentation | | | |
| Poor usability of BMS user interface | | | |
| Insufficient staffing of BMS personnel | | | |
| Lack of adequate BMS retro-commissioning | | | |
| Inadequate re-commissioning of BMS | | | |
| Lack of service and technical support after installation by supplies | | | |
| Inadequate operations and maintenance activities. | | | |
| Lack of certified and trained BMS operators | | | |

4. From your daily practice, what are the other challenges faced during the implementation of the BMS during the operation and maintenance stages?

5. In your opinion what are the best remedies for those challenges?

# APPENDIX II

بسم الله الرحمن الرحيم

**King Fahd University of Petroleum and Minerals**
College of Environmental Design
Architectural Engineering Department

Date: September 1, 2012

Dear Sir,

**Subject:** Study of the Challenges Affecting the Implementation of Building Management Systems in Office Buildings in Saudi Arabia

*"Building Management Systems (BMS) (also called Building Automation Systems or (BAS)) are used in buildings for automatic monitoring and control of services such as lighting, plumbing, fire services, heating and air conditioning systems"*(Mustafa and Bansal, 2002). They can be considered a vital tool in the hands of building operations personnel to provide more effective and efficient control over all building systems.

In this study, the researcher aims to investigate and assess the significance of the challenges that influence the implementation of BMS during the life cycle (including design, installation, operation and maintenance stages) of the office building. The attached questionnaire with this letter consists of three sections. Section one includes general information about the respondents. Section two includes a description of office buildings equipped with BMS. Section three includes the assessment of the challenges affecting the implementation of building management systems during the **design and briefing stages only**.

Your input to this questionnaire is valuable and hopefully will lead to a better understanding of these challenges. Any information gained through this questionnaire will stringently be used for educational purposes.

**Please return this questionnaire once filled to the following address:**


Mr. Ameen Mabrook Bin Mohanna

Architectural Engineering Department

King Fahd University of Petroleum and Minerals

Dhahran Saudi Arabia

E-mail: Ameenmabrook@gmail.com      Mobile: 0535101975

بسم الله الرحمن الرحيم

**King Fahd University of Petroleum and Minerals**
College of Environmental Design
Architectural Engineering Department

Date: September 1, 2012

Dear Sir,

**<u>Subject:</u>** Study of the Challenges Affecting the Implementation of Building Management Systems in Office Buildings in Saudi Arabia

*"Building Management Systems (BMS) (also called Building Automation Systems or (BAS)) are used in buildings for automatic monitoring and control of services such as lighting, plumbing, fire services, heating and air conditioning systems"*(Mustafa and Bansal, 2002). They can be considered a vital tool in the hands of building operations personnel to provide more effective and efficient control over all building systems.

In this study, the researcher aims to investigate and assess the significance of the challenges that influence the implementation of BMS during the life cycle (including design, installation, operation and maintenance stages) of the office building. The attached questionnaire with this letter consists of three sections. Section one includes general information about the respondents. Section two includes a description of office buildings equipped with BMS. Section three includes the assessment of the challenges affecting the implementation of building management systems during the **<u>installation, acceptance, and warranty stages only.</u>**

Your input to this questionnaire is valuable and hopefully will lead to a better understanding of these challenges. Any information gained through this questionnaire will stringently be used for educational purposes.

**Please return this questionnaire once filled to the following address:**

Mr. Ameen Mabrook Bin Mohanna

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E-mail: Ameenmabrook@gmail.com Mobile: 0535101975

بسم الله الرحمن الرحيم

**King Fahd University of Petroleum and Minerals**
College of Environmental Design
Architectural Engineering Department

Date: September 1, 2012

Dear Sir,

**Subject:** Study of the Challenges Affecting the Implementation of Building Management Systems in Office Buildings in Saudi Arabia

*"Building Management Systems (BMS) (also called Building Automation Systems or (BAS)) are used in buildings for automatic monitoring and control of services such as lighting, plumbing, fire services, heating and air conditioning systems"* (Mustafa and Bansal, 2002). They can be considered a vital tool in the hands of building operations personnel to provide more effective and efficient control over all building systems.

In this study, the researcher aims to investigate and assess the significance of the challenges that influence the implementation of BMS during the life cycle (including design, installation, operation and maintenance stages) of the office building. The attached questionnaire with this letter consists of two sections. Section one includes general information about the respondents. Section two includes the assessment of the challenges affecting the implementation of building management systems during the **operation and maintenance stages only.**

Your input to this questionnaire is valuable and hopefully will lead to a better understanding of these challenges. Any information gained through this questionnaire will stringently be used for educational purposes.

**Please return this questionnaire once filled to the following address:**

Mr. Ameen Mabrook Bin Mohanna

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King Fahd University of Petroleum and Minerals

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# QUESTIONNAIRE

A/E Firms (designers) Questionnaire

## Section One: General Information

1) **Respondent Information** (Optional)**:**

| | |
|---|---|
| Name | |
| Office or Company Name | |
| Telephone no | |
| Facsimile | |
| E-Mail Address | |
| Office or Company Address | |

2) **Respondent position:**

| | |
|---|---|
| Project Manager | |
| Architectural Engineer | |
| Electrical Engineer | |
| Plumbing Engineer | |
| Others (please specified) ………………………….. | |

3) **The Experience Years :**

| | | | |
|---|---|---|---|
| Less than 5 years | | 5-10 years | |
| 10-20 years | | Over 20 years | |

4) **Please list below the office buildings that your firm has designed the BMS* for:**

| Building Name | Is the building constructed | Construction year | Building address |
|---|---|---|---|
| | ☐ Yes<br>☐ No | | |
| | ☐ Yes<br>☐ No | | |
| | ☐ Yes<br>☐ No | | |
| | ☐ Yes<br>☐ No | | |

BMS that control or monitor at least four subsystems. *

**Section Two of Challenges that Influence the Successful Implementation of BMS during the Briefing and Design Stages:**

Please rate the degree of importance of each of the following challenges by selecting one of the following evaluation scales:

**"Extreme effect (1), Strong effect (2), Moderate effect (3), Slight effect (4), Does not effect (5)."**

| Challenges influencing the successful implementation of BMS during the briefing and design stages | | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| 1 | Lack of clients' involvement in the briefing process | | | | | |
| 2 | Lack of end-user' involvement in the briefing process | | | | | |
| 3 | Unfamiliarity of the briefing developer with the technical requirements of BMS | | | | | |
| 4 | Insufficient technical experience of the client with the BMS | | | | | |
| 5 | Absence of commissioning practices during the briefing process | | | | | |
| 6 | Poor communication between the client and the brief developer | | | | | |
| 7 | Provision for sub-optimal requirements of the BMS | | | | | |
| 8 | Inappropriate selection of the A/E team | | | | | |
| 9 | Lack of sub-contractor's involvement in the design of the BMS as "a design-assist" | | | | | |
| 10 | Absence of commissioning practices during the design process | | | | | |
| 11 | Inappropriate selection of the BMS | | | | | |
| 12 | Others (please specified)............. | | | | | |
| 13 | Others (please specified)............. | | | | | |
| 14 | Others (please specified)............. | | | | | |

# QUESTIONNAIRE

Construction Firms (contractors) Questionnaire

## Section One: General Information

1) **Respondent Information** (Optional)**:**

| | |
|---|---|
| Name | |
| Office or Company Name | |
| Telephone no | |
| Facsimile | |
| E-Mail Address | |
| Office or Company Address | |

2) **Respondent position:**

| | |
|---|---|
| Project Manager | |
| Architectural Engineer | |
| Electrical Engineer | |
| Others (please specified) ………………………… | |

3) **The Experience Years :**

| | | | |
|---|---|---|---|
| Less than 5 years | | 5-10 years | |
| 10-20 years | | Over 20 years | |

4) **Please list below the office buildings that your firm has constructed the BMS* for:**

| Building Name | Is the building Designed In KSA | The construction completed in (year) | Building address |
|---|---|---|---|
| | ☐ Yes<br>☐ No | | |
| | ☐ Yes<br>☐ No | | |
| | ☐ Yes<br>☐ No | | |

BMS that control or monitor at least four subsvstems. *

**Section Two: Evaluation of Challenges that influence the Successful Implementation of BMS during the Installation, Acceptance, and Warranty Stages:**

Please rate the degree of importance of each of the following challenges by selecting one of the following evaluation scales:

**"Extreme effect (1), Strong effect (2), Moderate effect (3), Slight effect (4), Does not effect (5)."**

| **Challenges influencing the successful implementation of BMS during the installation, acceptance, and warranty stages** | | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| 1 | Inappropriate selection of subcontractors to install the BMS | | | | | |
| 2 | Inappropriate selection of BMS suppliers | | | | | |
| 4 | Inadequate review of the BMS submittals and shop drawing provided by the subcontractors | | | | | |
| 3 | Frequent change orders due to client's demands | | | | | |
| 5 | Provision of incomplete plans and specifications of the BMS | | | | | |
| 6 | Absence of alternative design proposals provided by the BMS contractors | | | | | |
| 7 | Lack of involvement of the commissioning agent during the installation, acceptance and warranty processes of the BMS | | | | | |
| 8 | Improper selection of the commissioning agent | | | | | |
| 9 | Lack of end user involvement during the commissioning practices | | | | | |
| 10 | Consultant’s supervisors may not possess collective experience about BMS installation | | | | | |
| 11 | Lack of coordination and collaboration among the project team members | | | | | |
| 12 | Others (please specified)…………. | | | | | |
| 13 | Others (please specified)…………. | | | | | |
| 14 | Others (please specified)…………. | | | | | |

# QUESTIONNAIRE

Facility managers Questionnaire

## Section One: General Information

1) **Respondent Information** (Optional)**:**

| | |
|---|---|
| Name | |
| Office or Company Name | |
| Telephone no | |
| Facsimile | |
| E-Mail Address | |
| Building Address | |

2) **Respondent position:**

| | |
|---|---|
| Facility Manager | |
| Maintenance Department Manager | |
| Others (please specified) ………………………….. | |

3) **The Experience Years:**

| | | | |
|---|---|---|---|
| Less than 5 years | | 5-10 years | |
| 10-20 years | | Over 20 years | |

## <u>Section Two:</u> Evaluation of challenges that Influence the Successful Implementation of BMS during the Operation and Maintenance Stages:

Please rate the degree of importance of each of the following challenges by selecting one of the following evaluation scales:
**"Extreme effect (1), Strong effect (2), Moderate effect (3), Slight effect (4), Does not effect (5)."**

| Challenges influencing the successful implementation of BMS during the operation and maintenance stage | | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| 1 | Inadequate initial training for the BMS facility personnel | | | | | |
| 2 | Lack of continued training for the BMS facility personnel | | | | | |
| 3 | Lack of adequate technical documentations provided by contractors and suppliers | | | | | |
| 4 | Insufficient staffing for the BMS operation | | | | | |
| 5 | Poor usability of the BMS user interface | | | | | |
| 6 | Lack of service and technical support after installation by suppliers | | | | | |
| 7 | Poor operations and maintenance activities | | | | | |
| 8 | Lack of adequate BMS retro-commissioning | | | | | |
| 9 | Inadequate re-commissioning of BMS | | | | | |
| 10 | Lack of certified and trained BMS operators | | | | | |
| 11 | Others (please specified)............. | | | | | |
| 12 | Others (please specified)............. | | | | | |
| 13 | Others (please specified)............. | | | | | |

**بسم الله الرحمن الرحيم**

**جامعة الملك فهد للبترول والمعادن**
كلية تصاميم البيئة
قسم الهندسة المعمارية

**<u>التاريخ:</u> ١ سبتمبر ٢٠١٢**

**عزيزي المستجيب،**

**<u>الموضوع:</u> دراسة المعوقات المؤثره على تطبيق منظومة إدارة المبنى في المباني الإدارية في المللكة العربية السعودية.**

"*<u>منظومة إدارة البنى</u> ( وهي ايضا تعرف بـ منظومة ميكنة المبنى) تستخدم في المباني لغرض ميكنة التحكم والمراقبة لمنظومات الخدمات الموجودة في المبنى مثل منظومة الإنارة، منظومة المياة، منظومة الحريق وايضا منظومة تكيف وتدفئة المبنى*"(Mustafa and Bansal, 2002). منظومة إدارة المبنى تعتبر إداة حيوية في يد مشغلي المبنى والتى توفر لهم تحكم ومراقبة وفعالة وعملية لمختلف الانظمة الموجودة في المبنى.

يهدف الباحث من هذه الدراسة إلى تحديد وتقيم المعوقات المؤثرة على تطبيق منظومة إدارة المبنى خلال دورة حياة(متضمة مرحل التصميم، والتركيب والتشغيل والصيانة) المباني الإدارية. الإستبيان المرفق بهذا الخطاب يتكون من ثلاثه اجزاء. الجزء الأول يتضمن معلومات عامة عن المستجيب .الجزء الثاني يتضمن وصف للمباني المكتبية المجهزه بمنظومة إدارة المبنى .الجزء الثالث يتضمن جدول تقيم المعوقات المؤثرة على تطبيق المبنى خلال مرحلة **<u>البرمجة والتصميم فقط</u>**.

مشاركتم في هذا الإستبيان سوف يكون لها دور في إثراء هذا البحث. مؤكدين لكم ان هذه المشاركة لن تستخدم إلا لأغراض تعليمية فقط.

**بعد الإنتهاء من تعبئة هذه الإستبانة يرجاء أرسالها على العنوان التالي:**

أمين مبروك بن مهنا
قسم الهندسة المعمارية
جامعة الملك فهد للبترول والمعادن
الظهران
المملكة العربية السعودية
البريد الإلكتروني: ameenmabrook@gmail.com
جوال: ٠٥٣٥١٠١٩٧٥

**بسم الله الرحمن الرحيم**

**جامعة الملك فهد للبترول والمعادن**

كلية تصاميم البيئة

قسم الهندسة المعمارية

**<u>التاريخ:</u> ١ سبتمبر ٢٠١٢**

**عزيزي المستجيب،**

**<u>الموضوع:</u> دراسة المعوقات المؤثره على تطبيق منظومة إدارة المبنى في المباني الإدارية في المللكة العربية السعودية.**

"*<u>منظومة إدارة البني</u> ( وهي ايضا تعرف بـ منظومة ميكنة المبنى) تستخدم في المباني لغرض ميكنة التحكم والمراقبة لمنظومات الخدمات الموجودة في المبنى مثل منظومة الإنارة، منظومة المياة، منظومة الحريق وايضا منظومة تكيف وتدفئة المبنى*" (Mustafa and Bansal, 2002). منظومة إدارة المبنى تعتبر إداة حيوية في يد مشغلي المبنى والتى توفر لهم تحكم ومراقبة وفعالة وعملية لمختلف الانظمة الموجودة في المبنى.

يهدف الباحث من هذه الدراسة إلى تحديد وتقيم المعوقات المؤثرة على تطبيق منظومة إدارة المبنى خلال دورة حياة(متضمة مرحل التصميم، والتركيب والتشغيل والصيانة) المباني الإدارية. الإستبيان المرفق بهذا الخطاب يتكون من ثلاثه اجزاء. الجزء الأول يتضمن معلومات عامة عن المستجيب .الجزء الثاني يتضمن وصف للمباني المكتبية المجهزه بمنظومة إدارة المبنى .الجزء الثالث يتضمن جدول تقيم المعوقات المؤثرة على تطبيق المبنى خلال مرحلة **<u>التركيب،القبول والضمان فقط</u>**.

مشاركتم في هذا الإستبيان سوف يكون لها دور في إثراء هذا البحث. مؤكدين لكم ان هذه المشاركة لن تستخدم إلا لأغراض تعليمية فقط.

**بعد الإنتهاء من تعبئة هذه الإستبانة يرجاء أرسالها على العنوان التالي:**

أمين مبروك بن مهنا

قسم الهندسة المعمارية

جامعة الملك فهد للبترول والمعادن

الظهران

المملكة العربية السعودية

البريد الإلكتروني: ameenmabrook@gmail.com

جوال: ٠٥٣٥١٠١٩٧٥

**بسم الله الرحمن الرحيم**

**جامعة الملك فهد للبترول والمعادن**
كلية تصاميم البيئة
قسم الهندسة المعمارية

**التاريخ: ١ سبتمبر ٢٠١٢**

**عزيزي المستجيب،**

**الموضوع: دراسة المعوقات المؤثره على تطبيق منظومة إدارة المبنى في المباني الإدارية في المللكة العربية السعودية.**

*"منظومة إدارة البنى ( وهي ايضا تعرف بـ منظومة ميكنة المبنى) تستخدم في المباني لغرض ميكنة التحكم والمراقبة لمنظومات الخدمات الموجودة في المبنى مثل منظومة الإنارة، منظومة المياة، منظومة الحريق وايضا منظومة تكيف وتدفئة المبنى"*(Mustafa and Bansal, 2002). منظومة إدارة المبنى تعتبر إداة حيوية في يد مشغلي المبنى والتى توفر لهم تحكم ومراقبة وفعالة وعملية لمختلف الانظمة الموجودة في المبنى.

يهدف الباحث من هذه الدراسة إلى تحديد وتقيم المعوقات المؤثرة على تطبيق منظومة إدارة المبنى خلال دورة حياة(متضمة مرحل التصميم، والتركيب والتشغيل والصيانة) المباني الإدارية. الإستبيان المرفق بهذا الخطاب يتكون من جزئين. الجزء الأول يتضمن معلومات عامة عن المستجيب والجزء الثاني يتضمن جدول تقيم المعوقات المؤثرة على تطبيق المبنى خلال مرحلة **الصيانة والتشغيل فقط**. مشاركتم في هذا الإستبيان سوف يكون لها دور في إثراء هذا البحث. مؤكدين لكم ان هذه المشاركة لن تستخدم إلا لأغراض تعليمية فقط.

**بعد الإنتهاء من تعبئة هذه الإستبانة يرجاء أرسالها على العنوان التالي:**

أمين مبروك بن مهنا
قسم الهندسة المعمارية
جامعة الملك فهد للبترول والمعادن
الظهران
المملكة العربية السعودية
البريد الإلكتروني: ameenmabrook@gmail.com
جوال: ٠٥٣٥١٠١٩٧٥

## الاستبيان

استبيان مكاتب الهندسية المعمارية (المصمميين)

**الجزء الأول: معلومات عامة**

**١- معلومات عن المستجيب** (أختياري)

| | |
|---|---|
| **الأسم** | |
| **أسم الشركه أو المكتب** | |
| **رقم الهاتف** | |
| **رقم الفاكس** | |
| **البريد الألكتروني** | |
| **عنوان الشركة أو المكتب** | |

**٢- المستوى الوظيفي**

| المسمى | |
|---|---|
| **مدير مشروع** | |
| **مهندس معماري** | |
| **مهندس كهربائي** | |
| **مهندس صحي** | |
| **مسمى آخر**(يرجى التحديد)........................................................... | |

**٣- سنوات الخبره**

| | | | |
|---|---|---|---|
| **أقل من ٥ سنوات** | | **٥-١٠ سنوات** | |
| **١٠-٢٠ سنة** | | **أكثر من ٢٠ سنة** | |

**٤- يرجى سرد المباني الإدارية المجهزة بـ ( منظومة إدارة المبنى(BMS) *) والتى قامت شركتم أو مكتبكم الهندسي بتصميمها:**

| اسم المبنى | هل تم تشيد المبنى | سنة إكتمال التشيد | عنوان المبنى |
|---|---|---|---|
| | نعم ☐<br>لا ☐ | | |
| | نعم ☐<br>لا ☐ | | |
| | نعم ☐<br>لا ☐ | | |

*BMS تتحكم او تراقب على الاقل أربعة انظمة فرعية

**الجــــــزء الثاني : تقييم المعوقات المؤثرة على التطبيق الناجح لمنظومة إدارة المبنى (BMS) خلال مرحلة البرمجة والتصميم لمشاريع المباني الإدارية.**

الرجاء تحديد درجة أهمية كل معوق من المعوقات أدناه بإستخدام أحد المقاييس التاليه:

**تأثير قوي جدا (١)، تأثير قوي (٢)، تأثير متوسط(٣) ، تأثير خفيف(٤) لا يوجد تأثير (٥)**

| | المعوقات المؤثرة على التطبيق الناجح لمنظومة إدارة المبنى خلال مرحلة البرمجة والتصميم لمشاريع المباني الإدارية. | ١ | ٢ | ٣ | ٤ | ٥ |
|---|---|---|---|---|---|---|
| ١ | قصور في مشاركة المالك بجدية في عملية البرمجة المعمارية لمنظومة إدارة المبنى. | | | | | |
| ٢ | قصور في مشاركة المستخدم النهائي في عملية البرمجة المعمارية لمنظومة إدارة المبنى. | | | | | |
| ٣ | عدم إلمام معد البرنامج المعماري بالمتطلبات التقنية لمنظومة إدارة المبنى. | | | | | |
| ٤ | قصور في مستوى الخبرة التقنية للمالك فيما يخص منظومة إدارة المبنى. | | | | | |
| ٥ | غياب ممارسات التكليف اثناء عملية إعداد البرنامج المعماري. | | | | | |
| ٦ | ضعف التواصل بين معد البرنامج المعماري والمالك ( مثلا بسبب استخدام مصطلحات مختلفة). | | | | | |
| ٧ | توفير متطلبات غير ملائمة لمنظومة إدارة المبنى. | | | | | |
| ٨ | اختيار غير ملائم لمكتب الهندسة المعمارية ( المصمميين). | | | | | |
| ٩ | قصور في مشاركة المقاول في عملية تصميم منظومة إدارة المبنى ( كمساعد في التصميم فقط). | | | | | |
| ١٠ | غياب ممارسات التكليف اثناء عملية تصميم منظومة إدارة المبنى. | | | | | |
| ١١ | اختيار غير ملائم لمنظومة إدارة المبنى . | | | | | |
| ١٣ | **أخرى** (يرجى التحديد) ............................................ | | | | | |
| ١٤ | **أخرى** (يرجى التحديد) ............................................ | | | | | |
| ١٥ | **أخرى** (يرجى التحديد) ............................................ | | | | | |

## الأستبيان

أستبيان شركات الإنشاءات ( المقاولين)

### الجزء الأول: معلومات عامة

١- **معلومات عن المستجيب** (أختياري)

| | |
|---|---|
| **الأسم** | |
| **أسم الشركه أو المكتب** | |
| **رقم الهاتف** | |
| **رقم الفاكس** | |
| **البريد الألكتروني** | |
| **عنوان الشركة أو المكتب** | |

٢- **المستوى الوظيفي**

| **المسمى** | |
|---|---|
| **مدير مشروع** | |
| **مهندس معماري** | |
| **مهندس كهربائي** | |
| **مهندس صحي** | |
| **مسمى آخر**(يرجى التحديد)................................................................ | |

٣- **سنوات الخبره**

| | | | |
|---|---|---|---|
| **أقل من ٥ سنوات** | | **٥-١٠ سنوات** | |
| **١٠-٢٠ سنة** | | **أكثر من ٢٠ سنة** | |

٤- **يرجى سرد المباني الإدارية المجهزة بـ ( منظومة إدارة المبنى(BMS)* ) والتى قامت شركتم او مؤوسستكم بتنفيذها:**

| **اسم المبنى** | **هل تم تصميم المبنى في المملكة** | **سنة إكتمال التشيد** | **عنوان المبنى** |
|---|---|---|---|
| | نعم ☐<br>لا ☐ | | |
| | نعم ☐<br>لا ☐ | | |
| | نعم ☐<br>لا ☐ | | |

*BMS تتحكم او تراقب على الاقل أربعة انظمة فرعية

**<u>الجـــــزء الثاني</u> : تقييم المعوقات المؤثرة على التطبيق الناجح لمنظومة إدارة المبنى (BMS) خلال <u>التركيب ،القبول و الضمان لمشاريع المباني الإدارية</u>.**

الرجاء تحديد درجة أهمية كل معوق من المعوقات أداه بإستخدام أحد المقاييس التاليه:

**تأثير قوي جدا (١)، تأثير قوي (٢)، تأثير متوسط(٣) ، ثأثير خفيف(٤) لا يوجد تأثير (٥)**

| | المعوقات المؤثرة على التطبيق الناجح لمنظومة إدارة المبنى خلال مرحلة <u>التركيب ،القبول و الضمان</u> لمشاريع المباني الإدارية. | ١ | ٢ | ٣ | ٤ | ٥ |
|---|---|---|---|---|---|---|
| ١ | الاختيار الغير ملائم للمقاولين من الباطن لتركيب منظومة إدارة المبنى. | | | | | |
| ٢ | الاختيار الغير مناسب لموردي منظومة إدارة المبنى. | | | | | |
| ٣ | المراجعة غير الكافية لطلبات الإعتماد والمخططات التنفيذية المقدمة من قبل المقاولين بالباطن. | | | | | |
| ٤ | حدوت أوامر التغير بشكل متكرر بسبب متطلبات المالك. | | | | | |
| ٥ | توفير مواصفات ومخططات غير مكتملة لمنظومة إدارة المبنى. | | | | | |
| ٦ | غيباب التصاميم البديلة المقدمة من جهة المقاول. | | | | | |
| ٧ | قصور في مشاركة متعهد التكليف في عملية التركيب،القبول والضمان لمنظومة إدارة المبنى. | | | | | |
| ٨ | الاختيار الغير المناسب لمتعهد التكليف. | | | | | |
| ٩ | قصور في خبرة مشرفي الاستشاري فيما يتعلق بتركيب منظومة إدارة المبنى. | | | | | |
| ١٠ | قصور في التنسيق والتعاون بين أعضاء فريق المشروع. | | | | | |
| ١١ | قصور في مشاركة المستخدمين النهائين خلال ممارسات التكليف. | | | | | |
| ١٢ | **أخرى** (يرجى التحديد) ............................................ | | | | | |
| ١٣ | **أخرى** (يرجى التحديد) ............................................ | | | | | |
| ١٤ | **أخرى** (يرجى التحديد) ............................................ | | | | | |

# الاستبيان

إستبيان مديري المنشآت الإدارية

## الجزء الأول: معلومات عامة

### ١- معلومات عن المستجيب(أختياري)

| | |
|---|---|
| الاسم | |
| اسم المبنى | |
| رقم الهاتف | |
| رقم الفاكس | |
| البريد الألكتروني | |
| عنوان المبنى | |

### ٢- المستوى الوظيفي

| المسمى | |
|---|---|
| مدير مبنى | |
| مدير الصيانة | |
| مسمى آخر(يرجى التحديد)............................................................ | |

### ٣- سنوات الخبره

| | | | |
|---|---|---|---|
| أقل من ٥ سنوات | | ٥-١٠ سنوات | |
| ١٠-٢٠ سنة | | أكثر من ٢٠ سنة | |

**الجــــــزء الثاني : تقييم المعوقات المؤثرة على التطبيق الناجح لمنظومة إدارة المبنى (BMS) خلال مرحلة التشغيل والصيانة لمشاريع المباني الإدارية.**

الرجاء تحديد درجة أهمية كل معوق من المعوقات أدناه بإستخدام أحد المقاييس التاليه:

**تأثير قوي جدا (١)، تأثير قوي (٢)، تأثير متوسط(٣) ، تأثير خفيف(٤) لا يوجد تأثير (٥)**

| | المعوقات المؤثرة على التطبيق الناجح لمنظومة إدارة المبنى خلال مرحلة التشغيل والصيانة لمشاريع المباني الإدارية. | ١ | ٢ | ٣ | ٤ | ٥ |
|---|---|---|---|---|---|---|
| ١ | عدم حصول موظفي منظومة إدارة المبنى على التدريب الأولي الكافي. | | | | | |
| ٢ | قصور في التدريب المستمر لموظفي المرافق فيما يخص منظومة إدارة المبنى. | | | | | |
| ٣ | قصور الوثائق التقنية ( مثل المخططات المنفذة فعليا، دليل التشغيل والصيانة..). | | | | | |
| ٤ | ضعف قابلية الاستخدام لواجهة منظومة إدارة المبنى. | | | | | |
| ٥ | وجود عدد غير كاف من الموظفين لتشغيل وصيانة منظومة إدارة المبنى( مثلا غياب موظف الاداء البيئي). | | | | | |
| ٦ | قصور في عملية إعادة التصميم لمنظومة إدارة المبنى التى لم تحظى بعملية التكليف مسبقا. | | | | | |
| ٧ | عدم كفاية عملية إعادة التكليف لمنظومة إدارة المبنى. | | | | | |
| ٨ | قصور في فعاليات تشغيل وصيانة منظومة إدارة المبنى. | | | | | |
| ٩ | عدم توافر الخدمات والدعم الفني من جانب الموردين بعد التركيب. | | | | | |
| ١٠ | قصور في توفر المشغلين المدربيين والؤهلين لمنظومة إدارة المبنى. | | | | | |
| ١١ | أخرى (يرجى التحديد) ........................................... | | | | | |
| ١٢ | أخرى (يرجى التحديد) ........................................... | | | | | |
| ١٣ | أخرى (يرجى التحديد) ........................................... | | | | | |

# APPENDIX III

بسم الله الرحمن الرحيم

**King Fahd University of Petroleum and Minerals**
College of Environmental Design
Architectural Engineering Department

Date: September 1, 2012

Dear Sir,

**Subject:** Study of the Challenges Affecting the Implementation of Building Management Systems in Office Buildings in Saudi Arabia

"*Building Management Systems (BMS) (also called Building Automation Systems or (BAS)) are used in buildings for automatic monitoring and control of services such as lighting, plumbing, fire services, heating and air conditioning systems*"(Mustafa and Bansal, 2002). They can be considered a vital tool in the hands of building operations personnel to provide more effective and efficient control over all building systems.

In this study, the researcher aims to investigate and assess the significance of the challenges that influence the implementation of BMS during the life cycle (including design, installation, operation and maintenance stages) of the office building. The attached questionnaire with this letter consists of two sections. Section one includes general information about the respondents. Section two includes the assessment of the challenges affecting the implementation of building management systems.

Your input to this questionnaire is valuable and hopefully will lead to a better understanding of these challenges. Any information gained through this questionnaire will stringently be used for educational purposes.

**Please return this questionnaire once filled to the following address:**

Mr. Ameen Mabrook Bin Mohanna

Architectural Engineering Department

King Fahd University of Petroleum and Minerals

Dhahran

Saudi Arabia

E-mail: Ameenmabrook@gmail.com  Mobile: 053510197

## PAIRWAISE QUESTIONNAIRE

## Section One: General Information

**1) Respondent Information:**

| | |
|---|---|
| Name (Optional) | |
| Office or Company Name | |
| Telephone no | |
| Facsimile | |
| E-Mail Address | |
| Office or Company Address | |

**2) The Experience Years (VERY IMPORTANT):**

| | | | |
|---|---|---|---|
| Less than 5 years | | 5-10 years | |
| 10-20 years | | Over 20 years | |

**3) Respondent position:**

| | |
|---|---|
| Project Manager | |
| Architectural Engineer | |
| Electrical Engineer | |
| Facility Manager | |
| Others …………………………. | |

## Section Two: Evaluation of Challenges that Influence the Successful Implementation of BMS during design, briefing phases:

Please determine the effect of the challenges pertaining to the phases of BMS implementation (namely (briefing and design phases), (installation, acceptance, and warranty phases), and (operation and maintenance phases)). The impact of each challenge on the overall decision is based on a scale of 1 to 9. The following table explains the meaning of each point on the scale.

| | **Extremely Effect** | **V. Strongly Effect** | **Strongly Effect** | **Weak Effect** | **equally** | **Weak Effect** | **Strongly Effect** | **V. Strongly Effect** | **Extremely Effect** | |
|---|---|---|---|---|---|---|---|---|---|---|
| **challenges** | **9** | **7** | **5** | **3** | **1** | **3** | **5** | **7** | **9** | **challenges** |
| A | | | √ | | | | | | | B |
| | | | | | | √ | | | | C |
| B | | | | | | √ | | | | C |

Your input to this questionnaire will lead to a better understanding of the challenges that influence the Successful Implementation of BMS.

## Phases Influencing the Successful Implementation of BMS

| Main Categories | Extremely Effect | V. Strongly Effect | Strongly Effect | Weak Effect | Equally | Weak Effect | Strongly Effect | V. Strongly Effect | Extremely Effect | Main Categories |
|---|---|---|---|---|---|---|---|---|---|---|
| | 9 | 7 | 5 | 3 | 1 | 3 | 5 | 7 | 9 | |
| Which one of these challenges has more effect? | | | | | | | | | | |
| Challenges pertaining to the design and briefing phases | | | | | | | | | | Challenges pertaining to the installation, acceptance, and warranty phases |
| | | | | | | | | | | Challenges pertaining to the operation and Maintenance |
| Challenges pertaining to the installation, acceptance, and warranty phases | | | | | | | | | | Challenges pertaining to the operation and Maintenance |

## Challenges Influencing the Successful Implementation of BMS during Design and briefing Stages

| Challenges pertaining to the design and briefing phases | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Challenges | Extremely effect | V. Strongly Effect | Strongly Effect | Weak Effect | Equally | Weak Effect | Strongly Effect | V. Strongly Effect | Extremely Effect | Challenges |
| | 9 | 7 | 5 | 3 | 1 | 3 | 5 | 7 | 9 | |
| Which one of these challenges has more Effect? | | | | | | | | | | |
| Lack of clients' involvement in the briefing process. | | | | | | | | | | Lack of end-user' involvement in the briefing process. |
| | | | | | | | | | | Unfamiliarity of the brief developer's with the technical requirements of BMS. |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | Insufficient technical experience of the client with the BMS. |
| | | | | | | | | | | Absence of commissioning practices during the briefing process. |
| | | | | | | | | | | Poor communication between the client and the brief developer |
| | | | | | | | | | | Provision of sub-optimal requirements of BMS. |
| | | | | | | | | | | Inappropriate selection of the A/E team |
| | | | | | | | | | | Lack of sub-contractor's involvement in the design of BMS as "a design-assist". |
| | | | | | | | | | | Absence of commissioning practices during the design process |
| | | | | | | | | | | Inappropriate selection of the BMS |
| Lack of end-user' involvement in the briefing process. | | | | | | | | | | Unfamiliarity of the brief developer's with the technical requirements of BMS. |
| | | | | | | | | | | Insufficient technical experience of the client with the BMS. |
| | | | | | | | | | | Absence of commissioning practices during the briefing process. |
| | | | | | | | | | | Poor communication between the client and the brief developer. |
| | | | | | | | | | | Provision of sub-optimal requirements of BMS. |
| | | | | | | | | | | Inappropriate selection of the A/E team |
| | | | | | | | | | | Lack of sub-contractor's involvement in the design of BMS as "a design-assist". |
| | | | | | | | | | | Absence of commissioning practices during the design process |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | Inappropriate selection of the BMS |
| Unfamiliarity of the brief developer's with the technical requirements of BMS. | | | | | | | | | | Insufficient technical experience of the client with the BMS. |
| | | | | | | | | | | Absence of commissioning practices during the briefing process. |
| | | | | | | | | | | Poor communication between the client and the brief developer. |
| | | | | | | | | | | Provision of sub-optimal requirements of BMS. |
| | | | | | | | | | | Inappropriate selection of the A/E team |
| | | | | | | | | | | Lack of sub-contractor's involvement in the design of BMS as "a design-assist". |
| | | | | | | | | | | Absence of commissioning practices during the design process |
| | | | | | | | | | | Inappropriate selection of the BMS |
| Insufficient technical experience of the client with the BMS. | | | | | | | | | | Absence of commissioning practices during the briefing process. |
| | | | | | | | | | | Poor communication between the client and the brief developer. |
| | | | | | | | | | | Provision of sub-optimal requirements of BMS. |
| | | | | | | | | | | Inappropriate selection of the A/E team |
| | | | | | | | | | | Lack of sub-contractor's involvement in the design of BMS as "a design-assist". |
| | | | | | | | | | | Absence of commissioning practices during the design process |
| | | | | | | | | | | Inappropriate selection of the BMS |
| Absence of commissioning practices during the briefing process. | | | | | | | | | | Poor communication between the client and the brief developer. |
| | | | | | | | | | | Provision of sub-optimal requirements of BMS. |
| | | | | | | | | | | Inappropriate selection of the A/E team |
| | | | | | | | | | | Lack of sub-contractor's involvement in the design of BMS as "a design-assist". |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | Absence of commissioning practices during the design process |
| | | | | | | | | | | Inappropriate selection of the BMS |
| Poor communication between the client and the brief developer. | | | | | | | | | | Provision of sub-optimal requirements of BMS. |
| | | | | | | | | | | Inappropriate selection of the A/E team |
| | | | | | | | | | | Lack of sub-contractor's involvement in the design of BMS as "a design-assist". |
| | | | | | | | | | | Absence of commissioning practices during the design process |
| | | | | | | | | | | Inappropriate selection of the BMS |
| Provision of sub-optimal requirements of BMS. | | | | | | | | | | Inappropriate selection of the A/E team |
| | | | | | | | | | | Lack of sub-contractor's involvement in the design of BMS as "a design-assist". |
| | | | | | | | | | | Absence of commissioning practices during the design process |
| | | | | | | | | | | Inappropriate selection of the BMS |
| Inappropriate selection of the A/E team | | | | | | | | | | Lack of sub-contractor's involvement in the design of BMS as "a design-assist". |
| | | | | | | | | | | Absence of commissioning practices during the design process |
| | | | | | | | | | | Inappropriate selection of the BMS |
| Lack of sub-contractor's involvement in the design of BMS as "a design-assist". | | | | | | | | | | Absence of commissioning practices during the design process |
| | | | | | | | | | | Inappropriate selection of the BMS |
| Absence of commissioning practices during the design process | | | | | | | | | | Inappropriate selection of the BMS |

**Challenges Influencing the Successful Implementation of BMS during installation, acceptance, and warranty phases**

| Challenges pertaining to the installation, acceptance, and warranty phases | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Challenges** | **Extremely Effect** | **V. Strongly Effect** | **Strongly Effect** | **Weak Effect** | **Equally** | **Weak Effect** | **Strongly Effect** | **V. Strongly Effect** | **Extremely Effect** | **Challenges** |
| | **9** | **7** | **5** | **3** | **1** | **3** | **5** | **7** | **9** | |
| Which one of these challenges has more Effect? | | | | | | | | | | |
| Inappropriate selection of subcontractors to install the BMS. | | | | | | | | | | Inappropriate selection of BMS suppliers. |
| | | | | | | | | | | Inadequate review of BMS submittals and shop drawing provided by subcontractors. |
| | | | | | | | | | | Frequent change orders due to client's demands. |
| | | | | | | | | | | Provision of incomplete plans and specifications of the BMS. |
| | | | | | | | | | | Absence of alternative design proposals provided by BMS contractors. |
| | | | | | | | | | | Lack of involvement of the commissioning agent during installation, acceptance, and warranty process of the BMS. |
| | | | | | | | | | | Improper selection of the commissioning agent. |
| | | | | | | | | | | Consultant’s supervisors may not possess collective experience about BMS installation. |
| | | | | | | | | | | Lack of coordination and collaboration among the project team members. |
| | | | | | | | | | | Lack of end user involvement during commissioning practices |
| Inappropriate selection of BMS suppliers. | | | | | | | | | | Inadequate review of the BMS submittals and shop drawing provided by subcontractors. |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | Frequent change orders due to client's demands. |
| | | | | | | | | | | Provision of incomplete plans and specifications of the BMS. |
| | | | | | | | | | | Absence of alternative design proposals provided by BMS contractors. |
| | | | | | | | | | | Lack of involvement of the commissioning agent during installation, acceptance, and warranty process of the BMS. |
| | | | | | | | | | | Improper selection of the commissioning agent. |
| | | | | | | | | | | Consultant’s supervisors may not possess collective experience about BMS installation |
| | | | | | | | | | | Lack of coordination and collaboration among the project team members. |
| | | | | | | | | | | Lack of end user involvement during commissioning practices |
| Inadequate review of the BMS submittals and shop drawing provided by subcontractors. | | | | | | | | | | Frequent change orders due to client's demands. |
| | | | | | | | | | | Provision of incomplete plans and specifications of the BMS. |
| | | | | | | | | | | Absence of alternative design proposals provided by BMS contractors. |
| | | | | | | | | | | Lack of involvement of the commissioning agent during installation, acceptance, and warranty process of the BMS. |
| | | | | | | | | | | Improper selection of the commissioning agent. |
| | | | | | | | | | | Consultant’s supervisors may not possess collective experience about BMS installation. |
| | | | | | | | | | | Lack of coordination and collaboration among the project team members. |
| | | | | | | | | | | Lack of end user involvement during commissioning practices |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Frequent change orders due to client's demands. | | | | | | | | | | Provision of incomplete plans and specifications of the BMS. |
| | | | | | | | | | | Absence of alternative design proposals provided by BMS contractors. |
| | | | | | | | | | | Lack of involvement of the commissioning agent during installation, acceptance, and warranty process of the BMS. |
| | | | | | | | | | | Improper selection of the commissioning agent. |
| | | | | | | | | | | Consultant's supervisors may not possess collective experience about BMS installation. |
| | | | | | | | | | | Lack of coordination and collaboration among the project team members. |
| | | | | | | | | | | Lack of end user involvement during commissioning practices |
| Provision of incomplete plans and specifications of the BMS. | | | | | | | | | | Absence of alternative design proposals provided by BMS contractors. |
| | | | | | | | | | | Lack of involvement of the commissioning agent during installation, acceptance, and warranty process of the BMS. |
| | | | | | | | | | | Improper selection of the commissioning agent. |
| | | | | | | | | | | Consultant's supervisors may not possess collective experience about BMS installation. |
| | | | | | | | | | | Lack of coordination and collaboration among the project team members. |
| | | | | | | | | | | Lack of end user involvement during commissioning practices |
| Absence of alternative design proposals provided by BMS contractors. | | | | | | | | | | Lack of involvement of the commissioning agent during installation, acceptance, and warranty process of the BMS. |
| | | | | | | | | | | Improper selection of the commissioning agent. |
| | | | | | | | | | | Consultant's supervisors may not possess collective experience about BMS installation. |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | Lack of coordination and collaboration among the project team members. |
| | | | | | | | | | | Lack of end user involvement during the commissioning practices |
| Lack of involvement of the commissioning agent during installation, acceptance, and warranty process of the BMS. | | | | | | | | | | Improper selection of the commissioning agent. |
| | | | | | | | | | | Consultant's supervisors may not possess collective experience about BMS installation. |
| | | | | | | | | | | Lack of coordination and collaboration among the project team members. |
| | | | | | | | | | | Lack of end user involvement during commissioning practices |
| Improper selection of the commissioning agent. | | | | | | | | | | Consultant's supervisors may not possess collective experience about BMS installation |
| | | | | | | | | | | Lack of coordination and collaboration among the project team members. |
| | | | | | | | | | | Lack of the end user involvement during commissioning practices |
| Consultant's supervisors may not possess collective experience about BMS installation. | | | | | | | | | | Lack of coordination and collaboration among the project team members. |
| | | | | | | | | | | Lack of the end user involvement during commissioning practices |
| Lack of coordination and collaboration among the project team members. | | | | | | | | | | Lack of the end user involvement during commissioning practices |

## Challenges Influencing the Successful Implementation of BMS during Operation and Maintenance Phases

**Challenges pertaining to the operation and maintenance phases**

| Challenges | Extremely Effect 9 | V. Strongly Effect 7 | Strongly Effect 5 | Weak Effect 3 | Equally 1 | Weak Effect 3 | Strongly Effect 5 | V. Strongly Effect 7 | Extremely Effect 9 | Challenges |
|---|---|---|---|---|---|---|---|---|---|---|
| Which one of these Challenges has more Effect? | | | | | | | | | | |
| Inadequate initial training for the BMS facility personnel. | | | | | | | | | | Lack of continued training for the BMS facility personnel. |
| | | | | | | | | | | Lack of adequate technical documentations provided by contractors and suppliers |
| | | | | | | | | | | Poor usability of BMS user interface. |
| | | | | | | | | | | Insufficient staffing for the BMS operation |
| | | | | | | | | | | Lack of adequate BMS retro-commissioning practice. |
| | | | | | | | | | | Inadequate re-commissioning of BMS. |
| | | | | | | | | | | Lack of certified and trained BMS operators |
| | | | | | | | | | | Lack of service and technical support after installation by supplies. |
| | | | | | | | | | | Poor operations and maintenance activates. |
| | | | | | | | | | | Lack of adequate technical documentations provided by contractors and suppliers. |
| | | | | | | | | | | Poor usability of BMS user interface. |
| | | | | | | | | | | Insufficient staffing for the BMS operation. |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Lack of continued training for the BMS facility personnel. | | | | | | | | | | Lack of adequate BMS retro-commissioning practice. |
| | | | | | | | | | | Inadequate re-commissioning of BMS. |
| | | | | | | | | | | Lack of certified and trained BMS operators |
| | | | | | | | | | | Lack of service and technical support after installation by supplies. |
| | | | | | | | | | | Poor operations and maintenance activates. |
| Lack of adequate technical documentation provided by contractors and suppliers. | | | | | | | | | | Poor usability of BMS user interface. |
| | | | | | | | | | | Insufficient staffing for the BMS operation. |
| | | | | | | | | | | Lack of adequate BMS retro-commissioning practice. |
| | | | | | | | | | | Inadequate re-commissioning of BMS. |
| | | | | | | | | | | Lack of certified and trained BMS operators |
| | | | | | | | | | | Lack of service and technical support after installation by supplies. |
| | | | | | | | | | | Poor operations and maintenance activates. |
| Poor usability of BMS user interface. | | | | | | | | | | Insufficient staffing for the BMS operation. |
| | | | | | | | | | | Lack of adequate BMS retro-commissioning practice. |
| | | | | | | | | | | Inadequate re-commissioning of BMS. |
| | | | | | | | | | | Lack of certified and trained BMS operators |
| | | | | | | | | | | Lack of service and technical support after installation by supplies. |
| | | | | | | | | | | Poor operations and maintenance activates. |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Insufficient staffing for the BMS operation. | | | | | | | | | | Lack of adequate BMS retro-commissioning practice. |
| | | | | | | | | | | Inadequate re-commissioning of BMS. |
| | | | | | | | | | | Lack of certified and trained BMS operators |
| | | | | | | | | | | Lack of service and technical support after installation by supplies. |
| | | | | | | | | | | Poor operations and maintenance activates. |
| Lack of adequate BMS retro-commissioning practice. | | | | | | | | | | Inadequate re-commissioning of BMS. |
| | | | | | | | | | | Lack of certified and trained BMS operators |
| | | | | | | | | | | Lack of service and technical support after installation by supplies. |
| | | | | | | | | | | Poor operations and maintenance activates. |
| Inadequate re-commissioning of BMS. | | | | | | | | | | Lack of certified and trained BMS operators |
| | | | | | | | | | | Lack of service and technical support after installation by supplies. |
| | | | | | | | | | | Poor operations and maintenance activates. |
| Lack of certified and trained BMS operators | | | | | | | | | | Lack of service and technical support after installation by supplies. |
| | | | | | | | | | | Poor operations and maintenance activates. |
| Lack of service and technical support after installation by supplies. | | | | | | | | | | Poor operations and maintenance activates. |

# Vitae

| | |
|---|---|
| Name | :Ameen Mabrook Bin Mohanna |
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